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ATSDR
AGENCY FOR TOXIC SUBSTANCES AND DISEASE REGISTRY

DEPARTMENT OF HEALTH & HUMAN SERVICES·USA

CDC
CENTERS FOR DISEASE CONTROL AND PREVENTION

Synthetic Turf Field Recycled Tire Crumb Rubber Research Under the Federal Research Action Plan

FINAL REPORT PART 1– TIRE CRUMB RUBBER CHARACTERIZATION APPENDICES VOLUME 2

National Exposure Research Laboratory
Office of Research and Development

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Synthetic Turf Field Tire Crumb Rubber Research Under the Federal Research Action Plan

Final Report Part 1 – Tire Crumb Rubber Characterization Appendices

Volume 2

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By

U.S. Environmental Protection Agency / Office of Research and Development (EPA/ORD)

Centers for Disease Control and Prevention / Agency for Toxic Substances and Disease Registry (CDC/ATSDR)

Disclaimer

This document has been reviewed by the U.S. Environmental Protection Agency and the Agency for Toxic Substances and Disease Registry and approved for release. Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

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Foreword

The U.S. Environmental Protection Agency (EPA) Office of Research and Development (ORD) and the Centers for Disease Control and Prevention (CDC) Agency for Toxic Substances and Disease Registry (ATSDR) have worked collaboratively to complete the research activities on synthetic turf playing fields under the "Federal Research Action Plan on Recycled Tire Crumb Used on Playing Fields and Playgrounds." The Agencies plan to release the research activities' results in two parts. This report (Part 1) summarizes the research effort to characterize tire crumb rubber, which includes characterizing the components of, and emissions from, recycled tire crumb rubber. The exposure characterization report (Part 2) will summarize the potential exposures that may be experienced by users of synthetic turf playing fields with recycled tire crumb rubber infill, such as how people come in contact with the materials, how often and for how long. Part 2 will be released at a later date, along with results from a planned biomonitoring study conducted by CDC/ATSDR.

The study is not a risk assessment; however, the results of the research described in this and future reports will advance our understanding of exposure to inform the risk assessment process. We anticipate that the results from this multi-agency research effort will be useful to the public and interested stakeholders to understand the potential for human exposure to chemicals found in recycled tire crumb rubber used on synthetic turf fields.

This report has been prepared to communicate to the public the research objectives, methods, results and findings for the tire crumb rubber characterization research conducted as part of the Federal Action Research Plan. The report has undergone independent, external peer review in accordance with EPA and CDC policies. A summary of key reviewer recommendations and relevant responses on this part of the research is provided with this report. A response-to-peer review comments document will be released with Part 2.

The mission of the EPA is to protect human health and the environment so that future generations inherit a cleaner, healthier environment that supports a thriving economy. Science at EPA provides the foundation for credible decision-making to safeguard human health and ecosystems from environmental pollutants. ORD is the scientific research arm of EPA, whose leading-edge research helps provide the solid underpinning of science and technology for the Agency. ORD supports six research programs that identify the most pressing environmental health research needs with input from EPA offices, partners and stakeholders.

CDC works 24/7 to protect America from health, safety and security threats, both foreign and in the United States. ATSDR is a non-regulatory, environmental public health agency that was established by Congress under the Comprehensive Environmental Response, Compensation, and Liability Act of 1980. ATSDR protects communities from harmful health effects related to exposure to natural and man-made hazardous substances by responding to environmental health emergencies; investigating emerging environmental health threats; conducting research on the health impacts of hazardous waste sites; and building capabilities of and providing actionable guidance to state and local health partners.

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Acronyms and Abbreviations

ACGIH	American Conference of Governmental Industrial Hygienists
ACH	Air change per hour
ADI	Acceptable daily intake
ADPA	Acetone-diphenylamine condensation product
AEMD	Air and Energy Management Division
ANOVA	Analysis of variance
ANSI	American National Standards Institute
APHC	U.S. Army Public Health Center
ASTM	American Society for Testing and Materials
ASTSWMO	Association of State and Territorial Solid Waste Management Officials
ATSDR	Agency for Toxic Substances and Disease Registry
BHA	Butylated hydroxyanisole
BTEX	Benzene, toluene, ethylbenzene, xylenes
°C	Degrees Celsius
CAES	Connecticut Agricultural Experiment Station
CalEPA	California Environmental Protection Agency
CalOSHA	California Division of Occupational Safety and Health
CAS	Chemical Abstracts Service
CASE	Connecticut Academy of Science and Engineering
CDC	Centers for Disease Control and Prevention
CDEP	Connecticut Department of Environmental Protection
CDPH	Connecticut Department of Public Health
CFU	Colony forming units
CICAD	Concise International Chemical Assessment Documents
cm	Centimeter
COC	Chemicals of concern
COPC	Chemicals of potential concern
CPSC	Consumer Product Safety Commission
CSF	Cancer slope factor
CV	Coefficient of variance
d	day
DAD	Diode array detector
DAS	Data acquisition system
DBA + ICDP	Sum of Dibenz[a,h]anthracene and Indeno(1,2,3-cd)pyrene
DCC	Daily calibration checks
DDC	Direct dermal contact
ddPCR	Droplet digital polymerase chain reaction
DGI	Dust and gas inhalation
DNA	Deoxyribonucleic acid
DQI	Data quality indicators
ECHA	European Chemicals Agency
ECR	Excess cancer risk

EHHI	Environment and Human Health, Inc.
EOHSI	Environmental and Occupational Health Sciences Institute
EPA	U.S. Environmental Protection Agency
EU	European Union
FDEP	Florida Department of Environmental Protection
FLM	Fence line monitor
FR	Federal Register
FRAP	Federal Research Action Plan on Recycled Tire Crumb Used on Playing Fields and Playgrounds
g	Gram
GC/MS	Gas chromatography/mass spectrometry
GC/TOFMS	Gas chromatography/time-of-flight mass spectrometry
GS/MS/MS	Gas chromatography/tandem mass spectrometry
h	Hour
h^{-1}	Per hour
HEAST	Health Effects Assessment Summary Table
HHRA	Human health risk assessment
HI	Hazard index
HPLC	High performance liquid chromatography
HR-ICPMS	High resolution magnetic sector inductively coupled plasma mass spectrometer
IAP	Internal audit program
IARC	International Agency for Research on Cancer
ICP/AES	Inductively coupled plasma-atomic emission spectrometry
ICP/MS	Inductively coupled plasma/mass spectrometry
ICP-OES	Inductively coupled plasma – optical emission spectrometry
IDL	Instrument detection limit
IOAA	Immediate Office of the Assistant Administrator
IPCS	WHO International Programme on Chemical Safety
IRIS	U.S. EPA Integrated Risk Information System
ISRI	Institute of Scrap Recycling Industries, Inc.
JTI	Jacobs Technology, Inc.
KEMI	Swedish Chemicals Inspectorate
kg	Kilogram
L	Liter
LC/MS	Liquid chromatography/mass spectrometry
LC/TOFMS	Liquid chromatography/time-of-flight mass spectrometry
LIMS	Laboratory Information Management System
LOD	Limit of detection
LOQ	Limit of quantitation
LRGA	Literature Review and Data Gaps Analysis
m	Meter
mg	Milligram
MADL	Maximum allowable dose levels
Max	Maximum
MCL	Maximum contaminant limit
MDL	Method detection limit

mecA	Gene for methicillin resistance
mg	Milligram
min	Minute
mL	Milliliter
MOS	Margin of safety
MQL	Method quantifiable limit
MQL	Minimum quantitation level
MRL	Minimum reportable limit
MRL	Minimum risk level
MRM	Multiple reaction monitoring
MRSA	Methicillin-resistant *Staphylococcus aureus*
N/A	Not applicable/Not available
NAAQS	National Ambient Air Quality Standards
NCCT	U.S. EPA National Center for Computational Toxicology
NCEA	U.S. EPA National Center for Environmental Assessment
NCEH	CDC National Center for Environmental Health
ND	Nondetect
NERL	U.S. EPA National Exposure Research Laboratory
NFL	National Football League
ng	Nanogram
NHEERL	U.S. EPA National Health and Environmental Effects Research Laboratory
NHTSA	National Highway Traffic Safety Administration
NIOSH	National Institute for Occupational Safety and Health
NIPH	Norwegian Institute of Public Health
NIST	National Institute of Standards and Technology
NOAEL	No observed adverse effect level
NOEC	No observable effects concentration
NOEL	No observable effects limit
NR	Not reported
NRMRL	U.S. EPA National Risk Management Research Laboratory
NSRL	No significant risk level
NTP	U.S. National Toxicology Program
NYDEC	New York Department of Environmental Conservation
NYDOH	New York Department of Health
OCHP	U.S. EPA Office of Children's Health Protection
OEHHA	California Office of Environmental Health Hazard Assessment
OEHHA	U.S. EPA Office of Land and Emergency Management
OLEM	U.S. Office of Management and Budget
OMB	Oak Ridge Associated Universities
ORAU	U.S. EPA Office of Resource Conservation and Recovery
ORCR	U.S. EPA Office of Research and Development
ORD	Oak Ridge Institute for Science and Education
ORISE	Occupational Safety and Health Administration
OSHA	U.S. EPA Office of Science Policy
OSP	N-Oxydiethylenedithiocarbamyl-N`-oxydiethylenesulfenamide
OTOS	Off-the-road
OTR	

PAH	Polyaromatic hydrocarbon
PCB	Polychlorinated biphenyl
PCR	Polymerase chain reaction
PQL	Practical quantification limit
PEHSU	Pediatric Environmental Health Specialty Unit
PEL	Permissible exposure limit
PM	Particulate matter
PNEC	Predicted no effect concentration
POP	Priority organic pollutants
ppbv	Parts per billion by volume
ppm	Parts per million
PQAM	Program Quality Assurance Manager
PPRTV	Provisional peer-reviewed toxicity value
PRA	Paperwork Reduction Act
PSA	Particle size analysis
PUF	Polyurethane foam
QA	Quality assurance
QAM	Quality assurance manager
QAPP	Quality assurance project plan
QMP	Quality management plan
QC	Quality control
REACH	Registration, Evaluation, Authorisation, and Restriction of Chemicals
REL	Recommended exposure limit/Reference exposure levels
RfC	Reference concentration
RfD	Reference dose
RH	Relative humidity
RIVM	Netherlands National Institute for Public Health and the Environment
RM	Rubber mulch
RMA	Rubber Manufacturers Association
RNA	Ribonucleic acid
RPD	Relative percent difference
rRNA	Ribosomal ribonucleic acid
%RSD	Percent relative standard deviation
RTP	Research Triangle Park (North Carolina)
RWC	Rain water contact
SA/BW	Surface area to body weight ratio
SBR	Styrene-butadiene rubber
SEE	Senior Environmental Employee
SEM	Scanning electron microscopy
SF	Slope factor
SOP	Standard operating procedure
SPME	Solid-phase microextraction
SSC	Student Services Contractor
STC	Synthetic Turf Council
STEL	Short term exposure limit
Sum15PAH	Sum of 15 of the 16 EPA 'priority' PAHs

SumBTEX	Sum of benzene, toluene, ethylbenzene, m/p-xylene, and o-xylene
SVOC	Semivolatile organic compound
TCC	Tire Crumb Characterization
TCLP	Toxicity characteristic leaching procedure
TCR	Tire crumb rubber
TCRS	Tire Crumb Research Study
TLV	Threshold limit value
TOF	Time of flight
TOFMS	Time-of-flight mass spectrometry
TPE	Thermoplastic elastomers
TSA	Technical systems audit
TSP	Total suspended solids
TWA	Time weighted average
TWP	Tire wear particles
UCHC	University of Connecticut Health Center
µg	Microgram
µm	Micrometer
µL	Microliter
UR	Unit risk
URL	Uniform resource locator
U.S.	United States of America
U.S. EPA	United States Environmental Protection Agency
UV	Ultraviolet spectrometry
VID	Video identification number
VOC	Volatile organic compound
WDOH	Washington State Department of Health
WHO	World Health Organization
WM	Wood mulch
XRF	X-ray fluorescence spectrometry
yr	Year

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Appendix A
Industry Overview

[copied from 2016 Status Report Section IV.A]

Industry Overview

The agencies used outreach efforts and publicly available information to gain a better understanding of the synthetic turf industry, tire manufacturing process, processes for creating tire crumb rubber, and procedures for synthetic turf field installation and maintenance. This section provides information related to these topics.

Waste Tire Generation and Recovery Estimates

A large volume of used automobile and truck tires enters the waste stream in the United States each year. An estimated 4.77 million tons of waste tires were generated in 2013, and 40.5 percent, or 1.93 million tons, were recovered through recycling and production of retreaded tires (U.S. EPA, 2015). Much of the waste tire material is used in fuel markets, including cement kilns, utility boilers, industrial boilers, pulp and paper mills, and dedicated scrap tire-to-energy facilities (RMA, 2016a). In 2013, approximately 172,000 tons of scrap tires were converted to tire shreds for use in road and landfill construction, septic tank leach fields, and other construction applications (RMA, 2016a). Approximately 975,000 tons of scrap tires (i.e., approximately 59.5 million tires) were used in the ground rubber applications market, which includes the manufacture of new rubber products, rubber-modified asphalt, and playground and sports surfacing (RMA, 2014 and 2016a). The Rubber Manufacturers Association (RMA) estimated that in 2013, 33 percent of these scrap tires were used in molded/extruded products, 31 percent in playground mulch, 17 percent in sports surfaces, 7 percent in asphalt, 6 percent in automotive products, and 6 percent were exported (RMA, 2014). Recycled rubber from tires is used in several types of recreational venues, including use as infill material in synthetic turf fields, on playgrounds either as loose rubber mulch or rubber mats, for running surfaces, and in equestrian arenas. Recycled tire material may also be used in other applications, such as tire-derived rubber flooring materials (CalRecycle, 2010).

Synthetic Turf Fields

Synthetic turf field systems initially were introduced in the 1960s. Currently, there are between 12,000 and 13,000 synthetic turf sports fields in the United States, with approximately 1,200 to 1,500 new installations each year (See Figure 1) (STC et al., 2016a). Synthetic turf fields are installed at municipal and county parks; schools and colleges; professional team stadiums and practice fields; and military installations. Users include professional and college athletes, youth athletes in school and/or other athletic organizations, adult and youth recreational users, coaches, team and facility staff, referees, and fans and bystanders of all ages. No data were identified to estimate the number of individuals using synthetic turf fields in the United States; however, given the large number of installed fields it can be reasonably anticipated that the number of users nationwide is in the millions.

Tire Manufacturing Process

The five main components of tires are tread, sidewall, steel belts, body plies, and bead (ChemRisk, 2008). Tires are manufactured with a range of materials, including natural and synthetic rubber and elastomers; reinforcement filler material; curatives including vulcanizing agents, activators, accelerators, antioxidants, antiozonants, inhibitors, and retarders; extender oils and softeners; phenolic resins and plasticizers; metal wire; polyester or nylon fabrics; and bonding agents (Dick and Rader, 2014; Cheng et al., 2014; ChemRisk, 2008; NHTSA, 2006). In tire manufacturing, the natural and synthetic ingredients are mixed together under heat and high pressure and rolled into rubber sheets. These rubber sheets either can be calendared with textile sheets or extruded together and forced through a die. A tire is built by applying layers of rubber, rubber-encased materials, steel belts, and tread rubber. The built tire then is cured at a temperature between 150° and 180 °C (300° and 360 °F) (ChemRisk, 2008). This tire-curing process is referred to as vulcanization, and it involves the formation of crosslinks between polymer chains in rubber. Figure 2 displays a cross-section of a tire.

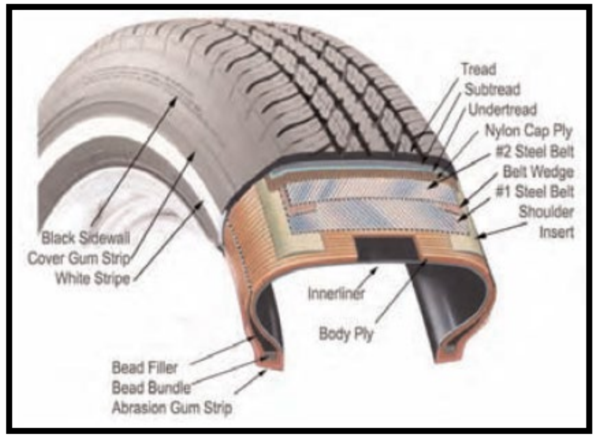

Figure 2: Cross Section of a Tire (NHTSA, 2016)

Chemicals of Interest or Concern in Tires

Many of the concerns that have been raised by the public are about the potential exposure to chemicals in tire crumb rubber infill used in synthetic turf fields. Chemicals of interest or concern used in tire manufacturing range from polyaromatic hydrocarbons (PAHs) in carbon black to zinc oxide (ZnO), which is used as a vulcanizing agent and could contain trace amounts of lead and cadmium oxides. Chemicals in many other classes could be used in tire manufacturing, including sulphenamides, guanidines, thiazoles, thiuams, dithiocarbamates, sulfur donors, phenolics, phenylenediamines, and others (ChemRisk, 2008). There is limited information to assess whether some of these chemicals might carry impurities or byproducts. During vulcanization, the rubber is heated with vulcanizing agents under pressure, which causes profound chemical changes at the molecular level, altering the initial composition of the tire and giving it its elasticity (Coran, 1994).

There is uncertainty about whether rubber material in vulcanized tires might undergo chemical transformation over time. The rubber could serve as a sorbent for chemicals in the air and in dust that falls onto the field. One laboratory reported irreversible adsorption of volatile organic compounds (VOCs) and semivolatile organic compound (SVOC) analytes spiked onto tire crumb rubber (NYDEC, 2009).

Tire Manufacturing Standards

The National Highway Traffic Safety Administration conducts research and mandates certain requirements for passenger-car tires to ensure crash avoidance and fuel efficiency (NHTSA, n.d.). The reason NHTSA was established was to implement the provisions of the Congressional Safety Act of 1966. For example, 49 CFR 571.109 (Standard Number 109: New Pneumatic and Certain Specialty Tires) requires testing of tires for physical properties and provides standards for tire labeling and serial numbers. Industry associations, such as the Tire and Rim Association, also establish engineering standards for tires, rims, and allied parts (NHTSA, 2006).

Tires introduced on the European tire market are also subject to the European Union's Registration, Evaluation, Authorisation, and Restriction of Chemicals (REACH) regulation that restricts the use of high-aromatic oils in tires produced after January 2010 (Eur-Lex-32005L0069-EN, n.d.). Tires or parts of tires must not contain more than 1 mg/kg of benzo[*a*]pyrene, or more than 10 mg/kg of the sum of benzo[*a*]pyrene, benzo[*e*]pyrene, benzo[*a*]anthracene, chrysene, benzo[*b*]fluoranthene, benzo[*j*]fluoranthene, benzo[*k*]fluoranthene and dibenzo[*a,h*]anthracene (Eur-Lex-32005L0069-EN, n.d.).

Tire Crumb Rubber Manufacturing Process

In the United States, tires typically are collected at tire dealerships and automobile service stations and shipped to tire recyclers. Tires of different types (e.g., passenger cars, trucks) and from different manufacturers are mixed together at tire collection stations and tire recycling plants. According to the Synthetic Turf Council (STC)[1], there are nine tire crumb rubber producers in the United States produce approximately 95 percent of the recycled rubber used as infill in synthetic turf field applications (STC et al., 2016a).

Tire Types

The STC's guidelines state that tire crumb rubber is derived from scrap car and truck tires that are ground up and recycled (STC, 2011) to a certain size for use in synthetic turf fields. The exact proportion of each tire type in the infill product is unclear and appears to vary depending on the tire crumb rubber producer.

The use of off-the-road (OTR) tires to produce tire crumb rubber infill may be more limited. An article in the newsletter published by the Institute of Scrap Recycling Industries, Inc. (ISRI) discusses the many challenges and considerations associated with the sourcing, transportation, and processing of OTR tires, including the needs for downsizing larger tires before feeding them into primary shredders and for removing bead bundles to reduce the wear on the shredders

[1] The Synthetic Turf Council is a non-profit trade association whose objective is to encourage, promote, and facilitate better understanding among all parties involved in the manufacture, selection, delivery, and use of today's synthetic turf systems (STC, n.d.-c).

(Mota, 2013). The logistics, cost, and additional processing required to use OTR tires limits their use as feedstock for producing tire crumb rubber infill (Sikora, 2016).

Ambient and Cryogenic Processes

Two tire recycling processes, (1) ambient and (2) cryogenic, are used to create tire crumb rubber in the 10- to 20-mesh (0.84- to 2.0-mm) size, which is generally the size used in synthetic turf infill. ASTM International a not-for-profit organization that develops and publishes international voluntary consensus standards[2] for materials, products, systems and services (ASTM, n.d.), developed Method ASTM D5644[3], which can be used to determine the average particle size distribution of recycled vulcanizate particulate (ASTM, 2013a). The number of tire recycling facilities using the ambient process is greater than the number of facilities using the cryogenic process (STC et al., 2016a).

The ambient process uses granulation or cracker mills to produce tire crumb rubber at room temperature (Scrap Tire News, 2016). Cracker mills use revolving rollers with serrations in them to size-reduce the tires. Once the granules are produced, they are fed through screens and sorted to the appropriate size (Scrap Tire News, 2016). The cryogenic process uses liquid nitrogen to freeze partially shredded tires, which then are fed into a hammer mill to create tire crumb rubber.

Fabric (i.e., polyester, nylon, or other fibers) and steel belt components of the scrap tire are separated in both processes (Scrap Tire News, 2016). Fabric is removed from the rubber using air classifiers or vacuums, while the steel is removed using magnetic separators. Gravity separators also can be used to remove contaminant particles, such as rocks, and can aid in the sorting process. Likewise, water can be used for pre-washing to remove gravel and dirt and cooling during the ambient process; otherwise no chemicals are added to the original rubber composition during either process. Following processing, tire crumb rubber typically is placed into one-ton sacks and distributed to fields for spreading.

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[2] The ASTM standards can be incorporated into contracts; used in laboratories and offices; referenced in codes, regulations, and laws; or referred to for guidance. Although ASTM standards are voluntary, in cases in which an ASTM standard is referenced in a law, regulation, or code, compliance with the ASTM standard could be required (ASTM, n.d.).
[3] All ASTM standards can be found at [https://www.astm.org/.](https://www.astm.org/)

Synthetic Turf Fields

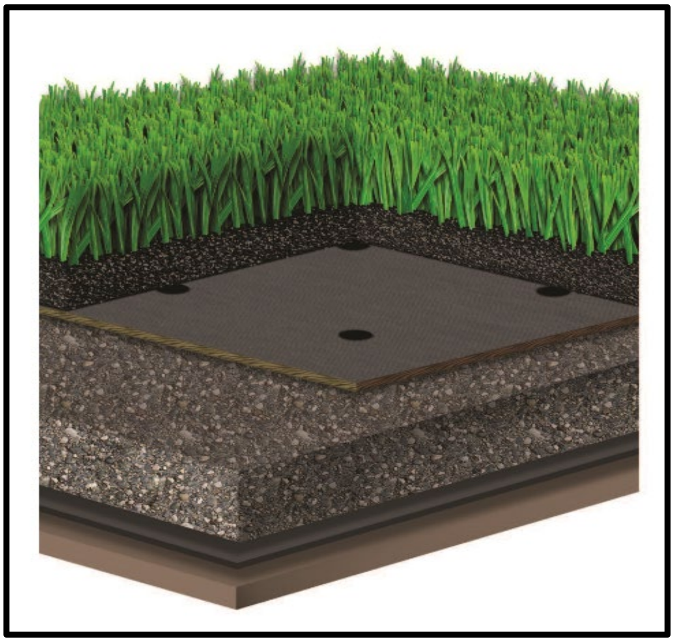

Figure 3: A cross-section of the layers of a typical synthetic turf field (STC, n.d.-b)

Synthetic turf fields are installed for various activities played at both the recreational and professional level, including football, soccer, and lacrosse. There are approximately eight major synthetic field installers in the United States with the largest four being national in scope, installing coast to coast (Sprinturf, 2016). An estimated 95 percent of the existing fields in North America use recycled rubber infill exclusively or in a mixture with sand or alternative infills; the remaining five percent contain only alternative infills (STC et al., 2016a). STC also reports that the use of exclusively alternative infills in new installations increased in 2016 (STC et al, 2016b). Outdoor synthetic turf fields are more common than indoor fields (FieldTurf, 2016a), with some sources indicating that indoor fields constitute approximately five to 15 percent of the market (Sprinturf, 2016). The differences in the construction between outdoor and indoor fields are the use of a more durable fiber in indoor fields (Sprinturf, 2016) and the use of adhesives to glue down the fiber carpet to the floor of indoor facilities (FieldTurf, 2016b).

Figure 4: Sand and packaged crumb rubber awaiting field installation (USEPA, 2016b)

Current generation synthetic turf fields are typically constructed with a bottom gravel/stone base layer to allow for drainage (STC, 2011). On top of the drainage layer lies the turf component, which is composed of multi-layered polypropylene and urethane backing material with polyethylene fiber blades. Sometimes a pad can be used for additional cushioning on a field (STC, 2011). Figure 3 displays a cross-section of a typical turf field and Figure 4 shows materials for a synthetic turf field before installation.

The colored lines, hash marks, numbers, and logos on a field are created either as part of the turf during the manufacturing process, or at the job site by cutting the original backing material from the field and gluing or sewing the colored pieces onto the backing material (STC, n.d.-c). Lines also can be temporarily painted on the field.

Figure 5: Tire crumb rubber is placed on a field in layers during installation (USEPA, 2016c)

Fields can be infilled with material in a few different ways. Sand is often used as a lower layer infill material to act as a ballast for the turf component. On top of this lower layer either will be tire crumb rubber or a sand/tire crumb rubber mix, topped by additional tire crumb rubber. Other fields can use an infill exclusively comprised of tire crumb rubber. On a small number of fields, tire crumb rubber could be coated with paint, typically green, either for aesthetic purposes or heat control (FieldTurf, n.d.-d; Sprinturf, n.d.). To a much lesser extent, natural materials (e.g., ground coconut husk), ethylene propylene diene monomer (EPDM), or thermoplastic elastomers (TPE) granules are used as the complete infill. These materials also can be used as the uppermost layer of infill (STC et al., 2016a). Infill material typically is spread using small utility vehicles that make multiple passes across entire fields, laying the material down in thin layers that are placed one on top of the other until the appropriate height is reached (Figure 5). Additional machinery can be used to drag or brush the blades upright to allow the material to fall between the blades (STC, 2011).

Synthetic Turf Field Standards

The *Standard Test Methods for Comprehensive Characterization of Synthetic Turf Playing Surfaces and Materials* (ASTM, 2009) can be used to identify the physical properties and compare the performance of synthetic turf systems and components of the system. The standard presents a list of test methods that can be used to test components of the field, including turf blades, carpet backing material, shock absorbing pads, and infill material.

The *Standard Specification for Extractable Hazardous Metals in Synthetic Turf Infill Materials* (ASTM, 2016a) specifies a test method to determine the amount of hazardous metals that have the potential to be extracted from synthetic turf infill materials, if ingested. The standard adopts both the specified test method and the limits on the extractable amounts of heavy metals from the *Consumer Safety Specification for Toy Safety* (ASTM 2016b). It also applies to any infill material used in synthetic turf, irrespective of whether it is synthetic or natural. On November 30, 2016, recycled rubber and synthetic turf industry groups announced that leading members of the Recycled Rubber Council, Safe Fields Alliance, and STC are voluntarily moving to ensure all synthetic turf infill products created and used by their organizations will comply with ASTM F3188-16 (BusinessWire, 2016).

Synthetic Turf Field Maintenance

As is the case with natural fields, synthetic turf fields, too need to be maintained through a set of routine maintenance practices (STC, 2015). Routine synthetic turf field maintenance is conducted to maintain a safe playing surface, improve its appearance, and extend the life of the field (STC, 2015). Recommended maintenance practices include brushing the field for infill redistribution, raking to rejuvenate the fibers and to relevel the top portion of the infill, and sweeping for debris removal (STC et al., 2016a; FieldTurf, n.d.-b). It is recommended that some of these practices be performed more frequently than others, depending on the frequency with which the field is used and specific guidelines for the sport played on the field. There are also guidelines that recommend using surfactants, such as liquid laundry fabric softener or static conditioner, to help reduce static electricity that builds up during maintenance (STC, 2015; FieldTurf, n.d.-b). Water also is used to reduce the static electricity in synthetic turf fields (Daily, 2016).

It is important to maintain an appropriate amount of infill in the field for proper cushioning and firmness. Tire crumb rubber can be lost for a number of reasons, such as migration in the shoes and clothing of athletes, in weather events such as rain or snow, and through routine maintenance practices (Pennsylvania State University Center for Sports Surface Research, 2016). Because of tire crumb rubber migration, new infill material sometimes is added to existing fields to refresh or replace the tire crumb rubber that is lost over time. Infill material also can be added to modify the sponginess of a field, which, as in the case of the National Football League (NFL), is required to maintain a certain field firmness level (NFL, 2014). Certain high-use locations on a field might require replacement material more often than others (STC, 2015). Prior to every game, the NFL field testing program requires surface hardness to be measured in multiple field locations using the Clegg Impact Tester device (NFL, 2014) which can determine the surface hardness of a field by measuring how quickly a weight stops upon impact to that field (NFL, 2014). Through the use of the Clegg Impact Tester, a Gmax[4] score can be determined, quantifying field firmness. Outside the NFL testing program, the *Standard Specification for Impact Attenuation of Turf Playing Systems as Measured in the Field* (ASTM F1936) also can be used to determine the field surface firmness (Sports Turf Managers Association, n.d.). This standard establishes its own test method (ASTM F355) to determine surface firmness, suggests test point locations and specifies an upper limit of surface hardness when using another testing device (ASTM, 2015).

Maintenance practices can vary based on the budget for field maintenance and employee knowledge of these practices (Pennsylvania State University Center for Sports Surface Research, 2016). Synthetic turf fields typically last about eight years before replacement, but can last longer, depending on the frequency of their use and level of maintenance (STC, 2016).

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[4] Surface hardness is measured in Gmax, which is the ratio of maximum negative acceleration on impact in units of gravities to the acceleration due to gravity (McNitt & Petrunak, 2013). The higher the Gmax value, the harder the surface. A Gmax value should be related to the device that is measuring hardness. For instance, a 100 Gmax with the Clegg Impact Tester is not the same as a 100 Gmax with the F355 device (NFL, 2014).

Appendix B
Stakeholder Outreach

[copied from 2016 Status Report Appendix A]

The EPA, CDC/ATSDR, and CPSC teams have engaged in a number of outreach activities to inform interested stakeholders about the Federal Research Action Plan (FRAP) and to gather and share information that may be used to inform the research. These outreach activities focused on three areas: 1) informing the public about the FRAP and encouraging them to provide feedback through a public comment process, 2) sharing information with government organizations that have planned and/or ongoing research efforts on this topic, and 3) conducting targeted outreach with organizations to gather additional information to help inform the implementation of the FRAP. These stakeholder outreach activities are further described below.

Informing the Public

Website

The FRAP was released on February 12, 2016. EPA, ATSDR, and CPSC developed a website (http://www.epa.gov/tirecrumb) describing the action plan and notified interested groups when the plan was announced. This website has been updated regularly throughout the research process in an effort to keep all stakeholders informed on the progress of the study. The website includes:

- An overview of the research;
- Frequently asked questions with answers;
- A fact sheet about the FRAP;
- Links to other available tire crumb rubber informational materials;
- A link to the Federal Register (FR) Notice, link to public comments and the agencies responses to public comments, and other information.

Using the website, interested individuals can sign-up to receive study updates via e-mail. To-date, more than 800 stakeholders have requested to receive updates about the study.

Webinar

The agencies published a FR Notice on February 18, 2016 requesting public comment on the data collection components of the FRAP (tire crumb rubber sample collection and collections related to the development of exposure scenarios). The data collection components were required to go through an Information Collection Request (https://www.epa.gov/icr) review conducted by Office of Management and Budget (OMB).

To encourage the general public to provide comments on the Federal Register Notice, the agencies hosted a webinar on April 14, 2016 describing the research study for anyone that was interested. This webinar was promoted on EPA's tire crumb rubber webpage, through the tire crumb rubber stakeholder e-mail list, and through EPA social media. The EPA, CDC/ATSDR, and CSPC research teams were available throughout the webinar to answer questions and provide extra detail where needed. More than 150 people participated in the webinar. The webinar was recorded and can be accessed through the FRAP website (http://www.epa.gov/tirecrumb).

Public Comment Period

The plans for the agencies to collect information (i.e. tire crumb sample collection and exposure information collection from field users) that are a part of the FRAP were available for public comment through a FR Notice. The agencies published the 60-day FR Notice on February 18, 2016 and extended the comment period at the public's request for two additional weeks to May 2, 2016. Once the FR Notice was posted, public comments were solicited by promoting the FR Notice on EPA's tire crumb rubber webpage, through the tire crumb rubber stakeholder e-mail list and through EPA social media. Members of the public submitted over 80 comments; these were addressed. The Notice, public comments, and responses to public comments are publicly available on OMB's website (http://www.reginfo.gov/public/do/PRAViewDocument?ref_nbr=201607-0923-001).

Sharing Information with Other Government Agencies

The EPA, CDC/ATSDR, and CSPC teams engaged in outreach activities to share information with government organizations that have planned or ongoing research efforts. These outreach activities facilitated the sharing of expertise and information to help inform the implementation of the FRAP. Specific outreach activities included in-person meetings and conference calls. Examples of government organizations sharing expertise and information through these outreach activities are included below.

Regular Conference Calls with States

CDC/ATSDR hosts monthly calls with state public health agencies to discuss the FRAP. These calls were held to share information and updates on the on-going research and to answer questions. These calls typically have between 10 and15 state public agencies participating. EPA also kept the Association of State and Territorial Solid Waste Management Officials (ASTSWMO) and interested state solid waste agencies informed through periodic conference calls and updates at meetings throughout 2016.

Webinar

The EPA team hosted a webinar on April 12, 2016 for state and local government organizations describing the FRAP and the FR Notice. The EPA, CDC/ATSDR, and CSPC research teams were available throughout the webinar to answer questions and provide extra detail where needed. About 100 state and local groups participated in the webinar. The webinar was recorded and shared with states to distribute to others within their organizations who might be interested in the topic.

Government Agencies Sharing Expertise and Information

Other government agencies that are sharing information and have ongoing or planned tire crumb rubber research include California's Office of Environmental Health Hazard Assessment, the U.S. National Toxicology Program (NTP), headquartered at the National Institute of Environmental Health Sciences, the European Chemicals Agency, and the Netherlands National Institute for Public health and the Environment. The EPA, CDC/ATSDR, and CPSC teams have been meeting regularly with these organizations through conference calls and in-person meetings.

- ***California.*** As mentioned above, the state of California's Office of Environmental Health Hazard Assessment has an in-depth tire crumb rubber study underway. This study includes a series of scientific studies to determine if chemicals in tire crumb rubber and synthetic turf field materials can potentially be released under various environmental conditions and what, if any, exposures or health risks these potential releases may pose to players who frequently play on artificial fields constructed with tire crumb rubber. The evaluation includes expert solicitation and stakeholder participation to help guide the design. EPA, CDC/ATSDR and CPSC have shared information about methodology being used for the studies. The research plan includes animal toxicity studies, which are being conducted by NTP/NIEHS.
- ***International Agencies.*** Once the FRAP was announced, the European Chemicals Agency (ECHA) contacted EPA expressing their interest. ECHA is an agency of the European Union that implements chemical legislation for the protection of human health and the environment. This interest has resulted in regular calls with ECHA and an in-person meeting. During these meetings, information related to research efforts are shared. In addition, the Netherlands and France are also interested in studying tire crumb rubber exposure and characterization and communications with these organizations are on-going.

Conducting Targeted Outreach to Gather Additional Information

The purpose of conducting targeted outreach was to request informational resources from industry and non-profit organization/interest groups to inform the implementation of the FRAP. The EPA team held discussions with stakeholder groups, toured recycling facilities and observed field installations. Specifically, EPA, CDC/ATSDR, and CPSC requested information and existing studies about how tires and tire crumb rubber are manufactured; how synthetic turf fields are constructed, installed, and maintained; and other studies or information that could be used for the study

The objective was to enhance the agencies' understanding of how tires and tire crumb rubber are manufactured; and how synthetic turf fields are constructed, installed, and maintained, in order to identify potential variabilities in the tire crumb rubber product that is produced and installed in synthetic turf fields across the country.

Approach

The Paperwork Reduction Act (PRA) limited the number of entities that could be engaged by EPA to fewer than nine within a stakeholder group. In meetings that involved several different stakeholders, EPA was not seeking group consensus, input, or advice. Between February and September of 2016, EPA met or held conference calls with: five industry trade associations, three synthetic turf field companies, two synthetic turf field maintenance professionals, one academic institution, and five non-profit organizations. The EPA team also toured a total of five tire recycling facilities located in the south, west, and northeast regions of the United States., where both the ambient and cryogenic tire processing technologies were observed. The facilities ranged in size from small to large operations with varying degrees of mechanized technologies to process the tires. EPA observed the tire crumb rubber infilling process on two field installations in the Washington, D.C. metropolitan area. Study team members from CDC and CPSC also participated in several of the recycling facility and field installation observations. Collectively, presentations and information exchanges spanned a number of topics, including:

- The state of tire manufacturing and scrap-tire collection and recycling;
- The nature and varieties of processes and machinery used in the processing of scrap tires into tire crumb rubber;
- Tire-manufacturing standards;
- Tire recycling processing standards and/or tire crumb rubber product standards;
- Tire crumb rubber infill product types; storage, packaging, and transportation of tire crumb rubber to fields;
- The number and distribution of synthetic turf fields;
- Synthetic turf field construction, installation, and maintenance practices.

Participants often recommended resources the study team could consult for more information.

Use of Information Obtained

As previously stated, the purpose of the outreach effort was to help inform the study design and implementation of the FRAP. The information was also used to develop a preliminary summary of the tire and tire crumb rubber manufacturing process, as well as the process by which synthetic turf fields are constructed, installed and maintained. Over the next several months, EPA will continue to review, analyze, and supplement the information included in this status report and will provide an updated summary in the study's final report.

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Appendix C

State-of-Science Literature Review/ Gaps Analysis

White Paper Summary of Results, December 2016
with Introductory Text

Literature Review and Data Gaps Analysis

The EPA, CDC/ATSDR, and CPSC FRAP research team conducted a Literature Review/Gaps Analysis (LRGA) to provide a summary of the available literature and to capture data gaps as characterized in relevant publications. The overall goals of the LRGA were to inform the FRAP research studies and to identify potential areas for future research. The LRGA did not include critical reviews of the strengths and weaknesses of each study, but does provide the authors' conclusions regarding their research, where applicable. The LRGA also did not make any conclusions or recommendations regarding the safety of recycled tire crumb rubber used in synthetic turf fields and playgrounds.

The review provides information useful for guiding and designing future research efforts needed to further address questions regarding exposures and risks for tire crumb rubber used in synthetic turf fields and playgrounds. The LRGA has been previously published in the FRAP 2016 status report (U.S. EPA, CDC/ATSDR, and CPSC, 2016b). The peer-reviewed LRGA report is included after this introduction.

Literature Review and Gaps Analysis Summary

To comprehensively understand the current state-of-the science and data gaps associated with the toxicity of and human exposure to constituents in tire crumb rubber, CDC/ATSDR, EPA and CPSC undertook a collaborative effort to review the scientific literature and analyze data gaps. The first objective of the Literature Review/Gaps Analysis (LRGA) collaboration was to identify the existing body of literature related specifically to human exposure to tire crumb rubber through the use of synthetic turf athletic fields and playgrounds. The second objective was to characterize and summarize the relevant data from the scientific literature. The final objective was to review the summary information and identify data gaps to build on the current understanding of the state-of-the-science and inform the development of specific research efforts that would be most impactful in the near-term.

Federal researchers examined a wide variety of information sources to build a list of relevant citations. The literature search included the following databases: PubMed Medline (OVID); Embase (OVID); Scopus; Primo (Stephen B. Thacker CDC Library); ProQuest Environmental Science Collection; Web of Science; ScienceDirect and Google Scholar. The LRGA focused on scientific publications that addressed tire crumb rubber use, physical characteristics and chemical composition, potential pathways of exposures, bioavailability, and component toxicity and risk assessment. It included studies that examined occupational exposures at tire recycling plants, human exposures related to field and playground installations, and subsequent exposures involved with use of synthetic turf and playground facilities. It did not include studies on automotive tire manufacturing processes and related exposures and risks. In determining whether or not to include a publication found in the course of the literature search, a set of relevance criteria was developed.

The LRGA identified 88 relevant references published through August 2016. Each reference that was reviewed was categorized according to 20 general information categories (e.g., study topic, geographic location, sample type, conditions, populations studied) and more than 100 sub-categories (e.g., for the study topic sub-categories included: site characterization, production process, leaching, off-gassing, microbial analysis, and human risk). As part of the effort, greater than 350 discrete chemical compounds also were identified in the literature collected for this effort and a list of potential chemical constituents was compiled to inform further research efforts.

The studies that were identified covered a wide range of topics and locations, but some topic areas received greater coverage than others. For example, information on chemical leaching and offgassing and volatilizing from tire crumb rubber was found in 36 and 25 studies, respectively, but less information was available on microbiological, bioavailability, and biomonitoring aspects of tire crumb rubber exposures (i.e., seven, five, and three studies, respectively). No epidemiological studies were identified in the literature search. Data gaps could be more pronounced for locations such as playgrounds and indoor fields, and for studies that examine environmental background levels of tire crumb rubber constituents. Studies on occupational exposures from turf and playground installations were also limited. Metal constituents of tire crumb rubber, such as lead and zinc, have been frequently identified in the literature as constituents of concern, but research on exposures to these metals by field and playground users is limited. While a number of volatile and semivolatile organic chemicals (especially polycyclic aromatic hydrocarbons) have been measured in some studies, research on other organic chemical constituents identified by the LRGA is more limited.

Other important data gaps include the lack of more in-depth characterizing of dermal and ingestion exposure pathways, identifying constituents and scenarios resulting in the highest exposures, developing and applying biomonitoring for constituents of concern, and assessing the feasibility and approaches for epidemiological investigations. Several important data gaps for assessing exposures and risks of tire crumb rubber at synthetic fields and playgrounds are summarized in the report.

Recent Research – Published After the LRGA was Released in December 2016

Several organizations and researchers have published important information on this topic since the FRAP literature review and data gaps analysis was completed and published in December 2016. Brief summaries of some of these research efforts and publications are provided below.

The California Office of Environmental Health Hazard Assessment (OEHHA) has continued planning and conducting research on tire crumb rubber and human exposures at synthetic turf fields. Regarding the latest study, no research reports have been published by Cal-OEHHA at this time, but materials documenting and describing their research efforts have been made available (https://oehha.ca.gov/risk-assessment/synthetic-turf-studies). Cal-OEHHA study components include:

- Expert, public and interagency consultation and input
- Hazard Identification
- Exposure Scenario Development
- Characterization of chemicals that can be released from synthetic turf and playground mats, and determination of the potential for human exposures
- Biomonitoring and personal monitoring protocol development
- Reporting
- Health assessment from play on synthetic turf and playground mats

The Netherlands National Institute for Health and Environment (RIVM) released a December 2016 report, updated in March 2017, titled "Evaluation of health risks of playing sports on synthetic turf pitches with rubber granulate" (RIVM, 2017). The RIVM collected rubber infill from 100 synthetic turf fields and performed analyses for selected polyaromatic hydrocarbons, phthalates, and metals along with bisphenol A and other chemicals of interest. Tests were conducted to determine to what extent substances are released from crumb rubber through ingestion, skin contact and by evaporation in hot weather. Exposure estimates were performed for five exposure scenarios using assumed exposure parameters for different ages and player categories. Exposure estimates and toxicological information were used to evaluate potential health risks. In addition, relationships between leukemia and lymphoma and sports on synthetic turf with rubber infill was examined compared to historical and overall rates in the Netherlands. RIVM conclusions from the 2016 research include:

"The results of this research indicate that playing sports on these fields is safe. The risk to health from playing sports on these synthetic turf fields is virtually negligible. While rubber granulate contains harmful substances, these substances are only released from the rubber granulate in very small quantities after ingestion, contact with the skin or evaporation in hot weather. RIVM recommends adjusting the standard for rubber granulate to one that is closer to the standard applicable to consumer products."

"No indications of a relationship between leukemia, lymph node cancer and sports on synthetic grass have been found."

RIVM researchers have also published a journal article, titled: "Synthetic turf pitches with rubber granulate infill: are there health risks for people playing sports on such pitches?" (Pronk, 2018). The article summarizes the research efforts and results included in the 2017 report. Findings and conclusions from this journal article included:

"Risks to human health were assessed by comparing toxicological reference values for these substances with the exposure estimates. A number of carcinogenic, mutagenic and reprotoxic substances were present in rubber granulate used on Dutch pitches. No concern was, however, identified for phthalates, benzothiazoles, bisphenol A and the metals cadmium, cobalt and lead, as their exposures were below the levels associated with adverse effects on health. PAHs appeared to be the substances of highest concern, but even they present no appreciable health risk with exposures resulting in additional cancer risks at or below the negligible risk level of one in a million. Our findings for a representative number of Dutch pitches are consistent with those of prior and contemporary studies observing no elevated health risk from playing sports on synthetic turf pitches with recycled rubber granulate. Based on current evidence, there is no reason to advise people against playing sports on such pitches."

The Washington State Department of Health released a report January 2017, updated in April 2017, "Investigations of Reported Cancer among Soccer Players in Washington State" (WDOH, 2017). The investigations were based on concerns raised by Amy Griffin, University of Washington Women's Associate Head Soccer Coach, regarding the number of soccer players, and goalkeepers in particular, identified with cancer and exposure to synthetic turf fields with tire crumb rubber infill. The Washington State Department of Health, in collaboration with the University of Washington School of Public Health, performed an investigation with two primary goals: 1) compare the number of cancers on a list compiled by the coach list to the number that would be expected if rates among soccer players were the same as rates among all Washington residents of the same ages; and, 2) describe individuals reported by the coach in terms of their demographics, factors related to cancer, and history of playing soccer and other sports. Of the 53 people on Coach Griffin's list, 27 met the investigation's case definition (diagnosis between 2002-2015, 6-24 years old at diagnosis, played soccer in Washington state prior to diagnosis, played soccer at least 0.4 years prior to diagnosis). The 27 people experienced 28 cancers. A total of 1384 cancers would have been expected among comparable Washington state soccer players. The report addresses complex questions about whether the number of expected cases were likely to be over- or underestimated. Conclusions and recommendations from the Washington DOH report include:

"Our investigation was not designed to determine if soccer players in general were at increased risk of cancer due to exposures from crumb rubber in artificial turf. Rather, its purpose was to explore whether the information from Coach Griffin's list warranted further public health response.

This investigation did not find increased cancer among the soccer players on the coach's list compared to what would be expected based on rates of cancer among Washington residents of the same ages. This finding is true for all soccer players on the coach's list, as well as soccer players on the list at the WYS-defined select and premier levels, and goalkeepers on the list. The variety of fields and residences suggests that no specific field or geographic residence is problematic in terms of soccer players getting cancer.

In addition, the currently available research on the health effects of artificial turf does not suggest that artificial turf presents a significant public health risk. Assurances of safety, however, are limited by lack of adequate information on potential toxicity and exposure. The Washington State Department of Health will continue to monitor new research on health and environmental impacts of crumb rubber.

Thus, the Washington State Department of Health recommends that people who enjoy soccer continue to play irrespective of the type of field surface."

The European Chemicals Agency (ECHA) released a report in February 2017 titled "Annex XV Report; An Evaluation of the Possible Health Risks of Recycled Rubber Granules Used as Infill in Synthetic Turf Sports Fields" (ECHA, 2017). ECHA evaluated human health risks for chemicals found in tire crumb rubber used on outdoor and indoor synthetic turf football (soccer) fields. ECHA compiled information for PAHs, metals, phthalates, VOCs, and SVOCs primarily from European studies. ECHA then created several exposure scenarios for children, adults, and workers installing or maintaining field and estimated inhalation, dermal, and ingestion exposures. Conclusions from the ECHA report include:

"ECHA has found no reason to advise people against playing sports on synthetic turf containing recycled rubber granules as infill material. This advice is based on ECHA's evaluation that there is a very low level of concern from exposure to substances found in the granules. This is based on the current evidence available. However, due to the uncertainties, ECHA makes several recommendations to ensure that any remaining concerns are eliminated."

A journal article was published, titled "Comprehensive multipathway risk assessment of chemicals associated with recycled ("crumb") rubber in synthetic turf fields" (Peterson, 2017). The article described approaches for selecting and using measurements of chemicals in tire crumb rubber (primarily from North American studies) as well as chemical release and/or bioaccessibility data. A systematic process was used for selecting 'chemicals of potential concern' for exposure and risk characterization. Exposures were estimated for youth soccer players and adult and child bystanders at synthetic turf fields. Information for toxicity for each chemical of potential concern, or similar-chemical surrogate toxicity information, were combined with exposure estimates assess cancer and non-cancer risks. Conclusions from Peterson et al. include:

"Estimated non-cancer hazards and cancer risks for all the evaluated scenarios were within US EPA guidelines. In addition, cancer risk levels for users of synthetic turf field were comparable to or lower than those associated with natural soil fields."

"This HHRA's results add to the growing body of literature that suggests recycled rubber infill in synthetic turf poses negligible risks to human health. This comprehensive assessment provides data that allow stakeholders to make informed decisions about installing and using these fields."

A journal article was published, titled “Incidence of malignant lymphoma in adolescents and young adults in the 58 counties of California with varying synthetic turf field density” (Bleyer & Keegan, 2018). The article describes an ecologic epidemiologic evaluation of county-level incidence of lymphomas among adolescents and young adults and synthetic turf field density in California, USA. Conclusions from Bleyer & Keegan include:

“Our findings in the state with the greatest number of such fields and a large, diverse patient population are consistent with those of a prior study observing no association between individual-level exposures to turf fields and cancer incidence. Avoidance of synthetic turf fields for fear of increased cancer risk is not warranted.”

“Higher rates of lymphoma incidence in regions with synthetic turf fields generally are explained by the age range, race/ethnicity distribution, and socioeconomic status as measured by family income assignable to counties that have such fields. County-level ecological evidence mitigates against a strong lymphomagenic effect of synthetic turf fields and supports the Washington State and Netherlands studies. Because regular physical activity during adolescence and early adulthood early adulthood helps prevent cancer later in life, restricting use or availability of all-weather year-round synthetic fields and thereby potentially reducing exercise could, in the long run, actually increase cancer incidence, as well as cardiovascular disease and other chronic illnesses. Therefore, it is important to consider the results of our and ongoing studies before the use and development of synthetic turf fields and playgrounds, which promote physical activity, are blocked, prevented or precluded because of cancer concerns.”

A journal article was published, titled “Evaluation of organic and inorganic compounds extractable by multiple methods from commercially available crumb rubber mulch” (Benoit & Demars, 2018). The article describes characterization of metals and organic chemicals associated with tire crumb rubber infill and shredded tire material sold for home use. Laboratory experiments were also performed to assess leaching with simulated acid rain and emissions from passive degassing. Findings and conclusions from Benoit & Demars include:

“Solvent extraction yielded 92 separate compounds, of which only about half have been tested for human health effects. Of these, nine are known carcinogens and another 20 are recognized irritants, including respiratory irritants that may complicate asthma. Strong acid extraction released measurable amounts of Pb and Cd and relatively large amounts of Zn. These three metals were specifically targeted for analysis, and others may be present as well, but were unmeasured. Simulated acid rain extracted only Zn in significant quantities. Passive volatilization yielded detectable amounts of 11 compounds. Results demonstrate that recycled tire materials contain and can release a wide variety of substances known to be toxic, and caution would argue against their use where human exposure is likely.”

A journal article was published, titled “Release of particles, organic compounds, and metals from crumb rubber used in synthetic turf under chemical and physical stress” (Canepari, 2018). The research characterized the chemical and morphological characteristics of materials released under chemical and physical stress for tire crumb rubber, natural rubber, and thermoplastic elastomer. Headspace analysis was performed for materials heated to 70 ºC, the release of metals under slightly acidic conditions was measured, and the formation of particles under mechanical and thermal stress was examined. Findings and conclusions include:

“The headspace solid-phase micro-extraction GC-MS analysis evidenced that at 70 °C natural rubber and thermoplastic elastomer release amounts of organic species much higher than recycled scrap tires.

In particular, the desorption of mineral oils, with a prevalence of toxicologically relevant low viscosity alkanes in the range C17–C22, and plasticizers (diisobutyl phthalate) was clearly evidenced. The new generation thermoplastic elastomer material also releases butylated hydroxytoluene. In slightly acidic conditions, quite high amounts of bioaccessible Zn, Cu, and Co are released from recycled scrap tires, while natural rubber releases mainly Se and Tl. In contrast, the thermoplastic elastomer does not contain significant concentrations of leachable heavy metals. The formation of small particles, also in the inhalable fraction, was evidenced by electron microscopy after mechanical or thermal treatment of natural rubber."

"The chemical and morphological characterization of the considered crumb rubber materials put into evidence how potential risks for health and environment can arise from the exposition of rubbers to chemical and physical agents."

"The use of natural rubber and of not-recycled thermoplastic materials, which are progressively replacing recycled tire scraps as synthetic turf fillers, does not seem to be adequately safe for human health, particularly when considering that children are the most exposed bracket of population. Exposure risks arising from the use of these materials deserve to be further deepened."

A journal article was published, titled "Evaluation of potential carcinogenicity of organic chemicals in synthetic turf crumb rubber" (Perkins, 2019). The article reports on a literature search for identifying chemicals associated with associated with crumb rubber from recycled tires, followed by prediction of carcinogenicity and genotoxicity of those chemicals using a computer program, and through comparison to US EPA and ECHA databases. Findings and conclusions from Perkins, et al., include:

"Through a literature review, we identified 306 chemical constituents of crumb rubber infill from 20 publications. Utilizing ADMET Predictor™, a computational program to predict carcinogenicity and genotoxicity, 197 of the identified 306 chemicals met our a priori carcinogenicity criteria. Of these, 52 chemicals were also classified as known, presumed or suspected carcinogens by the US EPA and ECHA. Of the remaining 109 chemicals which were not predicted to be carcinogenic by our computational toxicology analysis, only 6 chemicals were classified as presumed or suspected human carcinogens by US EPA or ECHA. Importantly, the majority of crumb rubber constituents were not listed in the US EPA (n=207) and ECHA (n=262) databases, likely due to an absence of evaluation or insufficient information for a reliable carcinogenicity classification. By employing a cancer hazard scoring system to the chemicals which were predicted and classified by the computational analysis and government databases, several high priority carcinogens were identified, including benzene, benzidine, benzo(a)pyrene, trichloroethylene and vinyl chloride. Our findings demonstrate that computational toxicology assessment in conjunction with government classifications can be used to prioritize hazardous chemicals for future exposure monitoring studies for users of synthetic turf fields. This approach could be extended to other compounds or toxicity endpoints."

Tire Crumb Research Study

State-of-the-Science Literature Review/Gaps Analysis

White Paper Summary of Results

December 2016

Prepared By

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Disclaimer

This document has been reviewed by the U.S. Environmental Protection Agency, Office of Research and Development, the Agency for Toxic Substances and Disease Registry, and the Consumer Product Safety Commission and approved for release. In accordance with guidance in the US EPA's Peer Review Handbook, the document was sent out for an independent, external peer review to three subject matter experts with expertise in analytical chemistry, human exposure assessment, and human exposure modeling. The document was revised based on reviewer recommendations.

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I. Executive Summary

Concerns have been raised by the public about the safety of recycled tire crumb rubber used in synthetic turf fields and playgrounds in the United States. Recycled tire materials used for synthetic turf infill and playground surface applications may lead to human exposures to chemical constituents in tire material. Human exposures to tire crumb rubber vary with time and activity associated with use of synthetic fields and playgrounds. Limited studies have not shown an elevated health risk from playing on fields with tire crumb, but the existing studies have not comprehensively evaluated the concerns about health risks from exposure to tire crumb rubber and important data gaps exist (U.S. EPA, 2016).

Because of the need for additional information, the U.S. Environmental Protection Agency (EPA), the Centers for Disease Control and Prevention/Agency for Toxic Substances and Disease Registry (ATSDR), and the U.S. Consumer Product Safety Commission (CPSC) launched a multi-agency action plan to study key environmental human health questions. The Federal Research Action Plan on Recycled Tire Crumb Used on Playing Fields and Playgrounds (referred to hereafter as the Federal Research Action Plan) includes numerous activities, including research studies (U.S. EPA, 2016). The Federal Research Action Plan includes numerous activities related to the design and implementation of a tire crumb research study. An important component of the Action Plan is to identify key knowledge gaps to inform the conduct of other elements of the Federal Research Action Plan.

To comprehensively understand the current state-of-the science and data gaps associated with the toxicity of and human exposure to constituents in tire crumb rubber, CDC/ATSDR, EPA and CPSC undertook a collaborative effort to review the scientific literature and analyze data gaps (See Appendix B). The first objective of the Literature Review/Gaps Analysis (LRGA) collaboration was to identify the existing body of literature related specifically to human exposure to tire crumb rubber through the use of synthetic turf athletic fields and playgrounds. The second objective was to characterize and summarize the relevant data from the scientific literature. The final objective was to review the summary information and identify data gaps to build on the current understanding of the state-of-the-science and inform the development of specific research efforts that would be most impactful in the near-term.

Federal researchers examined a wide variety of information sources to build a list of relevant citations. The LRGA focused on scientific publications that addressed tire crumb rubber use, physical characteristics and chemical composition, potential pathways of exposures, bioavailability, and component toxicity and risk assessment. It included studies that examined occupational exposures at tire recycling plants, human exposures related to field and playground installations, and subsequent exposures involved with use of synthetic turf and playground facilities. It did not include studies on automotive tire manufacturing processes and related exposures and risks. In determining whether or not to include a publication found in the course of the literature search, a set of relevance criteria was developed. A Quality Assurance Project

Plan was also developed to guide data collection, organization and analysis. A number of other steps were taken to ensure quality in data entry and analysis.

The LRGA identified 88 relevant references. Each reference that was reviewed was categorized according to 20 general information categories (e.g., study topic, geographic location, sample type, conditions, populations studied) and more than 100 sub-categories (e.g., study topic sub-categories: site characterization, production process, leaching, off-gassing, microbial analysis, and human risk). As part of the effort, greater than 350 discrete chemical compounds also were identified in the literature collected for this effort and a list of potential chemical constituents was compiled to inform further research efforts.

The studies that were identified covered a wide range of topics and locations, but some topic areas received greater coverage than others. For example, information on chemical leaching and offgassing and volatilizing from tire crumb rubber was found in 36 and 25 studies, respectively, but less information was available on microbiological, bioavailability, and biomonitoring aspects of tire crumb rubber exposures (i.e., seven, five, and three studies, respectively). No epidemiological studies were identified in the literature search. Data gaps could be more pronounced for locations such as playgrounds and indoor fields, and for studies that examine environmental background levels of tire crumb rubber constituents. Studies on occupational exposures from turf and playground installations were also limited. Metal constituents of tire crumb rubber, such as lead and zinc, have been frequently identified in the literature as a constituent of concern, but research on exposures to these metals by field and playground users is limited. While a number of volatile and semivolatile organic chemicals (especially polycyclic aromatic hydrocarbons) have been measured in some studies, research on other organic chemical constituents identified by the LRGA is more limited.

Other important data gaps include the lack of more in-depth characterizing of dermal and ingestion exposure pathways, identifying constituents and scenarios resulting in the highest exposures, developing and applying biomonitoring for constituents of concern, and assessing the feasibility and approaches for epidemiological investigations. Several important data gaps for assessing exposures and risks of tire crumb rubber at synthetic fields and playgrounds are summarized in Table B-1.

The LRGA does not include critical reviews of the strengths and weaknesses of each study but does provide the author’s conclusions regarding their research, where applicable. The LRGA does not make any conclusions or recommendations regarding the safety of the use of recycled tire crumb rubber in synthetic turf fields and playgrounds. The review provides information useful for guiding and designing future research efforts needed to further address questions regarding exposures and risks for tire crumb rubber used in synthetic turf fields and playgrounds.

Table B-1. Data Gaps for Research on Tire Crumb Rubber in Synthetic Fields and Playgrounds

	Research Area	Data Gaps
Tire Crumb Rubber Characterization	Chemical Characterization	• Studies that have measured metal, volatile organic chemicals (VOCs), and semivolatile organic chemicals (SVOCs) (e.g., polycyclic aromatic hydrocarbons [PAHs] and benzothiazole) were usually based on small numbers of tire crumb rubber samples. The wide range of organic chemicals potentially used in tire manufacture, or their degradates, have not been analyzed systematically across a large range of tire crumb rubber samples from synthetic fields and playgrounds in the United States. • Limited information is available on chemical constituents in molded rubber products made with tire crumb rubber used in some playground settings.
	Emissions Assessments	• Few laboratory-based studies have investigated VOC and SVOC emissions from synthetic fields and playgrounds under different temperature conditions. Measurements using dynamic emission chamber measurements have been reported, but the number and types of measured chemical emissions have been limited.
	Microbial Assessments	• Microbiological assessments for synthetic turf fields and playgrounds have been limited and have been based on traditional culture methods. The use of molecular methods has not been applied in studies of tire crumb rubber.
	Bioaccessibility	• Several studies have examined potential bioaccessibility of metals and PAHs. However, studies that systematically measure a wider range of metal and organic chemical constituents, using multiple simulated biological fluids, and across a large range of tire crumb rubber samples are lacking.
	Variability	• Most studies characterizing tire crumb rubber from synthetic fields and playgrounds in the United States have been relatively small and restricted to a few fields or playgrounds. Measurements for samples collected from a wider range of tire recycling plants, synthetic fields, and playgrounds across the United States is lacking. Also, information is limited on the range of chemical, microbiological, and physical characteristics and factors related to variability in tire crumb rubber and potential exposures.

Table B-1 (continued). Data Gaps for Research on Tire Crumb Rubber in Synthetic Fields and Playgrounds

	Research Area	Data Gaps
Exposure/Risk Characterization	Exposure Factors	• Exposure and risk assessments have typically relied on generic exposure factors. Information specific to the frequency and duration of synthetic field and playground uses, physical activities, contact rates, and hygiene are limited. • Exposure factor data are not available either across the wide variety of sports and recreational users of synthetic turf fields and playgrounds with tire crumb rubber, or for occupational exposures.
	Dermal/Ingestion Exposures	• While multiple studies have attempted to characterize potential inhalation exposures to tire crumb rubber chemical constituents, more limited information is available for understanding dermal and ingestion exposures.
	Broken Skin/Ocular Exposures	• Little information is available on the potential for increased exposures via broken skin (i.e., due to cuts and scrapes) and through ocular fluids.
	Particle Exposures	• There is limited information on exposure to tire crumb particles and their constituents through inhalation, dermal, and ingestion. Information on the exposure potential as synthetic fields and playgrounds age and weather, and for various uses and activities on synthetic fields and playgrounds is limited.
	Variability	• Few studies have evaluated the variability of exposures to tire crumb rubber constituents by activity type, exposure scenario, age, material type and condition, facility type and condition, and ambient conditions such as temperature and wind or ventilation. Limited information is available on the variability of exposures and related factors across a wide range of user groups and scenarios. • A few studies suggest that inhalation exposures at indoor facilities are higher compared to those at outdoor facilities, but the available information is limited.
	Biomonitoring	• Only a few biomonitoring studies have been performed. Only hydroxypyrene has been measured as a biomarker in athletes and workers. • Additional tire rubber-specific biomarker measurements have not been reported for synthetic field and playground users and biomarker analysis methods might be lacking for some chemicals. • Large scale biomonitoring studies of populations exposed and not-exposed to synthetic turf fields and playgrounds with tire crumb rubber have not been reported.
	Cumulative/Aggregate Assessments	• Exposures to multiple tire crumb constituents are likely to occur via multiple pathways (e.g., inhalation, ingestion, and dermal contact). However, studies that evaluated cumulative and aggregate exposure and risks are limited.
	Epidemiology Studies	• No epidemiological investigations for synthetic turf field or playground users were identified in the literature review. • Survey and biomonitoring tools for accurate assessment of relative exposures for synthetic field and playground users in an epidemiological study are lacking.
Alternative Assessments	Alternative Infills/Materials	• Most research to date has focused on characterizing tire crumb rubber infill. Similar research on other infill materials, including natural materials, ethylene propylene diene monomer (EPDM), thermoplastic elastomers (TPE), and recycled shoe rubber are either lacking or limited.
	Natural Grass Fields	• Few studies have been performed to assess potential chemical exposures from natural grass playing fields.
	Other Exposure Sources	• Only a few comparative assessments have been performed on relative exposures to chemicals associated with tire crumb rubber from other sources.

II. Table of Contents

III. Background

a. Problem Statement

Synthetic turf installations for athletic fields and other applications in the United States began to rise in popularity in the mid twentieth century. Modern synthetic turf products are typically composed of three layers – fiber material used to simulate grass blades, infill material for cushioning and stability, and backing material (Cheng et al., 2014). A common material used for infill is granulated crumb rubber from recycled tires.

One method of producing crumb rubber involves grinding used tires, removing steel and fiber tire components and sorting the rubber pellets by size. Pellet sizes can range from about one-sixteenth to one-quarter inch in diameter and are typically applied at a rate of two to three pounds per square foot of field surface (NYDOH, 2008). The Rubber Manufacturer's Association (2014) estimates that 24.4 percent of used scrap tires in the U.S. were recycled into crumb rubber. A major focus of the LRGA effort was to provide additional information on potential exposures at synthetic turf fields and playgrounds. Of the total tires recycled into crumb rubber in 2013, 31 percent was used in playground mulch and 17 percent was used in sports surfacing.

Given the widespread use of recycled tire rubber in synthetic turf and playground mulch applications, concerns about the toxicity of the recycled materials have arisen. Human exposures to the tire crumb rubber vary with time and activity associated with use of synthetic fields and playgrounds. Limited studies have not shown an elevated health risk from playing on fields with tire crumb rubber, but the existing studies do not comprehensively evaluate the concerns about health risks from exposure to tire crumb rubber (U.S. EPA, 2016).

Because of the need for additional information, the U.S. Environmental Protection Agency (EPA), the Centers for Disease Control and Prevention/Agency for Toxic Substances and Disease Registry (ATSDR), and the U.S. Consumer Product Safety Commission (CPSC) launched a multi-agency action plan to study key environmental human health questions. The Federal Research Action Plan includes numerous activities, including a literature search and data gap analysis (LRGA) as well as various other research efforts (U.S. EPA, 2016). A key objective of the Action Plan is to identify key knowledge gaps.

b. Objectives of Literature Review/Gaps Analysis

In order to more fully understand data gaps associated with human exposure to tire crumb rubber and their toxicity, ATSDR, CPSC and EPA undertook a collaborative effort in the form of a scientific literature review and subsequent gaps analysis. The first objective of the collaboration was to identify the existing body of literature related specifically to human exposure to tire crumb rubber through the use of synthetic turf athletic fields and playgrounds. The second objective was to characterize and summarize the relevant data from the scientific literature. The final objective was to review the summary information and identify data gaps to help inform the development of specific research efforts.

c. Scope of Effort

The ultimate objective of the Literature Review and Gap Analysis (LRGA) effort was to inform the design of a Tire Crumb Research Study (TCRS) (EPA, 2016). Therefore, the scope of the LRGA was focused on the needs of the scientists designing the TCRS. The LRGA focused on identification of scientific publications that studied tire crumb rubber use, physical characteristics and chemical composition, potential pathways of exposures, bioavailability, and component toxicity. The LRGA did not include studies related to human or ecological exposures in automotive tire manufacturing processes. The LRGA focused only on the life cycle of tires that reach the facilities where they are converted to crumb rubber. Studies that examine occupational exposures at "tire to crumb rubber" generation facilities, human exposures related to field / playground installations, and subsequent exposures involved with use of synthetic turf / playground facilities were considered as part of the scope for this effort. Where literature existed in these areas of study, it was included in the LRGA analysis.

IV. Methodology

a. Data Sources

Research and commentary on tire crumb rubber is represented in a diverse set of publications. The LRGA effort explored a wide variety of information sources to build a list of relevant citations for this effort. Initial searches for relevant material began with the preliminary list of reports and bibliographic lists below. Additional literature relevant to this effort was identified by reviewing the references listed in the preliminary lists. Material collection for this document was completed in late May 2016, with sources ranging in release dates from 1991 to 2015. Literature sources released after May 2016 have not been included in the LRGA.

Preliminary Lists used to Identify Relevant Literature

- A Scoping-Level Field Monitoring Study of Synthetic Turf Fields and Playgrounds (U.S. EPA, 2009)
- Tire Crumb and Synthetic Turf Field Literature and Report List as of Nov. 2015 (U.S. EPA, 2015)
- CDC Review of Published Literature and Select Federal Studies on Crumb Rubber and Synthetic Turf (see Appendix A)
- Literature review of microbial work done on tire crumb rubber artificial fields (See Appendix B)
- EPA-NCEA Summary of Available Exposure and Health Risk Assessment Studies on Artificial Turf, Playgrounds and Tire Crumbs (See Appendix C)

The sources listed in Appendices A, B and C provided an initial starting point for identifying relevant publications for the LRGA. The scientists working on the LRGA conducted a literature search using the following databases: PubMed, Medline (OVID), Embase (OVID), Scopus, Primo (Stephen B. Thacker CDC Library), ProQuest Environmental Science Collection, Web of Science, ScienceDirect, and Google Scholar. The Key Terms used in these searches included the following terms: Artificial Turf, Synthetic Turf, Crumb Rubber, Tire Crumb Rubber, Sports Field, Turf, Exposure, Analytes, Chemicals, Elements, Human Health Effects, Adverse Health Effects, Environmental Exposure, Health Risk, Health Impact, Toxicity, Toxic, Carcinogen, Emission, Off-gas, Routes of Exposure, Infill, Risk.

A separate, independent literature search was performed by the EPA library in Durham, NC. The goal of this search was to identify any relevant tire crumb rubber exposure publications and sources that were not identified in the initial search conducted by the LRGA scientists. The following terms were used for both searches:

- Tire Crumb
- Artificial Turf
- Synthetic Turf
- Toxicity
- Health Risks
- Eco Risks
- Leaching
- Human Exposure
- Benzothiazole (BHT)
- Lead
- PAHs

The EPA library literature search can be found in Appendix D.

Based on these information sources, the LRGA team identified relevant literature from the following areas: (1) Journal publications, (2) Reports, white papers, fact sheets, and similar publications developed by federal and state agencies (3) Reports on industry-sponsored research, including white papers, fact sheets, and similar publications and (4) Symposium/conference proceedings. The list of relevant publications is provided in Appendix E.

The references were stored in an Excel spreadsheet that was also used to synthesize the information from the studies. A Microsoft SharePoint site was created as a central repository of all the information relevant to the LRGA, including the literature, spreadsheet, and other materials.

b. Factors & Criteria for Literature Source Inclusion

Factors outlined by the EPA Science Policy Council in "A Summary of General Assessment Factors for Evaluating the Quality of Scientific and Technical Information" were considered in the identification of literature for this project (U.S. EPA, 2003). These are (1) Applicability and

Utility; (2) Evaluation and Review; (3) Soundness; (4) Clarity and Completeness; and (5) Uncertainty and Variability.

The objective of the LRGA team was to cite literature that conformed to these five factors. However, several of the studies did not fully conform to some aspect of the outlined criteria. For instance, there were several white papers and reports in relevant technical areas that were not independently peer-reviewed or peer review was not documented. Although these and other references did not fully conform to one or more of the criteria, they were included in the LRGA because they provided useful information in better understanding risks from tire crumb rubber.

In determining whether or not to include a publication in the LRGA, a set of relevance criteria were developed. An iterative approach was used to address the relevancy of the publications. First, the title of the publication was reviewed to see if it included one or more of the criteria terms below. If it was unclear whether the publication was relevant based upon the title, the publication abstract was reviewed for relevance. If it was unclear whether the publication was relevant based upon the abstract, parts or all of the body of the publication was reviewed. If the information was found to be applicable, the publication was included in the LRGA.

Relevance Criteria
Tire Crumb
Artificial Turf
Synthetic Turf
Tire Crumb Toxicity
Tire Crumb Health Risks
Tire Crumb Ecological Risks
Synthetic Turf Leaching
Human Exposure to Tire Crumb

c. Quality Assurance & Assumptions

A Quality Assurance Project Plan (QAPP) was developed as part of this effort to guide data collection, organization and analysis. EPA policy (U.S. EPA, 2008) is based on the national consensus standard ANSI/ASQ E4-2004 Quality Systems for Environmental Data and Technology Programs: Requirements with Guidance for Use. This standard recommends a tiered approach that includes the development and use of Quality Management Plans (QMPs). The organizational units in EPA that generate and/or use environmental data are required to have Agency-approved QMPs. A programmatic QMP was developed for the overall TCRS. The TCRS QMP is supported by project-specific QA project plans (QAPPs). A QAPP was prepared and included the technical details and associated QA/QC procedures for the LRGA components.

Due primarily to time constraints, a number of assumptions were made in the conduct of the literature review and subsequent analysis of data gaps. For example, while the LRGA team performed extensive searches to find relevant literature for analysis it is possible that other sources exist which were inaccessible, unavailable or not found during the literature search.

Because publications were typically "screened" for relevance based upon their title and/or abstract, but not always the entire publication, it is possible that relevant information may have been overlooked. Finally, as indicated in Section IV B., it was assumed that most, if not all, journal articles from the scientific literature had been peer reviewed. However, peer review status was not always used as a deciding factor whether to include a source in the LRGA (see Section IV B).

d. Literature Review and Data Extraction

All relevant studies were reviewed and characterized according to the information categories and sub-categories shown in Table B-2 The information was extracted from the papers and reports and entered into an Excel spreadsheet that allowed the data to be sorted according to the various topic areas. The results were filtered according to the various categories and subcategories to assess the frequency that the various topic categories were represented by the universe of literature reviewed. A brief description of the results and conclusions from each study was also provided in the spreadsheet. A screenshot of a portion of the LRGA spreadsheet is provided in Figure B-1. The entire LRGA spreadsheet can be viewed on the EPA's Federal Research Action Plan on Recycled Tire Crumb Status Report website.

Table B-2. Information Categories and Subcategories Used in LRGA Spreadsheet

Categories	Subcategories	
1. Reference Type	Journal Article Report Report of Peer Review Abstract	1. Reference Type
2. Study Topic(s)	Literature Review Data Gaps Site Characterization Production Process Constituent Characterization Leaching Stormwater Runoff Site Monitoring Headspace/de-gassing-Bulk Off-gassing/volatilizing Human Exposure	2. Study Topic(s)
3. Geographic Location	See spreadsheet: Status Report website	
4. Study/sample Location	Laboratory Indoor Field Outdoor Field Natural Grass Field	4. Study/sample Location
5. Sample Type	Bulk Crumb Rubber Bulk Grass Blades or Fibers Alternative Fill Type Leachate Urine	5. Sample Type
6. Conditions Studies	Age or Weathering Meteorological Geographical Indoor vs Outdoor Synthetic vs Natural	6. Conditions Studies
7. Populations Studied	Children/Teens Adults Athletes	7. Populations Studied
8. Constituents Evaluated	VOCs SVOCs Inorganics Lead	8. Constituents Evaluated
9. Specific Constituents Studies	See Appendix F and Status Report website	
10. Constituents of Highest Concern	See Status Report website	
11. Number of Observations/Samples	See Status Report website	
12. Human Exposure Route	Ingestion Inhalation Dermal	
13. Exposure Factors Used to Assess Exposure	Body Weight Inhalation Rate Ingestion Rate Skin Surface Area Adherence Bioavailability Fraction Absorption Fraction	13. Exposure Factors Used to Assess Exposure
14. Risk Assessment	Cancer Non-cancer Screening	14. Risk Assessment
15. Toxicity or Regulatory Data Used	See Status Report website	
16. Risk Characterization	See Status Report website	
17. Risk of Highest Concern	See Status Report website	
18. Brief Description of Results	See Section VI, and Status Report website	
19. Additional Information or Comments	See Status Report website	
20. Related References	See Status Report website	

Literature Review and Data Gap Analysis Spreadsheet						Reference Type								Study Topic(s)															
Study #	Have study?	Reviewed?	See Constituent Tab	See Related References	References - Scientific Literature	Journal Article	Report	Report of Peer Review	Abstract	Manuscript	Summary Only	Website	Memo	Literature Review	Data Gaps	Site Characterization	Production Process	Constituent Charac.	Leaching	Stormwater runoff	Site Monitoring	Head Space/de-gassing-Bulk	Off-gassing/volatilizing	Human Exposure	Human Risk	Microbial	Epidemiologic	Biomonitoring	Bioavailability
1	y	y	n	n	Anderson, ME; Kirkland, KH; Guidotti, TL, Rose, C. (2006). A Case Study of Tire Crumb Use on Playgrounds: Risk Analysis and Communication When Major Clinical Knowledge Gaps Exist. Environ Health Perspect. 114(1):1-3.	x								x	x														
2	y	y	y	n	Anthony, D.H.J. and Latawiec, A. (1993). A preliminary chemical examination of hydrophobic tire leachate components. National Water Research Institute, Burlington, Ontario, Canada, Report No. 93-78. Part III. **Parts I and II not reviewed: not relevant (see comments).**		x												x										
3	y	y	n	n	Bass, JJ; Hintze, DW. (2013). Determination of Microbial Populations in a Synthetic Turf System. Skyline-The Big Sky Undergraduate Journal 1(1):1.	x																			x	x			
4	y	y	n	n	Beausoleil, M; Price, K; Muller, C. (2009). Chemicals in outdoor artificial turf: a health risk for users? Public Health Branch, Montreal Health and Social Services Agency. http://www.ncceh.ca/sites/		x							x	x									x	x				

Figure B-1. Screenshot of a portion of the LRGA spreadsheet (see full spreadsheet on the Status Report website).

A list of potential chemical constituents was also developed based on chemicals identified in the various studies. The list included the name of the chemical, CAS number, synonyms, and concentrations observed in the various studies. EPA's National Center for Computational Toxicology assisted by providing CAS numbers and synonyms for constituents for which this type of information was not provided in the study. The constituents list is provided in Appendix F. A screenshot of a portion of the chemical constituents' spreadsheet is provided in Figure B-2.

Analyte	Synonym(s)	CAS#	12. Cheng and Reinhard 2014; Potential Contaminants that can Leach from Tires	15. CDPH 2010; Maximum Detected			
				4 Outdoor Fields		1 Indoor Field	
				ug/m^3	Monitor type	ug/m^3	Monitor typ
Carbon Tetrachloride		56-23-5					
Chlorobenzene		108-90-7					
Chloroform	Trichloromethane	67-66-3					
Chloromethane	Methyl chloride	74-87-3		1.7	Personal	1.57	Personal
Chrysene		218-01-9	x	3.40E-04	Stationary		
Coronene		191-07-1	x				
o-Cyanobenzoic acid	2-Cyanobenzoic acid	3839-22-3					
Cyclohexanamine	Cyclohexylamine	108-91-8					
Cyclohexanamine, N-cyclohexyl-	Dicyclohexylamine	101-83-7					
Cyclohexanamine, N-cyclohexyl-N-methyl-	N-Cyclohexyl-N-methylcyclohexanamine	7560-83-0					
Cyclohexane		110-82-7		17.5	Personal	10.3	Personal
Cyclohexane, isocyanato	Isocyanatocyclohexane	3173-53-3					
Cyclohexane, isothiocyanato-		1122-82-3					
Cyclohexanone		108-94-1					
N-Cyclohexyl-2-benzothiazolesulfenamide (CBS)	N-Cyclohexyl-2-benzothiazolesulfenamide	95-33-0					
n-Cyclohexyl-formamide	N-Cyclohexylformamide; Formamide, N-cyclohexyl	766-93-8					
Cycloninasiloxane, octadecamethyl-	Octadecamethylcyclononasiloxane	556-71-8					
Cyclopenta[cd]pyrene		27208-37-3	x				
4H-cyclopenta[def]phenanthren-4-one	4H-Cyclopenta(def)phenanthren-4-one	5737-13-3	x				
4H-cyclopenta[def]-phenanthrene	4-H-Cyclopenta(d,e,f)phenanthrene	203-64-5	x				

Figure B-2. Screenshot of a portion of the constituent spreadsheet (see Appendix F for the list of constituents; the full spreadsheet is available on the Status Report website).

V. Results

a. Summary Statistics

A total of 97 studies were identified by the methods described in Section IV. Seven were reviewed, but not included in the LRGA analysis because were found to be outside the scope of the project, and two were found to be duplicates of studies already included in the LRGA (see the full literature review spreadsheet for additional details on the Status Report website). The final number of studies evaluated was 88. More than 350 potential chemical constituents were identified in the resources reviewed for the LRGA (see Appendix F for additional details).

Table B-3. Summary Statistics	
References Identified for Consideration in the LRGA	97
References Not Included in LRGA Analysis Due to Irrelevance, etc.	7
Duplicate references	2
TOTAL NUMBER OF REFERENCES INCLUDED IN LRGA	**88**
Discrete Chemical Compounds Identified in Constituent Analysis	>350
LRGA References Included in Constituents List	38

b. Reference Types

Reference Type refers to the nature of the document reviewed. Journal articles are publications in the scientific literature that are typically peer reviewed. Reports represent documents prepared by government, contractor, university, industry or other entities. Reports of peer reviews are typically summaries of comments by reviewers of reviewed documents. Abstracts include short descriptions of documents which may precede a more detailed discussion on the relevant topic. Additional reference types included summaries only, website text, and memos which are self-explanatory.

The Literature Review/Gaps Analysis (LRGA) team examined all of the above reference types in the course of the effort. The majority of sources identified were either Journal Articles (43) or Reports (40). Of the other reference types included in the analysis (i.e., Report of Peer Review, Abstract, Summary Only, Website, and Memo), only one citation was identified for each reference type. This demonstrated the extent to which the literature search was oriented toward Journal Articles and Reports, which typically provided the most relevant, comprehensive information on tire crumb rubber.

c. Study Topics

The LRGA team identified 20 different Study Topics across the literature reviewed. An "other" category was also included to capture additional topics not covered by the 20 main categories. "Study Topic" refers to the focus of the document. In some cases, documents included information on one topic (e.g., a literature review). In other cases, documents addressed more than one topic. For example, a document may include both a review of the existing scientific literature, but also include the results of novel research aimed at addressing specific questions (e.g., leaching of chemicals from tire crumb rubber, or site monitoring to assess human health risk from exposure to tire crumb rubber). Table B-4 provides a summary of the number of studies that addressed each of the various topic areas.

Table B-4. Number of Studies that Addressed Various Topic Areas	
Leaching	36
Human Risk	32
Human Exposure	27
Eco Exposure/Risk	26
Literature Review	24
Toxicity Assessment	19
Constituent Characterization	16
Headspace/de-gassing-Bulk (lab)	13
Off-gassing/volatilizing (field)	12
Site Monitoring	12
Data Gaps	11
Stormwater Runoff	7
Microbial	7
Production Process	6
Bioavailability	5
Modeling	5
Site Characterization	4
Biomonitoring	3
Risk Communication	2
Epidemiologic	0
Other	31

The bulk of the Study Topics identified in the LRGA addressed leaching of tire crumb rubber constituents, exposures to humans and ecosystems from tire crumb rubber and subsequent risks from those exposures, and previous literature reviews intended to better understand tire crumb rubber constituents, exposures or toxicity. Toxicity assessment, characterization of constituents found in tire crumb rubber and site monitoring and volatilizing of constituents from crumb material in either the lab or field were also frequently recorded Study Topics. Studies that were categorized in the 'Other' topic category included topics such as gastric digestion simulations, skin abrasion, assessments of study protocols, mutagenicity assessments, etc. A full list of the "Other" types can be found in the Literature Review Spreadsheet on the Status Report website. Lack of information in Study Topic areas may be an early indicator of data gaps which may require more research.

d. Geographic Locations

Information related to geographic location was collected as part of the LRGA effort in order to provide spatial context for the data. The level of geographic information was typically recorded at the state or country scale. Geographic location was recorded for more than 50 of the studies included in the LRGA. Thirteen U.S. states were represented by one or more studies (i.e., California, Colorado, Connecticut, Florida, Maine, Nevada, New Jersey, New York, Ohio, Pennsylvania, Utah, Virginia, and Washington). Other countries identified in the analysis included nations such as Canada, Denmark, France, Italy, Japan, Korea, Norway, Spain, Sweden, Taiwan and The Netherlands. There were a total of 30 sources for which no locational information was provided or was non-applicable.

e. Study/Sample Locations

The Study/Sample Location category differs from the Geographic Location category. It refers to the type(s) of site(s) where samples were collected or analyzed. For example, a study to identify the constituents in tire crumb rubber may have been conducted entirely in the laboratory using manufactured tire crumb rubber. Alternatively, tire crumb rubber samples may have been collected from an indoor or outdoor field. Samples may also have been collected from both synthetic turf and natural fields or background locations, or from playgrounds or other locations where tire crumb rubber may be used.

The subset of Study/Sample Locations included Scientific Laboratories, Indoor Fields, Outdoor Fields, Natural Grass Fields, Synthetic Grass Fields, Playgrounds and Other types. For the purpose of the LRGA, "Scientific Laboratories" were defined as indoor facilities with controlled environments and specific quality assurance procedures. "Indoor Fields" were located inside enclosed facilities with climate control, and "Outdoor Fields" were in open or partially contained facilities with some open air access. "Synthetic Grass Fields" included a variety of designs, but were typically composed of an underlay material, tire crumb rubber infill and synthetic blades. "Natural Grass Fields" were surfaces with specifically real grass plants with natural soil material. A variety of "Playgrounds" were included which generally refer to an area with recreational equipment anchored in the ground with surrounding tire crumb rubber used for cushioning surface. An eighth type of Study/Sample Location was identified as "Background" which refers to analyses conducted to determine background levels of tire crumb rubber constituents.

Of the sources included in the LRGA, most (42) involved analysis in a scientific laboratory (Table B-5). The analysis also showed that 35 literature sources included analysis conducted on or in the area of a synthetic turf field; 20 of these involved outdoor fields and 8 involved indoor fields, and others did not specify. There were 8 studies that addressed natural grass fields and 8 that addressed background locations. Nine sources examined playground environments, however because Kim et al. (2012b) uses the term "playgrounds" to mean facilities traditionally defined as athletic fields, this number was adjusted to eight sources. The 13 "Other" locations included roadbeds, parking lots, new/commercial products, test plots, mulch, green roofs, and rubber running tracks. A full list of the "Other" types can be found in the Literature Review Spreadsheet on the Status Report website.

The focus of the LRGA was synthetic athletic field and playground environments. Artificial turf marketed for private residential homes may also provide an additional exposure pathway and may contribute to cumulative exposures to a variety of materials found in tire crumb rubber. However, publications pertaining to residential use were not included in the LRGA.

Table B-5. Number of Studies in Each Study/Sample Site Category	
Laboratory	42
Synthetic Grass Field	35
Outdoor Field	20
Playground	8
Indoor Field	8
Natural Grass Field	8
Background	8
Other	13

f. Sample Types

The Sample Type category refers to the nature of the sample(s) collected. For example, samples of bulk tire crumb rubber or artificial grass blades/fibers may have been collected for the purpose of leaching studies, or air samples may have been collected by stationary area samplers or by personal breathing zone samplers. Other examples include wipe samples from fields or tire crumb rubber for assessing dermal exposure, or urine samples from biomonitoring studies.

The term "Alternative Infill Type" was used to designate sources that examined infill materials other than tire crumb rubber (e.g., sand). Another sample type identified as "Leachate" generally refers to sources that studied samples of liquid or solid material that had been removed from the immediate area of the tire crumb rubber via normal maintenance, meteorological or hydrogeologic processes.

The majority of the literature sources (44) provided information of the analysis of bulk crumb rubber (Table B-6). Leachate samples were studied in 22 sources, while stationary air samples were evaluated in another 20 sources. The 20 "Other" sample types included materials such as elastic compounds, dust, glue, bio-fluid extracts, rubber pavers natural grass and soil from test plots, and other materials. A full list of the "Other" types can be found in the Literature Review Spreadsheet on the Status Report website.

Table B-6. Number of Studies Addressing Sample Type Category	
Bulk Crumb Rubber	44
Leachate	22
Stationary Air Samples	20
Bulk Grass Blades or Fibers	13
Personal Exposure (air)	9
Wipe Samples	5
Alternative Fill Type	4
Urine	3
Other	20

g. Conditions Studied

The Conditions Studied category refers to analyses that may have been done to identify differences in constituent concentrations or exposures based on age or weathering of the artificial turf, or the effects of meteorological conditions or geography. This study element also refers to analyses that evaluate for differences between indoor and outdoor environments, synthetic and natural turf, site and background conditions, differences based on active or inactive play, or other activity related conditions.

The LRGA team identified 20 literature sources that examined exposures based upon age or weathering of the artificial turf, while 10 other sources analyzed the effect of meteorological conditions on artificial turf and tire crumb rubber (Table B-7). Nine of the literature sources examined levels of constituents found in tire crumb rubber in relation to background levels of the same constituents at the study sites. There were 12 “Other” conditions studied types, which included temperature, coated vs non-coated crumb rubber, tire crumb rubber chip size, and pH. A full list of the “Other” types can be found in the Literature Review Spreadsheet on the Status Report website.

Table B-7. Number of Studies by Conditions Studied	
Age or Weathering	20
Meteorological	10
Site vs Background	9
Synthetic vs Natural	6
Indoor vs Outdoor	5
Activity Related	5
Active vs Inactive Play	4
Other Sources	3
Geographical	1
Other	12

h. Populations Studied

Populations Studied are those populations that were considered in an exposure or human health assessment (e.g., children/teens, adults, workers, athletes). Fourteen literature sources examined children/teen exposures, while 13 sources studies adults and 10 studied athletes (Table B-8). Four sources included in the LRGA looked at worker exposures to tire crumb rubber installations / maintenance. “Other” types of populations identified in the analysis include athletic coaches, spectators, gardeners, and microbial populations. A full list of the “Other” types can be found in the Literature Review Spreadsheet on the Status Report website.

The age groups identified in the various studies differed for non-adult individuals. Thus, for the purpose of categorizing the studies based on age, children and teens were combined in one category and adults were categorized separately. Activities based on the ages of the populations studied may be different due to differing behavior patterns. Likewise, other exposure factors (e.g., inhalation rates, skin surface area, body weight) may differ based on age, and can affect exposure levels.

Table B-8. Number of Studies by Populations Studied	
Children/Teens	14
Adults	13
Athletes	10
Workers	4
Other	6

i. Constituents Evaluated

The Constituents Evaluated results capture the general category of contaminants that were addressed in the study (e.g., volatile organic compounds (VOCs), semi volatile organic compounds (SVOCs), inorganics, microbes, particulate matter). Polycyclic aromatic hydrocarbons (PAHS) are also included as a broad category because they are frequently included in the literature sources. Likewise, lead and benzothiazole are included because they are frequently included in the sources. A separate column in the spreadsheet (found on the Status Report website) is included to capture information on the Specific Constituents Studied. A separate Constituents Tab in the spreadsheet provides additional information on the constituents studied (e.g., concentration data) (see Appendix F for a list of constituents with more details available on the spreadsheet found on the Status Report website).

Forty-nine of the literature sources included in the LRGA evaluated inorganic compounds related to rubber exposures (Table B-9). The next most prevalent constituents identified in the literature review were PAHs, identified in 41 sources, followed by VOCs (38 sources), SVOCs (31 sources) and lead (Pb) by 29 sources. Particulate matter, Benzothiazole and Microbes were constituents studied to a lesser extent. "Other" types of constituents identified included 'extractable substances,' dissolved organic carbon, and 'organics.' A full list of the "Other" types can be found in the Literature Review Spreadsheet on the Status Report website. Specific references were made to zinc and a variety of metals, phthalates, benzene, nitrosamines, a variety of complex organic compounds, and others. Zinc and other metals were identified most often as the constituents of highest concern in the literature sources.

Table B-9. Number of Studies by Chemical Constituents Studied

Inorganics	49
PAHs	41
VOCs	38
SVOCs	31
Lead	29
Benzothiazole	20
Particulate Matter	18
Microbes	6
Other	6

j. Number of Samples or Number of Observations

The number of observations or number of samples collected in each of the studies reviewed for the LRGA varied according to the study purpose and scope. These data were included in the spreadsheet when they were available in the publication reviewed. For detailed information on the numbers of observations or number of samples collected, see the LRGA spreadsheet on the Status Report website.

k. Human Exposure Routes

Human Exposure Route identifies whether ingestion, inhalation, or dermal exposures were evaluated in a human exposure/risk assessment. Some studies evaluated more than one route of exposure. Twenty-two of the LRGA literature sources investigated inhalation exposures. Another 16 sources considered ingestion exposures, while 12 sources reviewed dermal exposure scenarios. Secondary exposures (e.g., from residual tire crumb rubber contacted through activities such as washing clothes) is also possible, but were not considered in the literature reviewed.

l. Exposure Factors

The Exposure Factors category provides specific information on the exposure factors used studies that estimated human exposure/risk. The U.S. EPA generally defines exposure factors as factors related to human behavior and characteristics that help determine an individual's exposure to an agent. The LRGA identified 14 unique exposure factors, as well as an "other" group. The 14 unique factors included: Body Weight, Inhalation Rate, Ingestion Rate, Skin Surface Area, Surface Area to Body Weight ratio (SA/BW), Adherence, Bioavailability fraction, Absorption fraction, Hand-to-mouth contacts/hr, Hand-to-surface contacts/hr, Hand-to-mouth transfer fraction, Exposure Duration, Exposure Frequency, and Exposure Time.

Fourteen literature sources in the LRGA provided information on the use of one or more exposure factors. The exposure factors that were reportedly used are summarized in Table B-10. Exposure frequency (d/yr or d/week) (n=13) and exposure time (hr/day) (n=11) were the exposure factors that were most often reported, followed by exposure duration (years) (n=10), body weight (kg) (n=9), and inhalation rate (m^3/hr or m^3/day) (n=9). Ingestion rate (g/day) was reported in 8 studies and skin surface area (cm^2) was reported in 6 studies. The other factors were reported by three or fewer LRGA literature sources (for additional details see the spreadsheet on the Status Report website).

Table B-10. Exposure Factors Used by LRGA References

Factor	N	Value(s)
Exposure Frequency (d/yr or d/wk)	13	24-365 d/yr; 4-7 d/wk[a]
Exposure Time (hr/day)	11	0.54-10[a]
Exposure Duration (yrs)	10	1-50[a,b]
Body Weight (kg)	9	15-70[b]
Inhalation Rate (m^3/hr or m^3/day))	9	1.9-6 m^3/hr; 17.0-22.4 m^3/day[a,b]
Ingestion Rate (g/day)	8	0.02-10[a]
Skin Surface Area (cm^2)	6	20-17,084[a,b]
Adherence Factor (mg/cm^2)	2	0.04-1
Bioavailability	2	0.04-1
Absorption Fraction	2	7
Hand-to-mouth Contacts/hr	1	0.01-0.1
Surface Area to BW Ratio (cm^2/kg)	1	246-352[b]
Hand to Surface Contacts/hr	1	23

[a] Varies depending on scenario evaluated.
[b] Varies by age.

m. Risk Assessment

The Risk Assessment category refers to the type of endpoints evaluated and the type of assessment conducted. Five endpoints / assessment types were identified. Fifteen quantitative assessments were identified, in addition to 14 qualitative assessments, and nine screening level assessments. The LRGA also identified fourteen literature sources with cancer endpoints and 13 sources with non-cancer endpoints. Eight "other" types of assessments were also noted including ecological risk, aquatic or cell toxicity, worst-case, margin of safety, microbial risks, and growth inhibition. A full list of the "Other" types can be found in the Literature Review Spreadsheet on the Status Report website.

Table B-11. Number of Studies by Type of Risk Assessment	
Quantitative	15
Qualitative	14
Cancer	14
Non-cancer	13
Screening	9
Other	8

n. Toxicity or Regulatory Data Used to Assess Risk

A variety of data sources were used to evaluate risks in the literature sources evaluated in the LRGA, including reference doses (RfDs) and cancer slope factors (CSFs) from EPA's integrated Risk Information System (IRIS), Health Effects Assessment Summary Tables (HEAST), National Ambient Air Quality Standards (NAAQS) and drinking water standards. Other data sources included the Agency for Toxic Substances and Disease Registry (ATSDR) Minimal Risk Levels (MRLs), Consumer Product Safety Commission (CPSC) guidance, American Council of Government Industrial Hygienists (ACGIH) threshold limit values (TLVs), and state and regional guidance. Some studies used World Health Organization (WHO) drinking water standards, European acceptable daily intakes (ADIs), or other country-specific national targets, limits, or regulatory values. In some cases, no observable effects concentrations (NOECs) or no observable effects limits (NOELs) were used. The Ames test, AhR-based bioassays, and toxicity characteristic leaching procedures (TCLPs) were used by others (for details see the spreadsheet on the Status Report website).

VI. General Conclusions as Stated in the Literature

Brief summaries of results, conclusions, and recommendations from the LRGA studies are provided below. They are provided in chronological order according to eight broad topic areas: (1) exposure and human health risks to children and athletes, (2) occupational risks, (3) ecological risks, (4) leaching, (5) air concentrations, volatilization, and particulate matter, (6) microbial populations, (7) weathering/aging, and (8) data gaps and recommendations for further study. Although some LRGA studies covered more than one topic area, summaries of their conclusions are provided primarily under a single topic area. In most cases, the conclusions are provided exactly as written by the author(s). These summaries are intended to provide the reader with a general sense of the conclusions of the studies, as provided by the authors. For additional details on these studies, see the LRGA spreadsheet on the Status Report website, or refer to the individual studies which provide the reader with a sense of the distribution of results when utilizing the LRGA.

Exposure, Toxicity, and Human Health Risk to Children and Athletes from Chemical Constituents in Tire Crumb Rubber

Several of the LRGA studies provided conclusions with regard to the human health risks associated with the use of tire crumb rubber in artificial turf fields or other applications. Some of these conclusions were based on reviews of existing literature. Others were based on data collection and analysis. Examples of the conclusions are provided below. While many of the studies indicated that risks to human were minimal, others suggested that potential risks exist and should be further explored.

> Birkholz et al. (2003) *"designed a comprehensive hazard assessment to evaluate and address potential human health and environmental concerns associated with the use of tire crumb in playgrounds. Human health concerns were addressed using conventional hazard analyses, mutagenicity assays, and aquatic toxicity tests of extracted tire crumb. Hazard to children appears to be minimal. Toxicity to all aquatic organisms (bacteria, invertebrates, fish, and green algae) was observed; however, this activity disappeared with aging of the tire crumb for three months in place in the playground. We conclude that the use of tire crumb in playgrounds results in minimal hazard to children and the receiving environment."*
>
> Sullivan (2006) conducted an assessment of environmental toxicity and potential contamination from artificial turf using shredded or crumb rubber and concluded that *"The impacts on human health of crumb rubber used in artificial turf are not known at this time. However, there is some evidence that tire rubber can be harmful either from direct contact or from associated dust. The most common detrimental health effect resulting from direct exposure to tire rubber is allergic or toxic dermatitis. Inhalation of components of tire rubber or dust particles from tire rubber can be irritating to the respiratory system and can exacerbate asthma. It is not clear whether dermal or inhalation exposure to tire rubber can lead to sufficient absorption of chemicals to cause mutagenic or carcinogenic effects. The degree of direct contact between the rubber used in artificial turf is not well enough known at this time to determine whether the level of the potential for harm to humans playing on artificial turf containing crumb rubber."*
>
> The Norwegian Institute of Public Health and the Radium Hospital (2006) conducted an assessment of the risks to football players on indoor artificial turf fields and concluded that *"the use of artificial turf halls does not cause any elevated health risk. This applies to children, older children, juniors and adults."*
>
> In 2006, KEMI, the Swedish Chemicals Inspectorate, published a status report on synthetic turf from a chemical perspective. The conclusions were that *"Measurement of*

indoor air and exposure calculations have shown that there is probably a small health risk associated with simply being on or playing on synthetic turf surfaces that use rubber from recycled tyres. The exposure levels and any allergic reactions, however, have been poorly studied"(KEMI, 2006).

California's Office of Environmental Health Hazard Assessment evaluated the health effects of recycled waste tires in playground and track products, and stated *"Overall, we consider it unlikely that a onetime ingestion of tire shreds would produce adverse health effects." "Only exposure to zinc exceeded its health-based screening value"* (OEHHA, 2007).

Hofstra (2007a) stated that *"Based on the available literature on exposure to rubber crumb by swallowing, inhalation and skin contact and our experimental investigations on skin contact we conclude, that there is not a significant health risk due to the presence of rubber infill for football players an artificial turf pitch with rubber infill from used car tyres."*

Based on a study involving leaching of lead from turf glades blades, the U.S. Consumer Product Safety Commission (CPSC, 2008) reported that *"The results…for this set of tested synthetic turf fields show no case in which the estimated exposure for children playing on the field would exceed 15 ug lead/day."*

Johns (2008) conducted an initial evaluation of potential human health risks associated with playing on synthetic turf fields on Bainbridge Island, Washington using the highest chemical concentrations obtained from Norwegian Institute of Public Health and Radium Hospital (2006), Plesser and Lund (2004), and California OHHEA (2007). Health risks were evaluated for children (8-10 yrs old) and teenagers (11-18 years old) participating in team sports. Johns (2008) concluded that *"Overall, the balance of the studies reviewed indicate that human health risks from playing on synthetic turf fields is minimal, even though low concentrations of some chemicals have been demonstrated to leach from the tire crumb, or volatilize as vapor."*

Based on a literature review and the results of the 2007 CalEPA study, Denly et al. (2008) concluded that *"Based on the information reviewed none of the risk assessments showed concentrations of contaminants that would be at a level of concern, even under conservative assumptions and thus it does not appear that the ingestion of tire crumb would pose a significant health risk for children or adults."*

Based on a Danish study conducted by Nilsson et al., (2008), "*Four representative substances were selected for the health assessment: benzothiazole, dicyclohexylamine, cyclohexanamine and dibutyl phthalate. These substances are present in high concentrations in contact water from the leaching tests and are representative of the harmful substances emitted from the products." Nilsson et al. (2008)* reported that *"there* *are no health effects associated with exposure to the four substances tested, with the exception of a potential risk for developing allergy in particularly sensitive individuals (benzothiazole and the two amines).”*

Beausoleil et al. (2009) concluded that *“the health risks for players who use artificial turf are not significant and that it is completely safe to engage in sports activities on this type of outdoor field” b*ased on literature reviews and qualitative reviews of the data.

The New York Department of Environmental Conservation (NYDEC, 2009) conducted a public health evaluation *“on the results from the ambient air sampling and concluded that the measured levels of chemicals in air at the Thomas Jefferson and John Mullaly Fields do not raise a concern for non-cancer or cancer health effects for people who use or visit the fields...the findings do not indicate that these fields are a significant source of exposure to respirable particulate matter."*

A human health risk assessment of five artificial turf fields in Connecticut indicated that *“cancer risks were only slightly above de minimis levels for all scenarios evaluated including children playing at the indoor facility, the scenario with the highest exposure” (CDPH, 2010).* The Connecticut Academy of Science and Engineering (CASE) (2010) Peer Review Committee *“concluded based on a review of the state’s reports that there is a limited human health risk, and an environmental risk as shown by the high zinc levels detected.”*

Based on a literature review, Van Ulirsch et al. (2010) concluded that *"Data collected from recreational fields and child care centers indicate lead in synthetic turf fibers and dust at concentrations exceeding the Consumer Product Safety Improvement Act of 2008 statutory lead limit of 300 mg/kg for consumer products intended for use by children, and the U.S. Environmental Protection Agency’s lead-dust hazard standard of 40 µg/ft^2 for floors.....Synthetic turf can deteriorate to form dust containing lead at levels that may pose a risk to children."*

Simon (2010) stated that *"A review of existing literature points to the relative safety of crumb rubber fill playground and athletic field surfaces. Generally, these surfaces, though containing numerous elements potentially toxic to humans, do not provide the opportunity in ordinary circumstances for exposure at levels that are actually dangerous.”*

Van Rooij and Jongeneelen (2010) monitored football players in The Netherlands before and after playing on artificial turf fields. Only 1 of the 7 participants showed an increase in post-exposure urine concentration over pre-exposure concentrations. Van Rooij and Jongeneelen (2010) concluded that there is *"evidence that uptake of PAH by football players active on artificial grounds with rubber crumb infill is minimal. If there is any* *exposure, then the uptake is very limited and within the range of uptake of PAH from environmental sources and/or diet."*

Shalat (2011) conducted an evaluation of potential exposures to lead and other metals as the result of aerosolized particulate matter from artificial turf playing fields in New Jersey and concluded that *"there is a potential for inhalable lead to be present on turf fields that have significant amounts of lead present as detectable by surface wipes. It also would appear likely from this sample that if the lead is present to any appreciable extent in the wipes it will likely be present in the breathing zone of players who are active on these fields, and that furthermore, these levels potentially exceed ambient EPA standards. Given that these are only occasional exposures this tends to reduce the risk of adverse health effects."*

Likewise, Lioy and Weisel (2011) concluded that *"Overall the metals, PAHs and semi-volatile compounds found all classes of materials to be at very low concentrations. Thus, for the metals and compounds identified there would be de minimus exposures and risk among anyone using fields with the exception of lead in a single new turf material. It is therefore prudent to reemphasize the need to avoid lead-based pigments in these materials as coloring agents."*

Ginsberg et al. (2011) conducted a human health risk assessment of synthetic turf fields based upon investigation of five fields in Connecticut. The results indicated that *"Cancer and noncancer risk levels were at or below de minimis levels of concern. The scenario with the highest exposure was children playing on the indoor field. The acute hazard index (HI) for this scenario approached unity, suggesting a potential concern, although there was great uncertainty with this estimate. The main contributor was benzothiazole, a rubber-related semivolatile organic chemical (SVOC) that was 14-fold higher indoors than outdoors. Based upon these findings, outdoor and indoor synthetic turf fields are not associated with elevated adverse health risks."*

Menichini et al. (2011) concluded that *"Compared with the Italian limits for "green area" soils, high contents of Zn and PAHs were found in the granulates present in playing fields, whatever the origin of the rubber. Zn and BaP concentrations largely exceeded such limits by up to two orders of magnitude...PCBs and PCDDs+PCDFs were found in a recycled tyre granulate, at levels in the order of magnitude of the mentioned limits."*

In a Korean study, Kim et al. (2012a) calculated the risk of ingestion exposure of lead by particle sizes of crumb rubber in artificial turf filling material with consideration of bioavailability. The range of bioavailability depended on the particle size and the type of extraction used. The < 250 um and acid extraction had the highest bioavailability. *"Results of this study confirm that the exposure of lead ingestion and risk level increases as the particle size of crumb rubber"* (Kim et al., 2012a). Average lead exposure ranged from 1.7 x 10-5 mg/kg-day to 4.1x 10-4 mg/kg-day with the highest exposure value for children 7-9 years old with the acid extraction method and the lowest exposure to children 13-18 years in both the acid and digestion extraction. Mean hazard quotients were <1.

Kim et al. (2012b) conducted a health risk assessment for artificial turf playgrounds in school athletic facilities in Korea and concluded that *"On the basis of the knowledge that is currently available concerning health effects and exposure linked to the use of artificial turf playgrounds, we did not find a direct health risk for users, except for children with pica."* The LRGA team noted that this publication uses the term "playgrounds" to mean facilities traditionally defined as athletic fields in US installations

Cardno Chem Risk (2013) concluded that *"adverse health effects are not likely for children or athletes exposed to recycled tire materials found at playgrounds or athletic fields...similarly, no adverse ecological or environmental outcomes from field leachate are likely."*

Pavilonis et al. (2014) conducted a study in New Jersey to assess the bioaccessibility and risk of exposure to metals and SVOCs in artificial turf field fill materials and fibers. *"Artificial biofluids were hypothesized to yield a more representative estimation of dose than the levels obtained from total extraction methods. PAHs were routinely below the limit of detection across all three biofluids precluding completion of a meaningful risk assessment. No SVOCs were identified at quantifiable levels in any extracts based on a match of their mass spectrum to compounds that are regulated in soil. The metals were measurable but at concentrations for which human health risk was estimated to be low. The study demonstrated that for the products and fields we tested, exposure to infill and artificial turf was generally considered de minimus, with the possible exception of lead for some fields and materials"* (Pavilonis et al., 2014).

Ruffino et al. (2013) conducted a risk assessment for synthetic turf fields in Italy, including the following exposure pathways: *"direct dermal contact (DDC)), dermal contact with the rainwater soaking the infill (rain water contact (RWC)) and inhalation of dusts and gases from the fields (dust and gas inhalation (DGI)."* Based on a variety of inorganic and organic chemicals, *"the cumulative carcinogenic risk proved to be lower than 10−6 and the cumulative noncarcinogenic risk lower than 1. The outdoor inhalation of dusts and gases was the main route of exposure for both carcinogenic and non-carcinogenic substances....the inhalation of atmospheric dusts and gases from vehicular traffic gave risk values of one order of magnitude higher than those due to playing soccer on an artificial field"* (Ruffino et al., 2013).

Llompart et al. (2013) analyzed rubber recycled tire playgrounds and pavers. *"The analysis confirmed the presence of a large number of hazardous substances including PAHs, phthalates, antioxidants (e.g. BHT, phenols), benzothiazole and derivatives,* *among other chemicals. The study evidences the high content of toxic chemicals in these recycled materials. The concentration of PAHs in the commercial pavers was extremely high, reaching values up to 1%"* (Llompart et al., 2013).

Marsili et al. (2014) conducted a preliminary hazard assessment for athletes based on the release of polycyclic aromatic hydrocarbons and heavy metals from rubber crumb in synthetic turf fields in Italy. *"The results of the present study demonstrate that PAHs are continuously released from rubber crumb through evaporation. Athletes frequenting grounds with synthetic turf are therefore exposed to chronic toxicity from PAHs. The main conclusion we can draw from this preliminary study, which will be validated by further field and laboratory research, is that although synthetic turf offers various advantages over natural grass, the quantity of toxic substances it releases when heated does not make it safe for public health"* (Marsili et al., 2014).

The health impact assessment of the use of artificial turf in Toronto, Canada concluded that, *"Available evidence indicates that under ordinary circumstances, adverse health effects among adults and children are unlikely to occur as a result of exposure to artificial turf infilled with crumb rubber in both outdoor and indoor settings."* The assessment elaborated further by stating, *"Based upon a review of the available evidence, third generation artificial turf is not expected to result in exposure to toxic substances at levels that pose a significant risk to human health provided it is properly installed and maintained and users follow good hygienic practices (for example washing hands, avoiding eating on artificial turf and supervision of young children to ensure they do not eat the infill material)"* (Toronto Public Health, 2015).

Analytical results of lead in crumb rubber from 113 athletic fields In New York City was provided online by the New York City Department of Parks and Recreation: Synthetic Turf Lead Results (http://www.dec.ny.gov/docs/materials_minerals_pdf/crumbrubfr.pdf) *"Aside from Thomas Jefferson Park, the test results for the remaining 112 fields and play areas were below the acceptable EPA lead level for soil (400 parts per million), the best standard available, and no potential lead hazards were found. Lead levels for the 112 fields ranged from 'not detected' to 240 ppm and 96% of the results were less than 100 ppm. Thomas Jefferson Park was the only field with an elevated lead level above the EPA standard."*

Occupational Exposure and Risk

A limited number of studies evaluated in the LRGA addressed occupational risks. Workers included coaches and those working in tire crumb rubber production facilities. These studies provide insight on potential human health risks for potentially exposed populations other than children and athletes. Examples of conclusions from those studies are provided below.

Chien et al. (2003) evaluated occupational health hazards in scrap tire shredding facilities in Taiwan and observed that *"Levels of volatile organics were not significant, but a few mutagens/carcinogens, such as styrene, benzothiazole, phthalate ester and naphthalene were identified. Total particulate levels ranged from 0.43 to 6.54 mg/m^3, while respirable particulates were in the range 0.23–1.25 mg/m3. Ames testing revealed indirect mutagenicity on strain TA98, indicating possible effects of frame-shift type mutagens. Chemical analysis of airborne particulates confirmed the presence of amines, aniline, quinoline, amides and benzothiazole, which are potentially convertible to frame-shift type mutagenic nitrosoamines."* Chien et al. (2003) concluded that *"particulate generated from scrap-tire shredding may pose a health threat to workers, and should not be regulated as 'nuisance'."*

Castellano et al. (2008) conducted a study of coaches working in areas where artificial turf pitches were used in Italy and concluded that *"there was no occupational exposure nor any additional exposure to the substances of interest other than an environmental exposure in urban areas."*

Savary and Vincent (2011) assessed exposure in four facilities in France where used tires are turned into rubber granulates. *"The results of this study indicate significant exposure to complex mixtures of rubber dust… exposure levels measured in these four facilities were between 0.31 and 41.00 mg/m^3; the ambient concentrations were between 0.17 and 6.23 mg/m^3." "VOC levels >1 ppm were not detected."*

Ecological Toxicity and Risk

While the primary focus of the LRGA was on human health risks, several of the papers reviewed provided information relevant to ecological risks. Examples of conclusions from these studies is provided below.

Kallqvist (2005) conducted an environmental risk assessment of artificial turf systems in Norway and concluded that *"The risk assessment shows that the concentration of zinc poses a significant local risk of environmental effects in surface water which receives run-off from artificial turf pitches. In addition, it is predicted that concentrations of alkylphenols and octylphenol in particular exceed the limits for environmental effects in the scenario which was used (dilution of run-off by a factor of ten in a recipient). The leaching of chemicals from the materials in the artificial turf system is expected to decrease only slowly, so that environmental effects could occur over many years. The total quantities of pollution components which are leached out into water from a normal artificial turf pitch are however relatively small, so that only local effects can be anticipated."*

Sullivan (2006) conducted an assessment of environmental toxicity and potential contamination from artificial turf using shredded or crumb rubber and concluded that

“The impacts on the environment of using crumb rubber in artificial turf also are not known at the present time...Zinc is the predominant toxicant to plants...The aquatic toxicity issue is not very clear cut."

In 2006, KEMI, the Swedish Chemicals Inspectorate, published a status report on synthetic turf from a chemical perspective. The conclusions were that *"Current knowledge allows the conclusion to be drawn that synthetic turf that contains rubber from recycled tyres may give rise to local environmental risks. Investigations have shown that zinc and phenols can leach from the rubber granulate, and these substances can affect aquatic and sediment dwelling organisms, if they reach neighbouring water courses"* (KEMI, 2006).

Based on an environmental and health evaluation of the use of elastomer granulates used as filling in artificial turf in France, Moretto (2007) concluded that *"From an ecotoxological point of view, the nature of the percolates having passed through a 3rd generation artificial pitch are proven to be without impact on the environment, irrespective of the type of filling granulates."*

California’s Office of Environmental Health Hazard Assessment (OEHHA) (2007) evaluated the effects of recycled waste tires in playground and track products and stated *"...ecological effects from contaminated soil cannot be ruled out…the selenium level in the soil was only marginally higher than the PRG and the zinc levels were close to the normal background levels."*

Johns and Goodlin (2008) found that *"Toxicity tests on storm water collected from installed fields, or in laboratory tests using simulated precipitation events, indicate that water the percolates through turf fields with tire crumb is not toxic in tests that cover a wide range of aquatic plants and animals, including algae, bacteria, crustaceans, and fish."*

Milone and McBroom (2008) reported that *"An analysis of the concentration of metals in the actual drainage water indicates that metals do not leach in amounts that would be considered a risk to aquatic life as compared to existing water quality standards."*

The New York Department of Environmental Conservation (NYDEC, 2009) conducted a risk assessment for aquatic life protection and *found that "...crumb rubber may be used as an infill without significant impact on groundwater quality...Analysis of crumb rubber samples digested in acid revealed that the lead concentration in the crumb rubber samples were well below the federal hazard standard for lead in soil...A risk assessment for aquatic life protection...found that crumb rubber derived entirely from truck tires may have an impact on aquatic life due to the release of zinc.”*

Based on an environmental and mutagenicity assessment of artificial turf fields conducted in Italy, Schilirò et al. (2013) concluded that *"On the basis of environmental monitoring, artificial turf football fields present no more exposure risks than the rest of the city."*

Leaching

Among the studies reviewed for the LRGA, leaching studies were frequently represented. Some of these studies addressed laboratory analyses of bulk samples, and other addressed leaching in the natural environment. Conclusions based on these studies are provided below.

Zelibor (1991) analyzed leachate from tire samples and reported that *"The results of the study indicated that none of the tire and other rubber products tested, cured and uncured, exceeded proposed TCLP Regulatory Levels or US EPA Drinking Water Standards. Most compounds detected were found at trace levels (near method detection limits) from ten to one hundred times less than proposed TCLP regulatory limits."*

Based on a study conducted in Canada, Groenevelt and Grunthal (1998) found *"No elevated levels of VOC's or BNA's were detected in the leachate collected. Slightly elevated levels of boron, sodium and zinc, leached from acidic sandy loam soil amended with 30% rubber crumb. Concentrations of these elements from soil mixed with rubber crumb and lime, however, did not differ from those observed for control plots...Rubber also significantly increased the concentration of zinc in turfgrass clippings. However, elevated concentrations were not sufficient to produce zinc toxicity in turfgrass."*

Florida Department of Environmental Protection (FDEP, 1999) evaluated stormwater runoff from a parking lot surface using ground tire rubber and other water samples and found that *"Except for the iron concentrations detected in groundwater samples collected from MW-1, MW-3, and MW-4, all remaining soil, groundwater, rain water, and surface water runoff concentrations were below State guidance concentrations."*

Plesser and Lund (2004) found that *"The leachate from the fibres contained zinc. The concentration is higher than the Norwegian Pollution Control Authority's limit for zinc in water with Environmental Quality Class V (very strongly polluted water), but lower than the permitted zinc concentration in Canadian drinking water...The total concentrations of zinc and PAH in the recycled rubber granulates exceed the Norwegian Pollution Control Authority's normative values for most sensitive land use. The concentrations of dibutylphthalate (DBP) and diisononylphthalate (DINP) exceed the PNEC values for terrestrial life taken from the EU's programme for risk assessment. The concentration of isononylphenol is above the limits specified for cultivated land in the Canadian Environmental Quality Guidelines...The concentration of zinc indicates that the leachate water is placed in the Norwegian Pollution Control Authority's Environmental Quality Class V (very strongly polluted water), but is lower than the permissible zinc* *concentration in Canadian drinking water. The concentration of anthracene, fluoranthene, pyrene and nonylphenols exceed the limits for freshwater specified in the Canadian Environmental Quality Guidelines."*

A laboratory study conducted in Italy by Gualteri et al. (2005) evaluated the effects of leachate from tire debris on human lung cells and *X. laevis*. Gualteri et al. (2005) concluded that the *"results confirm the significant role of zinc in leached [tire debris] and the presence of additional organic toxicants."*

Sheehan et al. (2006) conducted a study in Maine and observed *"Elevated levels of iron, manganese, and several other chemicals…in tire shred leachates. However, chronic toxicity tests with Ceriodaphnia dubia and fathead minnows (Pimephales promelas) showed no adverse effects caused by leachates collected from tire shreds installed above the water table. Exposure to leachates collected from tire shreds installed below the water table resulted in significant reductions to both survival and reproduction in C. dubia."*

Verschoor (2007) observed that zinc from rubber infill in artificial turf in The Netherlands *"leaches to the soil, groundwater and surface water"* and *"environmental quality standards for zinc in surface water and groundwater are exceeded."* However, *"The risks of zinc to public health are of no concern: the human toxicity of zinc is low and WHO drinking water criteria are not exceeded."*

As part of a study conducted in Connecticut, Mattina et al. (2007) examined crumb rubber produced from recycled tires. According to Mattina et al. (2007), *"The laboratory data…support the conclusion that under relatively mild conditions of temperature and leaching solvent, components of crumb rubber produced from tires (i) volatilize into the vapor phase and (ii) are leached into water in contact with the crumbs."*

Based on a study conducted in Washington, Johns and Goodlin (2008) suggested that *"The available literature demonstrates that some chemicals can leach from tire crumb when it is exposed to water. While some studies report the presence of organic chemicals in leachate, the chemicals were detected at such low concentrations that authors considered them to be of little environmental relevance. The most consistent chemical to be detected in leachate tests is the metal zinc."*

Based on a study in Japan, Aoki (2008) found that *"The concentrations of leaching heavy metals [from infills on artificial turf] increased with an increase in the acidity of the acid solutions."*

Based on a Danish study, Nilsson et al. (2008) reported that *"a number of environmentally harmful substances were found in the contact water from leaching tests on infills and artificial turf mats."*

Bocca et al. (2009) conducted a laboratory study in Italy to identify and quantify metal concentrations in leachate from crumb rubber samples. According to Bocca et al. (2009), *"The total amount and the amount leached during the acidic test varied from metal to metal and from granulate to granulate. The highest median values were found for Zn (10,229 mg/kg), Al (755 mg/kg), Mg (456 mg/kg), Fe (305 mg/kg), followed by Pb, Ba, Co, Cu and Sr... The highest leaching was observed for Zn (2300 μg/l) and Mg (2500 μg/l), followed by Fe, Sr, Al, Mn and Ba. Little As, Cd, Co, Cr, Cu, Li, Mo, Ni, Pb, Rb, Sb and V leached, and Be, Hg, Se, Sn, Tl and W were below quantification limits. Data obtained were compared with the maximum tolerable amounts reported for similar materials, and only the concentration of Zn (total and leached) exceeded the expected values."*

Based on a study in Portugal, Mota et al. (2009) stated that *"PAH leaching is negligenciable...heavy metals content in the acidic water leachates considerably lower than the limit values."*

Kanematsu et al. (2009) found that *"aqueous extracts of rubber mulches (RM) contain high concentrations of zinc (Zn) compared with wood mulches (WM), and its concentration increased at lower pH and higher temperature...Our results suggest that organic constituents in water extracts of RM which have AhR activity may not be of significant concern while leaching of Zn from RM appears to be a potentially larger water quality issue for RM."*

The Connecticut Department of Environmental Protection concluded that *"Zinc is the most prevalent contaminant in the leachate and stormwater studies." "The DEP concludes that there is a potential risk to surface waters and aquatic organisms associated with whole effluent and zinc toxicity of stormwater runoff from artificial turf fields...This study did not identify any significant risks to groundwater protection criteria in the stormwater runoff from artificial turf fields"* (CDEP, 2010).

Rhodes et al. (2012) found that *"zinc leaching from tire crumb rubber increases with smaller crumb rubber and longer exposure time."*

Cheng et al. (2014) reviewed studies where the toxicity characteristic leaching procedure (TCLP) was used and indicated that constituent concentrations were well below maximum contaminant limits (MCLs) or TCLP regulatory limits.

In a case study of PAH and other hazardous contaminant occurrence in recycled tire rubber surfaces at a restaurant playground in an indoor shopping center, Celeiro et al. (2014) found that, *"fourteen out of the sixteen EPA priority PAHs were identified and quantified in the investigated recycled tyre rubber playground surfaces. The analytical measurements also confirmed the presence of other harmful compounds including* *phthalates, adipates, antioxidants and benzothiazole among others, in some cases at high concentration levels*."

Crampton et al. (2014) assessed the effects of leachate from crumb rubber and zinc in green roofs on the survival, growth, and resistance characteristics of *Salmonella enterica subsp. enterica serovar typhimurium. "The median concentration of zinc in the crumb rubber-amended roof was 0.2 mg/liter ..., while the median concentration of zinc in the commercial medium was 0.15 mg/liter."*

The results of an Ohio study conducted by Dorsey et al. (2015) *"suggest that at the higher temperatures such as those on artificial athletic field surfaces, the crumb rubber infill on these artificial athletic fields can become the source of a water soluble agent with mutagenic potential in bacteria."*

Selbes et al. (2015) observed *"...a constant rate of leaching was observed for iron and manganese, which are attributed to the metal wires present inside the tires. Although the total amounts that leached varied, the observed leaching rates were similar for all tire chip sizes and leaching solutions."*

<u>Air Concentration, Volatilization/Off-gassing, and Particulate Matter</u>

Several of the studies reviewed collected air samples using stationary, personal breathing zone monitors, or other methods to assess the potential for volatilization of chemical constituents from artificial turf or other materials that contain tire crumb rubber. Conclusions from these studies are provided below.

Dye et al. (2006) conducted a study in Norway to obtain measurements of air quality for three indoor artificial turf pitches. The measurements were taken in a hall with recently laid rubber granulate (SBR rubber or Styrene Butadiene Rubber) and a hall with rubber granulate (SBR rubber) which had been in use for one year and a hall which used granulate made from thermoplastic elastomer. *"In all three halls, the proportion of organic material is considerable. The airborne dust contains polycyclic aromatic hydrocarbons (PAH), phthalates, semi-volatile organic compounds, benzothiazoles and aromatic amines. It also contains organic and inorganic pollutants which are not specified in this study. Possible problem areas linked to latex exposure via the skin and air passages should be assessed by specialists."*

Van Bruggen (2007) conducted a study in The Netherlands to assess releases of nitrosamines from crumb rubber by taking measurements at two different levels above artificial turf surfaces and found that *"None of the measurements showed the presence of nitrosamines in the atmosphere above the pitch. Supplementary laboratory tests on the materials showed that nitrosamines can only be released from rubber crumb to a very limited extent."*

EHHI (2007) concluded that *"It is clear that the recycled rubber crumbs are not inert, nor is a high-temperature or severe solvent extraction needed to release metals, volatile organic compounds, or semi-volatile organic compounds. The release of airborne chemicals and dust is well established by the current information. There are still data gaps that need to be filled in and additional studies are warranted."*

Vetrano and Ritter (2009) stated that *"An analysis of the air in the breathing zones of children above synthetic turf fields [in New York City] did not show appreciable levels from COPCs contained in the crumb rubber,"* but constituent characterization of bulk samples revealed lead and zinc concentrations that were above soil cleanup objectives for restricted residential land use.

California OEHHA (2010) collected air samples from 4 artificial fields and 4 natural fields and found that *"PM2.5 and associated elements (including lead and other heavy metals) were either below the level of detection or at similar concentrations above artificial turf athletic fields and upwind of the fields" and "The large majority of air samples collected from above artificial turf had VOC concentrations that were below the limit of detection."*

The University of Connecticut Health Center (UCHC) (2010) found that *"Of the 60 VOCs tested in air, 4 VOCs appear to be associated with turf. Of 22 PAHs, 6 were found in the air on the turf at 2 fold greater concentrations than in background locations on at least two fields…benzothiazole and butylated hydroxytoluene were the only chemicals detected in the personal and area air samples from outdoor turf fields ranging from <80-1200 ng/m^3 and <80-130 ng/m^3, respectively. Nitrosamine air levels were below reporting levels. PM10 air concentrations were greater in background locations than on the turf at all fields with the exception of Field B. However, the PM10 air concentration on turf at Field B, 5.89 ug/m^3, was within the range of other PM10 background concentrations. All of the composite samples of turf fibers and crumb rubber were below the level EPA considers as presenting a "soil-lead hazard" in play areas (400 ppm)."*

Li et al. (2010) found that *"Ten volatile compounds were identified in the vapor phase over all commercial [crumb rubber] samples and two aged field [crumb rubber] samples by SPME coupled with GC–MS. Six volatile compounds were quantitated by direct vapor phase injection. In all 16 virgin commercial [crumb rubber] samples, [benzothiazole] was the most abundant volatile compound. Zinc was the highest of all extractable metals in the acidified extraction fluid."*

Simcox et al. (2011) conducted a synthetic turf field investigation in Connecticut. The *"Results showed that personal concentrations were higher than stationary concentrations and were higher on turf than in background samples for certain VOC. In some cases, personal VOC concentrations from natural grass fields were as high as those on turf.*

Naphthalene, BZT, and butylated hydroxytoluene (BHT) were detected in greater concentration at the indoor field compared to the outdoor fields. Nitrosamine air levels were below reporting levels. PM10 air concentrations were not different between on-field and upwind locations. All bulk lead (Pb) samples were below the public health target of 400 ppm."

Microbial Assessment

Assessments of microbial populations associated with artificial turf were limited compared to those of other topics areas. Conclusions for some of these studies are summarized below.

McNitt et al. (2006) collected crumb rubber samples from both "high use" areas and "low used" areas in fields used by elementary to professional athletes in Pennsylvania. "*While microbes exist in the infill media the number was low compared to natural turfgrass field soils."* The range of CFU was 0-80,000 in the infill material compared to 259,500 found in natural soil.

California OEHHA (2010) found that *"Fewer bacteria were detected on artificial turf compared to natural turf."*

Serentis et al. (2011) found that in Pennsylvania, *"Indoor fields tended to have lower overall microbial populations (0–7267CFU/g of infill) than outdoor fields (0–80 000CFU/g)… While it is clear that microbes exist on synthetic turf surfaces, the number was low compared with those on natural turf grass." "S. aureus colonies were not found to be present on any field; however, S. aureus colonies were found on other tested surfaces, including blocking pads, used towels, and weight equipment."*

Bass and Hintze (2013) compared *"the occurrence of microbial populations on two infilled synthetic turf fields (year old turf vs. 6 year old turf) in three locations...Much higher microbial populations were found on the older turf field"* compared to the newer turf. *"Counts from the MSA plates revealed a relatively high number of mannitol-fermenting salt-tolerant bacteria, a possible indication of staphylococci."*

Weathering/Aging

Based on a study in Taiwan, Chang et al. (1999) found that *"Two years after the track installation, the VOC concentrations measured at 1.5 m above the track, the breathing height of school children, were not significantly higher than the background levels."* Chang et al. (1999) also noted that the synthetic fields were all installed with adhesive and backings which might also contribute to VOC offgassing.

Based on a study in The Netherlands, Hofstra (2007b) concluded that *"The impact of weathering of the rubber crumb for the technical lifetime of an artificial turf field* *(approx. 10 to 15 years) does not cause the leaching of zinc from the rubber crumb made from recycled car tyres to exceed the threshold values for dissolved zinc in surface water or the derived threshold value from the Decree on Soil Quality for the emission of zinc into the soil."*

Verschoor (2007) observed that *"Laboratory experiments and measurements of field samples of the rubber infill show that the emission of zinc increases over time, due to chemical and physical changes of the rubber particle."*

Zhang et al. (2008) reported on studies conducted in New York and concluded that *"Rubber granules often, especially when the synthetic turf fields were newer, contained PAHs at levels above health-based soil standards. PAH levels generally appear to decline as the field ages."*

A report on a study conducted at the Connecticut Agricultural Experiment Station (CAES) concluded that *"...although there is a decrease in the amounts of all six compounds which outgas over the ten weeks of this experiment, the decrease is the least for 4-t-octylphenol. Second, at approximately 20 days of weathering under the conditions in this experiment, the five compounds appear to reach a consistent level of outgassing"* (CAES, 2010).

Data Gaps/Recommendations for Further Study

Several studies provided information on data gaps and recommendations for further study. These conclusions ranged from statements about the general need for further investigation to specific suggestions for further research. Some examples of these recommendations are provided below.

Zelibor (1991) recommended *"that a field study be prepared in conjunction with key states (Ohio, Illinois, Pennsylvania, California, Texas, New York, New Jersey, North and South Carolina, Florida, Georgia, among others) and coordinated by the Scrap Tire Management Council."* Its purpose would be to address questions *"concerning the effect of leachate from scrap tire products in the environment...[specifically], 1) Which regulatory standards are appropriate to evaluate potential adverse effects on human health and environment from compounds leached from scrap tire or rubber products?; 2) Are there any realistic environmental conditions/applications where scrap tires leach compounds that exceed regulatory standards? 3) Are compounds leached from scrap tire products in the environment under specific applications? If so, what is the fate of those compounds in the environment?; [and] 4) Is there an adverse effect on groundwater, surface water or wetlands from the storage or application of scrap tires?"*

Plesser and Lund (2004) found that *"recycled rubber granulates give off a significant number of alkylated benzenes in gaseous form. Trichloromethane (sample 1) and cis-1,2-dichlorethene (sample 5) were also found."* They also recommended that *"measurements be taken of air quality above pitches to determine whether the air quality is satisfactory."*

Sullivan (2006) concluded that *"The actual amount of contamination leaching from artificial turf used on playgrounds or athletic fields needs further research to determine the potential harm to human health or the environment."* In term of human health, Sullivan et al. (2006) suggested that *"It is not clear whether dermal or inhalation exposure to tire rubber can lead to sufficient absorption of chemicals to cause mutagenic or carcinogenic effects. The degree of direct contact between the rubber used in artificial turf is not well enough known at this time to determine whether the level of the potential for harm to humans playing on artificial turf containing crumb rubber."* In terms of aquatic toxicity, Sullivan et al. (2006) stated that *"The unknown factor is how much zinc or organic compounds would be released from crumb rubber used on or beneath artificial turf."*

In 2006, KEMI, the Swedish Chemicals Inspectorate, published a status report on synthetic turf from a chemical perspective. Data gaps with regard to health risks from the use of synthetic turf were summarized as follows: *"Certain investigations and assessments have been carried out in order to illuminate the risks of using synthetic turf, but there remain major gaps in our knowledge. This is particularly true with respect to the extent to which the hazardous substances are released from the rubber, and the subsequent exposure to these substances of people and the environment."*

Verschoor (2007) made the following recommendations: *"Mechanisms of behaviour and ageing of (different types of) rubber should be investigated to obtain a better understanding of the risks of zinc and other components leaching from rubber…It is recommended that measurements are first taken in drainage water from existing artificial turf with rubber infill of differing age and quality. Sampling at several time intervals in different seasons is preferred...Bioassay is recommended to assess the toxicity of the drainage water...A mini artificial turf field (1x1x1 m) can be built and exposed to outdoor weather conditions in a lysimeter...more advanced models can be used for a refined risk assessment."*

LeDoux (2007) conducted a preliminary assessment of the toxicity from exposure to crumb rubber based on a literature review and concluded that *"Insufficient information was found to perform a complete formal exposure assessment/risk characterization on crumb rubber for the stated outdoor use at this time due to existing data gaps in the available information. After reviewing the information available, with the possible exception of allergic reactions among individuals sensitized to latex, rubber and related products, there was no obvious toxicological concern raised that crumb rubber in its intended outdoor use on playgrounds and playing fields would cause adverse health effects in the normal population."*

Based on a literature review, ChemRisk (2008) concluded that *"The current state of knowledge indicates that there are data gaps which significantly limit a scientifically robust analysis of the potential environmental health risks associated with the selected* *tire materials and tire wear particles [TWP]" "It was concluded that the most significant data gaps are: 1) lack of understanding of the chemical composition of TWP, 2) lack of understanding of the levels of TWP in the environment (air, soil, and sediments) and their potential associated health risks; and 3) lack of understanding of the potential for TWP to leach chemicals into the environment." "As such is it recommended that the following research be conducted to allow for environmental health risk assessment of TWP: chemical composition analysis of TWP generated under representative driving conditions; acute aquatic toxicity studies of TWP; characterization of TWP leachate under simulated environmental/biological conditions; development of chemical marker for TWP in environmental media; and, measurement of TWP in air, soil, water and sediment to determine representative exposure concentrations."*

In a 2008 editorial, Lioy and Weisel (2008) stated that *"At the present time, we believe that the million dollar expense to produce and install a synthetic field by communities and athletic facilities demands a much more thorough understanding of the environmental impacts, human exposure and health risk implications associated with all synthetic turf products available on the market. This calls for a comprehensive evaluation of artificial turf by exposure scientists, and others in environmental science and environmental health sciences."*

The New York Department of Environmental Conservation (NYDEC, 2008) noted that *"Many governmental bodies including Norway, Sweden and California have recently reviewed the health issues associated with the use of crumb rubber as infill at playgrounds and synthetic turf fields. Their assessments did not find a public health threat. However, several recent preliminary studies... indicated the presence of organic compounds, such as polycyclic aromatic hydrocarbons (PAH) and heavy metals, such as zinc, and raised concerns that these substances could have potential adverse impacts on the environment and public health, especially for children playing on these synthetic turf fields for extended time periods....to address these concerns, the DEC has initiated a study to assess the potential environmental impacts from the use of crumb rubber as an infill material in synthetic turf fields and to collect data that would be relevant for a public health and environmental assessment."*

U.S. EPA (2009) conducted a scoping-level field monitoring study of synthetic turf and playgrounds in the U.S. and concluded that *"On average, concentrations of components monitored in this study were below levels of concern; however, given the very limited nature of this study (i.e., limited number of components monitored, samples sites, and samples taken at each site) and the wide diversity of tire crumb material, it is not possible to reach any more comprehensive conclusions without the consideration of additional data."*

Based on a study conducted by the University of Connecticut Health Center (UCHC, 2010) *"airborne concentrations of VOCs, targeted SVOCs (e.g. benzothiazole) and miscellaneous SVOCs were highest at the indoor field. These data were collected from* *only one indoor facility. Higher concentrations of these chemicals at the indoor field likely reflects the lack of air movement relative to outdoor fields."* UCHC (2010) suggested that *"more research is needed to better understand chemical exposures in indoor facilities."*

Simcox et al. (2011) concluded that *"More research is needed to better understand air quality at indoor facilities."*

Menichini et al. (2011) suggested that *"Further work is needed to assess the actual scenarios of exposure to PAHs by inhalation and the corresponding risks, and to reach more comprehensive conclusions."*

Krüger et al. (2012) suggested that *"Considering the risk assessment of artificial turf systems, emphasis should be placed not only on the plastic components but also on mineral aggregates used for basic layers, which might contribute to the release of contaminants, especially of zinc. For a thorough and realistic risk assessment, column tests of complete artificial turf systems, simulating the actual installation, may be more realistic."*

Cheng et al. (2014) conducted a literature review of environmental and health impacts of artificial turf and stated *"There remains a significant knowledge gap that must be urgently addressed with the fast expansion of the artificial turf market. Given the wide range of designs, ages, and conditions of artificial turf fields, it is likely that the contaminant release and the environmental impacts are variable from site to site. It is also important to assess more systematically the risk posed by the tire rubber crumb on the environment and human health"*.

The health impact assessment of the use of artificial turf in Toronto, conducted by the city of Toronto (2015) concluded that there are *"still some information gaps: the allergenic potential of latex in crumb rubber has not been thoroughly investigated; exposure to lead, other metals, carbon nanotubes, as well as other contaminants have not been fully evaluated in all types of turf systems"*.

The Virginia Department of Health (VDOH, 2015) suggested that studies *"done exclusively in a controlled laboratory setting may not necessarily represent a "real world exposure" to chemicals in crumb rubber. However, laboratory analysis provides an alternative to identifying chemicals (by employing strong extraction techniques and concentrating chemicals to detectable concentration before analysis) in crumb rubber that might be present in low concentrations in the environment."*

Dorsey et al. (2015) conducted a study in Ohio and concluded that *"Risk assessment studies are needed to consider the health impact of repeated exposure to crumb rubber at the conditions relevant to artificial athletic fields."*

VII. Gaps Analysis Based on the Literature Review

Despite the use of tire crumb rubber in synthetic fields over the last several decades, there is not an extensive body of scientific research on the exposure to and toxicity of tire crumb rubber, and questions about the effects of this material on human health and the environment remain. The Literature Review/Gaps Analysis (LRGA) effort considered 97 reference sources for information related to tire crumb rubber. Eighty-eight of the references were included in the analysis. The LRGA analysis categorized the studies according to a set of general topic areas, to evaluate the relative areas of data richness and data gaps. Important data gaps remain in the characterization of tire crumb rubber material used in synthetic turf fields and playgrounds, assessing exposures for users of these fields and playgrounds, human and ecological risk assessment, and in health impact assessments. Selected data gaps described in Table B-12 focused on potential human exposure and health impact assessments for exposure to tire crumb rubber and its constituents. Some concerns related to synthetic turf fields and playgrounds were not addressed in this Literature Review/Gaps Analysis, including heat exposure and injury. Other potential gaps that might be important but were not directly addressed in the reviewed literature included limitations in tools and methodology available for characterizing constituents, exposure, and health impacts among user populations.

One of the LRGA topic areas was risk assessment characterizing the human and ecological effects of interaction with tire crumb rubber. While there are many definitions of the term “risk”, the U.S. EPA considers risk to be the chance of harmful effects to human health or to ecological systems resulting from exposure to an environmental stressor (U.S. EPA, *About Risk Assessment*). In general terms, risk depends on the following three factors:

- How much of a stressor (e.g., chemical) is present in an environmental medium (e.g., soil, water, air),
- How much contact (exposure) a person or ecological receptor has with the contaminated environmental medium,
- The inherent toxicity of the stressor.

In the ideal world, risk assessments would be based on a very strong knowledge base (i.e., reliable and complete data on the nature and extent of contamination, fate and transport processes, the magnitude and frequency of human and ecological exposure, and the inherent toxicity of all of the chemicals). Based on the tire crumb rubber literature reviewed here, data are not available for all of these factors in all of the studies, and only a limited number of studies provided quantitative estimates of risk to human or ecological population from tire crumb rubber constituents.

Only a subset of the 88 available references evaluated risks associated with constituents of tire crumb rubber. Among the studies that estimated human health risks, both cancer and non-cancer endpoints were considered, and the available studies each considered one or more routes of exposure (i.e., inhalation, ingestion, and dermal). A limited number of studies examined the activity patterns associated with tire crumb rubber exposures or provided population - and activity-specific exposure factors (e.g., time spent in contact with artificial turf fields) for use in risk assessment. There was a balance in the populations studied with respect to adults, children and athletes. Fewer studies addressed occupational exposures from turf and playground installations. Given the relative paucity of investigations on worker-associated risks and activity-related studies, there remains uncertainty in potential risks associated with the use of tire crumb rubber at synthetic turf fields and playgrounds.

Table B-12. Data Gaps for Research on Tire Crumb Rubber in Synthetic Fields and Playgrounds

	Research Area	Data Gaps
Tire Crumb Rubber Characterization	Chemical Characterization	• Studies that have measured metal, volatile organic chemicals (VOCs), and semivolatile organic chemicals (SVOCs) (e.g., polycyclic aromatic hydrocarbons [PAHs] and benzothiazole) were usually based on small numbers of tire crumb rubber samples. The wide range of organic chemicals potentially used in tire manufacture, or their degradates, have not been analyzed systematically across a large range of tire crumb rubber samples from synthetic fields and playgrounds in the United States. • Limited information is available on chemical constituents in molded rubber products made with tire crumb rubber used in some playground settings.
	Emissions Assessments	• Few laboratory-based studies have investigated VOC and SVOC emissions from synthetic fields and playgrounds under different temperature conditions. Measurements using dynamic emission chamber measurements have been reported, but the number and types of measured chemical emissions have been limited.
	Microbial Assessments	• Microbiological assessments for synthetic turf fields and playgrounds have been limited and have been based on traditional culture methods. The use of molecular methods has not been applied in studies of tire crumb rubber.
	Bioaccessibility	• Several studies have examined potential bioaccessibility of metals and PAHs. However, studies that systematically measure a wider range of metal and organic chemical constituents, using multiple simulated biological fluids, and across a large range of tire crumb rubber samples are lacking.
	Variability	• Most studies characterizing tire crumb rubber from synthetic fields and playgrounds in the United States have been relatively small and restricted to a few fields or playgrounds. Measurements for samples collected from a wider range of tire recycling plants, synthetic fields, and playgrounds across the United States is lacking. Also, information is limited on the range of chemical, microbiological, and physical characteristics and factors related to variability in tire crumb rubber and potential exposures.

Table B-12 (continued). Data Gaps for Research on Tire Crumb Rubber in Synthetic Fields and Playgrounds

	Research Area	Data Gaps
Exposure/Risk Characterization	Exposure Factors	• Exposure and risk assessments have typically relied on generic exposure factors. Information specific to the frequency and duration of synthetic field and playground uses, physical activities, contact rates, and hygiene are limited. • Exposure factor data are not available either across the wide variety of sports and recreational users of synthetic turf fields and playgrounds with tire crumb rubber, or for occupational exposures.
	Dermal/Ingestion Exposures	• While multiple studies have attempted to characterize potential inhalation exposures to tire crumb rubber chemical constituents, more limited information is available for understanding dermal and ingestion exposures.
	Broken Skin/Ocular Exposures	• Little information is available on the potential for increased exposures via broken skin (i.e., due to cuts and scrapes) and through ocular fluids.
	Particle Exposures	• There is limited information on exposure to tire crumb particles and their constituents through inhalation, dermal, and ingestion. Information on the exposure potential as synthetic fields and playgrounds age and weather, and for various uses and activities on synthetic fields and playgrounds is limited.
	Variability	• Few studies have evaluated the variability of exposures to tire crumb rubber constituents by activity type, exposure scenario, age, material type and condition, facility type and condition, and ambient conditions such as temperature and wind or ventilation. Limited information is available on the variability of exposures and related factors across a wide range of user groups and scenarios. • A few studies suggest that inhalation exposures at indoor facilities are higher compared to those at outdoor facilities, but the available information is limited.
	Biomonitoring	• Only a few biomonitoring studies have been performed. Only hydroxypyrene has been measured as a biomarker in athletes and workers. • Additional tire rubber-specific biomarker measurements have not been reported for synthetic field and playground users and biomarker analysis methods might be lacking for some chemicals. • Large scale biomonitoring studies of populations exposed and not-exposed to synthetic turf fields and playgrounds with tire crumb rubber have not been reported.
	Cumulative/Aggregate Assessments	• Exposures to multiple tire crumb constituents are likely to occur via multiple pathways (e.g., inhalation, ingestion, and dermal contact). However, studies that evaluated cumulative and aggregate exposure and risks are limited.
	Epidemiology Studies	• No epidemiological investigations for synthetic turf field or playground users were identified in the literature review. • Survey and biomonitoring tools for accurate assessment of relative exposures for synthetic field and playground users in an epidemiological study are lacking.
Alternative Assessments	Alternative Infills/Materials	• Most research to date has focused on characterizing tire crumb rubber infill. Similar research on other infill materials, including natural materials, ethylene propylene diene monomer (EPDM), thermoplastic elastomers (TPE), and recycled shoe rubber are either lacking or limited.
	Natural Grass Fields	• Few studies have been performed to assess potential chemical exposures from natural grass playing fields.
	Other Exposure Sources	• Only a few comparative assessments have been performed on relative exposures to chemicals associated with tire crumb rubber from other sources.

Many of the studies that did not characterize risks, examined factors related to potential public or environmental health impacts (e.g., identifying chemical constituents, or assessing leaching or off-gassing of chemicals from artificial turf). Among these other topic areas, there was relatively less information available on microbiological and bioavailability aspects of tire crumb rubber exposures. The availability of biomonitoring studies was also limited. No studies were identified that produced or evaluated epidemiological data on potential associations between the incidence of health effects and exposures related to tire crumb rubber. Related to sampling locations, there were more studies conducted in laboratories and synthetic fields. Thus, data gaps may be more pronounced for locations such as playgrounds and indoor fields, as well as studies that compare site-specific concentrations of tire crumb rubber constituents to background levels. Another less-studied factor relates to potential differences between constituent levels in environmental media and corresponding exposures based on activity levels (e.g., active versus inactive play) on artificial turf fields.

A wide range of chemicals were evaluated in the literature reviewed for the LRGA, and a significant portion of the LRGA involved compiling a list of potential tire crumb rubber constituents identified in the available literature. The constituents list spreadsheet, which can be found on the Status Report website, identifies more than 350 distinct chemical compounds. A list of the chemicals is provided in Appendix F. This spreadsheet is a comprehensive list of unique chemicals that were identified in the LRGA literature. Some major classes of constituents identified in the LRGA include inorganics, and VOCs/SVOCs. Frequently studied inorganics include lead, zinc, cadmium, and chromium. Frequently studied VOCs/SVOCs include benzothiazole and PAHs. Less frequently studied constituents included microbials, and a variety of complex organic compounds. In general, the available studies do not establish whether the observed results are widespread and generalizable. Systematic studies based on larger numbers of athletic fields and playgrounds designed to include a range of characteristics (rubber material source, location, age, etc) for the population of such fields and playgrounds across the United States have not been performed.

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IX. Appendices

Appendix A - CDC Review of Published Literature and Select Federal Studies on Crumb Rubber and Synthetic Turf

Review of Published Literature and Select Federal Studies on Crumb Rubber and Synthetic Turf

Product Sampling and Chemical Composition Studies

1. **Synthetic Turf Field Investigation in Connecticut**
   N. Simcox, A. Bracker, G. Ginsberg, B. Toal, B. Golembiewski, T. Kurland, C. Hedman; *Journal of Toxicology and Environmental Health, Part A*; **2011**.

   The purpose of the study is to characterize concentrations of VOCs, SVOCs, rubber-related chemicals, and PM10 in ambient air at selected fields with crumb rubber infill in Connecticut during summertime conditions and during active field use.

   Methods:
   - During July 2009, three types of fields were sampled:
     - Outdoor field with crumb rubber infill
     - Indoor facility with crumb rubber infill
     - Outdoor field with grass turf as background location
   - Air samples collected at older fields (>3 years) and at new fields (< 2 years).
   - Personal air sampling during simulated soccer game:
     - VOCs
     - SVOCs
     - Benzothiazole (BZT)
     - 2-mercaptobenzothiazole
     - 4-tert-octylphenol
     - Butylated hydroxyanisole
     - Butylated hydroxytoluene (BHT)
     - Nitrosamines
     - PM10

   Study results and/or conclusions:
   - For turf fiber and crumb rubber infill, lead levels were below the EPA "soil-lead hazard" limit and below the 300ppm target set by Consumer Product Safety Act for products to be used by children.
   - Of 60 VOCs, 31 were detected on field.
   - Personal air monitoring concentrations were higher on artificial turf than on grass for 21 VOCs.
   - Stationary samples on the outdoor fields were similar to background.
   - Total VOCs were higher indoors than outdoors, however, only a few VOCs were elevated indoors compared to background.
   - Benzo(a)pyrene was higher at the outdoor field than background (range ND-0.19 versus ND-0.05).
   - For the indoor field, 1-methylnapthalene, 2-methylnapthalene, fluorene, napthalene, and pyrene were 10-fold higher than background.
   - There were several other PAHs found only on the indoor turf, acenapthene, acenaphthylene, fluorene, napthalene, and 2,6-dimethylnapthalene.
   - BZT and BHT were higher on the indoor field than outdoor field (BZT range 11,000-14,000 ng/m^3 versus <80-1,200 ng/m^3; BHT range 1,240-3900 ng/m^3 versus <80-130 ng/m^3).

   Study limitations:
   - Potential selection bias as field location participation was voluntary.
   - Sample size was small.
   - Summer 2009 temperatures were lower than normal.
   - Personal sampling occurred at waist height, not in the breathing zone.
   - Some VOCs were found in the personal samples, but not the turf or background indicated non-turf related sources.

2. **Hazardous organic chemicals in rubber recycled tire playgrounds and pavers**
M. Llompart, L. Sanchez-Pardo, J. Lamas, C. Garcia-Jares, E. Roca; *Chemosphere*; **2013**.

The purpose of the study was to investigate the presence of hazardous organic chemicals in recycled tire playground surfaces.

<u>**Methods**</u>:

- 21 samples from 9 urban playgrounds
- 2 types of ground covers - floor tiles compositions and carpet covers
- 7 samples from a local store; 2 puzzle pavers and 5 recycled rubber tire tiles of different colors
- Ultrasound-assisted extraction followed by pressurized solvent extraction
- GC-MS for PAHs, plasticizers and other phthalates (31 compounds total)
- Solid-phase microextraction (SPME) for vapour phase composition profiles

<u>**Study results and/or conclusions**</u>:

- For playground samples
  - Full GC-MS scan identified a large number of VOCs, SVOCs, and POPs.
  - All samples contained PAHs with a range of 1.25 µg g-1 to 70.4µg g-1 total PAH amount with one sample having a concentration of 178µg g-1
  - Pyrene was the most abundant congener found in all samples.
  - Napthalene, phenanthrene, fluoranthene, and chrysene were found in 20 or 21 samples.
  - B(a)P was found in 5 samples with values ranging from 0.4µg g-1 to 5.0µg g-1.
  - Benzothiazole (BTZ) was found in all playground samples with a mean concentration of 10µg g-1.
  - 2-mercaptobenzathiole (MBTZ) was found in playground samples, but there were methodological issues with the analysis.
  - 4-tert-butylphenol (TBP) was present in half the playground samples at low concentrations.
  - Butylated hydroxytoluene (BHT) was found in all samples but butylated hydroxyanisole (BHA) was not found in the samples.
  - Phthalates were found in all samples with the most abundant congener being di(2-thylhexyl)phthalate, concentrations ranging from 4 to 64 µg g-1.
  - Diisononyl phthalate (DINP) was found in 8 of 21 playground samples but was not detected in commercial pavers.
  - For the SPME analysis, all PAHs found in the samples were detected excluding the less volatile ones. BZT, DEP, DIBP, DBP, DEHP, and BHT were found in all cases.

- For commercial pavers:
  - Higher PAH concentrations compared to playground samples.
  - For 5 of 7 samples, concentrations were extremely high - 2000µg g-1 to 8000µg g-1.
  - All PAHs were found in all samples with a mean concentration of B(a)P = 500µg g-1.
  - BZT was found in all commercial pavers with concentrations ranging from ~20 to >150 µg g-1.
  - MBTZ was not detected in commercial pavers.
  - TBP was present in all pavers with concentrations ranging from 8.6 to 21µg g-1.
  - BHT was found in all pavers with a mean concentration 19µg g-1.
  - Phthalate concentrations were higher in pavers than playground samples. DEHP concentrations ranged from 22 to 1200µg g-1.
  - For the SPME analysis, volatile PAHs and some less volatile PAHs (including B(a)P) were found in some samples. BZT, DEP, DIBP, DBP, DEHP, and BHT were found in all cases.
  - TBP was also found in most samples.
- Research is ongoing as a high number of compounds (excluding the ones in this study) were found in the samples.

<u>**Study Limitations**</u>:

- The study did not determine bioavailability of the chemicals after ingestion or upon dermal exposure.
- For the SPME analysis, inhalation exposure is indicated as possible by the authors; however, laboratory vapor phase composition does not mimic field conditions and thus potential exposure conditions.

3. **Metals contained and leached from rubber granulates used in synthetic turf areas**
B. Bocca, G. Forte, F. Petrucci, S. Costantini, P. Izzo; *Science of the Total Environment*; **2009**.

The purpose of the study was to quantify metals contained in and leached from different types of rubber granulates used in synthetic turf.

<u>**Methods**</u>:

- 32 samples from 32 different playgrounds in Italy were collected with samplings performed at different positions in the playground to obtain a representative sample for each area with 250g granulate obtained from 12 sectors.
- 50g granulate from each of the 12 samples pooled to obtain 1 sample per playground.
- Each sample was analyzed for metal content.
    - Al, As, Ba, Be, Cd, Co, Cr, Cu, Fe, Hg, Li, Mg, Mn, Mo, Ni, Pb, Rb, Sb, Se, Sn, Sr, Tl, V, W, Zn
- The levels were compared to the maximum concentrations allowable for soils.

Study results and/or conclusions:

- The rubber granulates contained all the metals included in the analysis, but the concentration range was wide in the different samples.
- Relatively high levels of Al, Fe, Mg, and Zn were found.
- All samples had metal concentrations significantly lower than the allowable limit, except Co, Sn, and Zn.
- 50% of samples exceeded the Co and Sn limit, while 97% of samples exceeded the limit for Zn with values around 100x higher than the standard.
- The highest leaching was observed for Zn (2,300 µg/L).
- Very low concentrations of As, Cd, CO, Cr, Cu, Li, Mo, Ni, Pb, Rb, Sb, and V were leached and Be, Hg, Se, Sn, Tl, and W were under the LOQ.

Study Limitations:

- Assessments of risk should be conducted for each individual case at a local level due to differences in local ground conditions, type of drainage, and the composition of the filler material.
- The results were compared to the allowable limit for metals in soil which may not be an appropriate comparison.

4. Health Risk Assessment for Artificial Turf Playgrounds in School Athletic Facilities: Multi-route Exposure Estimation for Use Patterns

H. Kim, Y. Lim, S. Kim, I. Yeo, D. Shin, J. Yang; *Environmental Health and Toxicology*; **2012**.

The purpose of the study was to identify major exposure routes and calculate total risk through a health risk assessment for chemicals released from artificial turf playgrounds and urethane flooring tracks.

Methods:

- 50 schools with artificial turf and urethane flooring at the playgrounds; 27 elementary schools and 23 middle and high schools
- Inhalation of VOCs and formaldehydes due to volatile outdoor air from surfaces of artificial turf and urethane flooring
- Dermal uptake from surfaces of artificial turf and urethane flooring
- Ingestion exposure to fine particles
- Trace metals (Pb, Cr, Ni, Cd, Zn, Hg)
    - Dust collected at 5L/min for 8 hours.
    - Urethane layer collected from flooring materials in schools.
    - Infill chip layer collected from chip flooring material in parks.
    - Product surface sampling was conducted using texwipe.
    - Hand surface sampling was performed using texwipe after children played on the facility.
- VOCs
    - Air samples collected at 0.2L/min at 1.5m for 2 hours
    - Infill chips (see Metals #2 and #3).
    - Air samples collected
    - Infill materials (see Metals #2 and #3; surface sampling and hand sampling not performed)
- Phthalates
    - Infill materials (see Metals #2 and #3)
    - Surface sampling (see Metals #4)
    - Hand sampling (see Metals #5)
- Sampling was conducted at the top of the central playground so as to eliminate other potential emission sources.

Study results and/or conclusions:

- Infill content for heavy metals had highest concentration of Zn > Pb > Cr.
- Pb exceeded standard in infill from 8 of the schools and exceeded the domestic standard (10mg/kg) in 2 of the schools.
- For the air monitoring, Zn had the highest concentration; Pb was detected but levels were 10% of Korean ambient air standards.
- Bioavailability values were estimated and for infill chips were shown to be 10-10,000 times lower than the measured content level; for the urethane flooring, the bioavailability was estimated to be approximately 10x lower than the infill chips.
- The excess cancer risk (ECR) for individual chemicals was estimated to be a level of one person out of one million (1×10-6) or less.

- The ECR for carcinogens in children with pica, who represent the most extreme exposure type among the facility users, was shown to be 1.14×10-7 for benzene and 8.47×10-7 for PAHs.
- The hazard index (HI) of the facility users for each individual chemical according to the mean exposure scenario was shown to be less than 0.1, which was low, except for children with pica.
- The HI of children with pica for non-carcinogenic materials was shown to be less than 0.001for Pb, 0.067 for Cr, Cd and Hg, 0.005 for Zn, 0.001 for VOCs; and 0.273 for phthalates, all of which were low, except for phthalates.

<u>Study Limitations</u>:
- The study did not consider asthma or allergic reactions in the health assessment.
- The authors assumed that all chemicals in the air sampling were from artificial turf or urethane flooring, and that there were no other air emission sources.

5. **Comparison of Batch and Column Test for the Elution of Artificial Turf System Components**
O. Kruger, U. Kalbe, W. Berger, K. Nordhaub, G. Christoph, H.P. Walzel; *Environmental Science and Technology*; **2012**

The purpose of the study was to compare the behavior of synthetic sports flooring components at different elution methods.

<u>Methods</u>:
- Artificial turf components from 6 German producers.
- Batch tests were performed with a liquid to solid ratio of 2L/kg.
- Column tests were performed with a liquid to solid ratio of 26.5 L/kg.
- pH, electric conductivity, turbidity of the eluates, and contaminant release were measured.
- Specific emphasis placed on zinc (ICP-OES) and PAHs (15 measured with HPLC).

<u>Study results and/or conclusions</u>:
- Lead and cadmium were under the LOQ while zinc concentrations varied from below LOQ - 129 mg/L.
- The PAH concentrations varied from 0.07-3.41 µg/L.
- The batch testing produced higher concentrations of zinc; however, column testing provides conditions closer to actual field conditions.

<u>Study Limitations</u>:
- Batch test conditions did not mimic actual field conditions.

6. **Release of Polycyclic Aromatic Hydrocarbons and Heavy Metals from Rubber Crumb in Synthetic Turf Fields: Preliminary Hazard Assessment for Athletes**
L. Marsili, D. Coppola, N. Bianchi, S. Maltese, M. Bianchi, M.C. Fossi; *Journal of Environmental and Analytical Toxicology*; **2014**.

The purpose of the study was to quantify the PAHs and heavy metals contained in the crumb rubber (tires produced before 2010), to determine whether PAHs are released and at what concentrations, and to estimate respiratory uptake by athletes training on these fields.

<u>Methods</u>:
- Samples were taken from nine different synthetic turfs from football fields in Italy
- 4 samples were new tire crumb rubber that was not yet on a fields.
- 4 samples of tire crumb rubber from fields 1-8 years old, and 1 sample from virgin rubber (i.e. not recycled tires)
- Heavy metals: Pb, Cu, Ni, Zn, Cr, Cd, Fe
  - Concentrations determined via spectrophotometer and spectrometer
- PAHs: 14 analytes determine via HPLC

<u>Study results and/or conclusions</u>:
- The majority of samples had concentrations of heavy metals that were below the maximum limits set by the Italian National Amateur League.
- Cd exceed the limit in 3 samples, 2 new and 1 installed.
- Zn was very high in all samples, exceeding the limit by a minimum factor of 20.
- PAH concentrations varied by sample. For all crumb rubber samples, highest concentrations were benzo(b)fluoranthene or pyrene.
- The data indicate that PAHs are released continually from the crumb rubber via evaporation and athletes frequenting fields could be exposed to chronic toxicity from PAHs.

Study Limitations:
- The preliminary hazard assessment overestimates the PAH contribution.
- Theoretical approach which must be considered as an extreme worst case scenario.

7. A Scoping-Level Field Monitoring Study of Synthetic Turf Fields and Playgrounds
U.S. Environmental Protection Agency; **2009.**

The purpose of the study was to generate limited field monitoring data that will be used by EPA to help determine possible next steps to address concerns regarding the safety of tire crumb infill in recreational fields.

Methods:
- Scoping level study evaluating environmental concentrations of tire crumb constituents in recreational fields.
- Two synthetic turf fields and one playground were chosen as the sampling locations.
- Air sampling was conducted at 1m height:
  - PM10 analyzed for mass, metals, and particle morphology
  - VOCs for 56 analytes (2pm collection time at the fields and at an upwind background location).
- Wipe sampling was conducted at the fields and also with tire crumb infill and turf blade samples
  - Pb, Cr, Zn, As, Al, Ba, Cd, Cu, Fe, Mn, Ni (ICP/MS).
- Percent bioaccessible Pb was calculated.

Study results and/or conclusions:
- All VOCs, PM, and metals were similar to all background levels and were below the national ambient air quality standards.
- Methyl isobutyl ketone was detected at one synthetic turf field and was not detected in the background samples.
- The extractable lead concentrations from the infill, turf blades, and tire crumb materials were low and below the EPA standard for lead in soil.
- Lead concentrations in the wipe samples were low and below the EPA standard for lead in residential floor dust.

Study Limitations:
- Semi volatile organic compounds were not measured in this study.
- Sites where samples were taken could have many variabilities in the materials used and possible environmental differences.
- There were some difficulties obtaining permission to access the playgrounds and synthetic turf fields.

8. CPSC Staff Analysis and Assessment of Synthetic Turf "Grass Blades"
Consumer Product Safety Commission

The purpose of the study was to determine the total lead content and accessibility of the lead.

Methods:
- Samples of synthetic turf at the time of installation and samples from when 1 field was dismantled.
- Lead content of grass blades was determined using ICP.
- Samples with detectable lead were tested for accessibility of lead.
- For in-service fields, X-ray fluorescence was used to detect the presence of lead.

Study results and/or conclusions:
- Synthetic turf lead content ranged from 0.09% to 0.96% and varied between the turfs and also within a field depending on color.
- The results for this set of tested synthetic turf fields show no case in which the estimated exposure for children playing on the field would exceed 15 mg lead/day (according to the CPSC's recommendation for chronic lead ingestion not exceeding 15 mg lead/day, daily).

Study Limitations:
- Accuracy of wipe sampling method for estimating exposure to lead contact residue is unknown.
- Dermal contact to skin with lead residue during a typical play event on a field was assumed.
- Experimental wipe method overestimated transfer to a persons' bare skin by a factor of 5 to 13.
- Bioavailability of lead from synthetic turf may not be the same as it is for the food and drink exposures that were the basis of the dose-response.

- Staff did not make adjustments in the assessment to account for differences in lead content as fields can have areas with different lead content (i.e. painted areas, etc.).

9. Environmental–sanitary risk analysis procedure applied to artificial turf sports fields
B. Ruffino, S. Fiore, M. C. Zanetti; *Environmental Science and Pollution Research*; **2013**.

The purpose of the study was to characterize chemicals in crumb rubber and assess their capacity to release the chemicals on contact with water. The study also evaluated if the rubber granules may pose a risk to child and adult players via direct contact, contact with rainwater soaking the field, or inhalation of dusts and gases released.

Methods:

- Four sports turf fields with crumb rubber infill, 1 field with thermoplastic elastomer, and 1 natural turf field.
- Field age varied from 1-3 years old.
- Rubber and soil samples were analyzed for BTX (GC-MS), PAHs (8, GC-MS), and metals (18, ICO-OES).
- In-water extractable compounds (BTX, PAHs, and metals) were analyzed.
- Gases and dusts were collected immediately above the ground, close to the sports fields, and at a point in the center of the city.
    - Samples were analyzed for BTX (gases) and PAHs (dust).

Study results and/or conclusions:

- Concentration of benzene is similar to those in the natural turf field.
- Pyrene concentrations in synthetic turf are approximately 20 mg/kg and B(a)P concentrations were 10 mg/kg.
- Zinc concentrations were substantially higher in synthetic turf compared to the natural turf sample; 115 times higher at the synthetic turf field with the lowest percentage zinc.
- The leaching tests identified higher BTX and PAHs in leachates from new infill material was higher than the old infill materials.
- For all turf fields examined and for all routes considered, the cumulative CR proved to be lower than 10−6 and the non-carcinogenic risk (for the sum of COCs) lower than 1, in line with Italian guidelines.
- Additionally, for the inhalation route, the inhalation of dust and gases from activity on artificial turf fields gave risk values less than those due to inhalation of atmospheric dust and gases from vehicular traffic.

Study Limitations:

- Some of the artificial turf fields were in various stages of age (the samples that were from newer fields had higher chemical and metals concentrations than older fields).
- Sample comparison was limited to one city's atmospheric dusts and gases and may not be the best representation of typical vehicular dust and gases being emitted.

10. Human Health Risk Assessment of Synthetic Turf Fields Based Upon Investigation of Five Fields in Connecticut
G. Ginsberg, B. Toal, N. Simcox, A. Bracker, B. Golembiewski, T. Kurland, C. Hedman; *Journal of Toxicology and Environmental Health, Part A*; **2011**.

The purpose of the study was to develop a screening level risk assessment in which high-end assumptions for exposure were used for uncertain parameters and surrogate data were employed for chemicals with inadequate toxicity information so that chemicals did not fall out of the assessment on the basis of missing data.

Methods:

- Personal air samples were taken from volunteers during 2-h sampling event at 5 artificial grass fields (4 outdoor and 1 indoor) with crumb rubber infill.
- Stationary air samples were also taken near the field.
- Air samples were analyzed for VOCs (60), SVOCs (120, including 22 PAHs), lead, nitrosamines (7), and PM10.

Study results and/or conclusions:

- 10 VOCs were considered chemicals of potential concern (COPC) for the outdoor and fields and 13 VOCs for the indoor fields.
- Personal monitoring results were higher for VOCs than the stationary sampling results.
- The VOCs of potential concern were above background concentrations at only one of the outdoor fields (not the same field in every case), except for toluene and hexane which were above background at two fields.

- Personal monitoring samples showed VOCs were 1.5-to-3-fold greater than background at outdoor fields, except methylene chloride which was 12.8-fold higher.
- Indoor VOCs detections tended to have greater elevations relative to background.
- 2 SVOCs were selected as COPC, benzothiazole (BTZ) and butylated hydroxytoluene (BHT).
- BZT was above background at indoor and outdoor fields; max indoor result was 11.7-fold higher than max outdoor result.
- BHT was detected at all fields and results were higher for stationary monitoring.
- BHT is a COPC for the indoor field.
- A variety of PAHs were detected above background but the concentrations were generally low (well below 1µg/m3).
- Less volatile PAHs were detected in the outdoor field while the more volatile PAHs were found indoors but generally not outdoors
- Lead results were below the 300ppm target set by the CPSC for lead in products intended for children.
- Based upon the findings, outdoor and indoor synthetic turf fields are not associated with elevated adverse health risks.

Study Limitations:
- Small number of fields in the study.
- Only one indoor field was included in the study.
- Some limitations in weather variables when taking samples at outdoor fields.
- Small number of samples taken per field.
- The study did not attempt to measure latex antigen in the crumb rubber or in the PM10 collected from on field air samples.
- Some VOC detections in the personal monitoring may have originated in the device. **Artificial Turf Football Fields: Environmental and Mutagenicity Assessment**

T. Schiliro, D. Traversi, R. Degan, C. Pignata, L. Alessandria, D. Scozia, R. Bono, G. Gilli; *Archives of Environmental Contamination and Toxicology*; **2013**.

The purpose of the study is to develop an environmental analysis drawing a comparison between artificial turf football fields and urban areas relative to concentrations of particles (PM10 and PM2.5) and PAHs, BTEX, and mutagenicity of organic extracts from PM10 and PM2.5.

Methods:
- 24 Air samples were taken from 6 football fields (5 were artificial turf) and 2 urban locations in 2 sampling events to study influence of meteorological and seasonal conditions and the presence of play.
- PM10, PM2.5, BTX (benzene, toluene and Xylene), and PAHs were measured in the air samples.
- The mutagenicity of the organic extracts of the PM and PM2.5 samples were studied using the Ames test.

Study results and/or conclusions:
- Air samples from the artificial turf field had no significant differences from the samples from the urban sites.
- BTX concentrations at the urban site were significantly greater than on the turf fields.
- Seasonal differences were also seen.
- In regards to environmental monitoring, artificial turf fields present no worse exposure risks than those found in the city.
- PAH concentrations, when detected, were low.
- PAH concentrations were greater in the winter than the summer.
- B(a)P was present on the football fields during the winter sampling.
- During the winter season sampling, PAHs, except anthracene, were often present on each football field and at the urban site.
- The mutagenicity showed a seasonal trend and was greater on fields characterized by traffic and/or industrial emissions in the surrounding area.

Study Limitations:
- Urban locations used to compare field results might not be a good overall representation of urban areas in general.
- Non-turf related environmental variables at both the fields and urban areas could be of influence.

11. Artificial-turf playing fields: Contents of metals, PAHs, PCBs, PCDDs and PCDFs, inhalation exposure to PAHs and related preliminary risk assessment

E. Menichini, V. Abate, L. Attias, S. De Luca, A. di Domenico, I. Fochi, G. Forte, N. Iacovella, A. L. Iamiceli, P. Izzo, F. Merli, B. Bocca; *Science of the Total Environment*; **2011**

The purpose of this study was to identify some potential chemical risks and to roughly assess the risk associated with inhalation exposure to PAHs from materials used to make up artificial turf fields.

Methods:

- Rubber granulates were collected from 13 Italian fields. For the 13 fields, samplings were performed at different positions in the playground to obtain a representative sample for each area (see Bocca et al #4).
- Rubber samples varied and included virgin thermoplastic, coated and uncoated recycled tires, recycled vulcanized rubber, and recycled ground gaskets.
- Samples were analyzed for 25 metals and 9 PAHs.
- Air samples were collected on filter at two fields, using static and personal samplers, and at background locations outside the fields.

Study results and/or conclusions:

- High contents of Zn and benzo(a)pyrene were found in the granules present in playing fields (above the Italian standards for soils).
- Other chemicals such as PAHs, VOCs, PCBs, PCDDs and PCDFs were found in the recycled crumb rubber but were at levels within the mentioned limits.
- Based on the 0.4 ng/m3 concentration and using a worst-case conservative approach, an excess lifetime cancer risk of 1×10^{-6} was calculated for an intense 30-year activity (5h/d, 5d/w, all year long).

Study Limitations:

- Only particle phase air samples were taken (TSP or PM10). So the inhalation exposure may be under-estimated for missing information on contaminants in the gaseous phase.
- Inhalation risk assessment was based on limited data and the risk assessment should be regarded as preliminary.
- Fields may vary in age and type of rubber used which could affect the samples and chemicals found in them. Environmental factors such as climate and weather could have an effect on study samples at the time of sampling.

12. Characterization of substances released from crumb rubber material used on artificial turf fields

X. Li, W. Berger, C. Musante, M. I. Mattina; *Chemosphere*; **2010**.

The purpose of the study was to assess major volatilized and leached chemicals from crumb rubber material (CRM); assess the change of alteration of the pattern of volatile compounds with time after installation for both laboratory and field-aged samples under natural weathering conditions.

Methods:

- Vapor offgas and leachate samples from 15 crumb rubber material (CRM) samples were analyzed.
- The CRM samples were obtained from local schools and commercial suppliers.
- 10 organic chemicals (PAHs and VOCs) were measured in the vapor phase over CRM.

Study results and/or conclusions:

- During the vapor phase, CRM emitted volatile PAHs and other compounds.
- Benzothiazole (BTZ) was the most abundant volatile compound found in all the samples.
- Zinc was found to be the highest of all metals found in the samples' extraction fluid.
- There was a significant reduction in volatile compounds found in samples that were from artificial turf fields that were 2 years old compared to newer fields.
- It was also determined that there is some variability in the out-gassing profile of CRM from different manufacturers.

Study Limitations:

- This study provides mostly qualitative, not quantitative results, which makes the results difficult to compare to other studies.

13. Toxicological Assessment of Coated Versus Uncoated Rubber Granulates Obtained from Used Tires for Use in Sports Facilities

J. Gomes, H. Mota, J. Bordado, M. Cadete, G. Sarmento, A. Ribeiro, M. Baiao, J. Fernandes, V. Pampulim, M. Custodio, I. Veloso; *Journal of the Air and Waste Management Association*; **2012**.

The purpose of the study was to investigate whether coating rubber granulates decreased emissions of leachates and airborne substances.

Methods:
- Raw rubber granulates were obtained along with two coatings, a polyvinyl chloride and a cross-linked alquidic polymer, both which contained color additives and a flame-retarding agent.
- The coated rubber granulates were compared with the raw rubber granulates.
- Chemicals analyzed:
    - PM2.5 and PM10
    - PAHs (16; GC-MS)
    - Heavy metals (Cd, Cr, Hg, Pb, Sn, Zn; ICP-OES)

Study results and/or conclusions:
- Rubber granulates obtained cryogenically and semicryogenically have lower inhalable particles than those obtained mechanically
- For PAHs in raw and coated samples, one type of coating resulted in increased content of some PAHs.
- However, the leaching of PAHs from raw, R1 coated or R2 coated is negligible.
- For heavy metals, the concentrations in the leachate is very small and the coating does appear to prevent leaching of the metals.
- Both R1 and R2 coatings showed lower ecotoxicity than the non-coated rubber granulates.

Study Limitations:
- There are only two types of coating included in the analysis.
- It is noted that one of the coatings include polyvinyl chloride which has been excluded from certain textile products due to concerns over potential adverse health effects after human exposure.

14. Evaluating and Regulating Lead in Synthetic Turf

G. Van Ulirsch, K. Gleason, S. Gerstenberger, D. B. Moffett, G. Pulliam, T. Ahmed, and J. Fagliano; *Environmental Health Perspectives*; **2010**

The purpose of the study was to present data showing elevated lead in fibers and turf-derived dust; identify risk assessment uncertainties; recommend that government agencies determine appropriate methodologies for assessing lead in synthetic turf; and recommend an interim standardized approach for sampling, interpreting results, and taking health-protective actions.

Methods:
- This is a commentary on lead in synthetic turf, using data collected from recreational fields and child care centers on lead levels in turf fibers and surface dusts.

Study results and/or conclusions:
- Synthetic turf can deteriorate to form dust containing lead at levels that may pose a risk to children.
- Given elevated lead levels in turf and dust on recreational fields and in child care settings, it is imperative that a consistent, nationwide approach for sampling, assessment, and action be developed.

Study Limitations:
- N/A. This is a commentary.
- Updated guidelines/standards for lead in synthetic turf blades were released after publication of the article.

Biomonitoring Study

1. Hydroxypyrene in urine of football players after playing on artificial sports field with tire crumb infill

J. G. M. Van Rooij, F. J. Jongeneelen; *International Archives of Occupational and Environmental Health*; **2010**.

The purpose of the study was to assess the exposure of football players to PAHs from sporting on synthetic ground with rubber crumb infill (by measuring urinary 1-hydroxypyrene).

Methods:

- All urine samples were collected over 3 days (the days before, of, and after a 2.5-h football match) from 7 football players.
- 1-Hydroxypyrene (PAH biomarker) was measured in urine.

Study results and/or conclusions:

- The football players spent a total of 2.5 hours on the synthetic turf field.
- Three players likely had PAH exposure from pre-sporting activities and were omitted from the analysis.
- Uptake of PAH by football players playing on synthetic turf with rubber crumb infill is minimal.
- If there is any exposure, then the uptake is very limited and within the range of uptake of PAH from environmental sources and diet.

Study Limitations:

- Only 7 football players were in the study. The sample size is too small to represent the target population.
- Short exposure duration (2.5-h) and PAHs from other sources (such as diet) could have affected the player's results.
- Dietary and lifestyle questionnaires were not administered.

Bioavailability Studies

1. **Bio-accessibility and Risk of Exposure to Metals and SVOCs in Artificial Turf Field Fill Materials and Fibers**
B. T. Pavilonis, C. P. Weisel, B. Buckley, P. J. Lioy; *Risk Analysis*; **2014**

The purpose of the study was to determine whether the bio-accessible fraction of metals and SVOCs found in artificial turf fields exceeded non-cancerous risk-based guidance values for children and adult athletes.

Methods:

- New crumb infill (n=9), new turf fiber products (n=8), and field samples (n=7) were collected.
- Using synthetic biofluid solutions, bio-accessibility analyses for metals and SVOCs were performed for the digestive system, respiratory system, and dermal absorption.

Study results and/or conclusions:

- PAHs were generally below the limit of detection in all three artificial biofluids.
- SVOCs found were not present in toxicological databases evaluated and were in everyday consumer products.
- Trace metals found were at minimal levels.

Study Limitations:

- Possible selection bias and the small number of fields used in this study.
- The simulated digestive fluid may not reflect accurately true digestive capabilities in humans.
- A large amount of variability was found among the field samples used in this study (some samples may have been from older fields or different versions/types of artificial turf).

2. **Health Risk Assessment of Lead Ingestion Exposure by Particle Sizes in Crumb Rubber on Artificial Turf Considering Bioavailability**
S. Kim, J. Yang, H. Kim, I. Yeo, D. Shin, Y. Lim; *Environmental Health and Toxicology*; **2012**.

The purpose of the study was to assess the risk of ingestion exposure of lead by particle sizes of crumb rubber in artificial turf filling material with consideration of bioavailability

Methods:

- Lead was measured using ICP-MS in the extracts of tire crumb particles of various size (larger or smaller than 250 um) extracted using artificial digestive and acid extraction methods.
- Average lead exposure amounts were calculated for students.

Study results and/or conclusions:

- Lead was found in the digestion extracts of tire crumb material.
- Acid extraction method resulted in lead concentrations 6.5 times higher than content concentration.
- Digestive extraction resulted in lead concentration 10.3 times higher than content concentration.

- Results of this study confirm that the exposure of lead via ingestion and risk level increases as the particle size of crumb rubber gets smaller.

Study Limitations:

- It appears that only one type of crumb rubber was investigated.
- There is uncertainty as to whether or not the EDPM rubber powder prototype used in the study is representative of the entire artificial turf.

3. **Hazardous chemicals in synthetic turf materials and their bio-accessibility in digestive fluids**
J. Zhang, I. Han, L. Zhang, W. Crain; *Journal of Exposure Science and Environmental Epidemiology*; **2008**.

The purpose of the study was to obtain data that will help assess potential health risks associated with chemical exposure from artificial turf and to determine the bio-accessibility of PAHs and toxic metals in synthetic human saliva, gastric fluid and intestinal fluid.

Methods:

- Seven samples of rubber granules and one sample of artificial grass fiber from synthetic turf fields at different ages of the fields.
- PAHs (15) and metals (Cr, Zn, As, Cd, Pb; ICP-MS) were measured in the granule/grass fiber samples and synthetic digestive fluids (saliva, gastric fluid, intestinal fluid).

Study results and/or conclusions:

- Total PAHs ranged from 4.4ppm to 38.15ppm.
- PAHs in rubber granules had low bio-accessibility (i.e., hardly dissolved) in synthetic saliva, gastric fluid, and intestinal fluid.
- Rubber granules often contained PAHs at levels above health-based soil standards.
- PAH levels declined as the field ages.
- Decay trend may be complicated by adding new rubber granules to compensate for loss of the material.
- Zinc contents were found to far exceed the soil limit, range 5710-9988.
- Lead content was low in all the samples compared to soil standards.
- Lead in the rubber granules was highly bioaccessible in the synthetic gastric fluid.

Study Limitations:

- The digestive system is difficult to simulate, and the simulated digestive fluid may not accurately reflect true digestive capability in humans.

Toxicological Studies

1. **Toxicological Evaluation for the Hazard Assessment of Tire Crumb for Use in Public Playgrounds**
D. A. Birkholz, K. L. Belton, T. L. Guidotti; *Journal of the Air and Waste Management Association*; **2012**.

The purpose of the study was to design a comprehensive hazard assessment to evaluate and address potential human health and environmental concerns associated with the use of tire crumb in playgrounds.

Methods:

- 200g tire crumbs were leached in water to produce the test leachate.
- Genotoxicity was assessed using *Salmonella typhimurium* mutagenicity fluctuation assay, SOS chromotest, and Mutatox.
- Human health concerns were addressed using conventional hazard analyses.

Study results and/or conclusions:

- All samples analyzed did not meet the criteria for genotoxicity and were considered negative.
- Genotoxicity testing of tire crumb samples following solvent extraction concluded that no DNA or chromosome-damaging chemicals were present.
- This suggests that ingestion of small amounts of tire crumb by small children will not result in an unacceptable hazard/risk for development of cancer.
- The use of tire crumb in playgrounds results in minimal hazard to children and the receiving environment.

Study Limitations:

- The authors of this study concentrated only on potential genotoxicity from the exposure to tire crumb material in playgrounds, other adverse health effects that may be caused by other elements/compounds in the tire crumbs may have been overlooked.

2. **Benzothiazole toxicity assessment in support of synthetic turf field human health risk assessment**

G. Ginsberg, B. Toal, T. Kurland; Journal *of Toxicology and Environmental Health, Part A*; **2011**.

The purpose of the study was to assess benzothiazole (BZT) toxicity in support of a risk assessment of synthetic turf fields conducted by the Connecticut Department of Public Health.

Methods:

- The study reviewed the following information on BZT and its surrogate, 2-mercaptobenzothiazole (2MBZT), to derive BZT toxicity values for cancer and non-cancer effects:
    - properties and uses
    - BZT exposure
    - toxicokinetics of BZT and 2MBZT
    - toxicity of BZT and 2MBZT with regard to acute toxicity, mutagenicity, subchronic and chronic toxicity and cancer, developmental and reproductive effects

Study results and/or conclusions:

- The following BZT toxicity values were derived:
    - Acute air target of 110 µg/m3 based upon a BZT RD50 study in mice relative to results for formaldehyde.
    - A chronic, noncancer target of 18 µg/m3 based upon the no observed adverse effect level (NOAEL) in a subchronic dietary study in rats, dose route extrapolation, and uncertainty factors that combine to 1000.
    - A cancer unit risk of 1.8E-07/µg-m3 based upon a published oral slope factor for 2-MBZT and dose-route extrapolation.

Study Limitations:

- There were numerous uncertainties and limited information in the BZT toxicology database.
- BZT was not tested in sub-chronic/ chronic studies, cancer bioassay, or developmental and reproductive studies.
- Some endpoints were studied using 2-MBZT as a surrogate, which makes an imperfect comparison due to differences in structure and metabolic pathways.
- Only a screening-level assessment for BZT exposure.
- The proposed toxicity values are for BZT in general, not specifically for BZT in synthetic turf.

3. **Evaluating the Risk to Aquatic Ecosystems Posed by Leachate from Tire Shred Fill in Roads Using Toxicity Tests, Toxicity Identification Evaluations, and Groundwater Modeling**

P.J. Sheehan, J.M. Warmerdam, S. Ogle, D. Humphrey, S. Patenaude; *Environmental Toxicology and Chemistry;* **2006**.

The purpose of the study was to evaluate the toxicity of leachates from tire shreds used as roadbed fill and to define the circumstances under which use of the tire shreds as roadbed fill, both above and below the water table, will pose a negligible hazard to adjacent surface-water ecosystems.

Methods:

- Shred infill obtained from two study sites, one above the water table and one at and below the water table. For this infill, tire shreds contain a mixture of steel and glass belted scrap tires and substantial amounts of steel belts are exposed at the cut edges.
- Site #1 constructed in 1993 with 3 sample collection areas with precipitation infiltrating the road embankment and into collection basins for sampling. There was one "control" basin without a tire shred layer.
- Site #2 was constructed in 1994 and tire shreds come into direct contact with groundwater. Water samples were collected from 3 wells: 1 upgradient, 1 within the trench with direct contact to tire shreds and 1 downgradient.
- Leachates analyzed for metals, VOCs, and SVOCs.
- Short-term chronic *C. dubia* test and short-term chronic fathead minnow test used to determine toxicity.

Study results and/or conclusions:

- Site #1:
    - No adverse effects on *P. promelas* survival or growth

- Substantial reduction in C. dubia survival in phase 2 of the reference water likely due to high conductivity of the leachate sample.
- Metals, VOCs and SVOCs were detected in two samples but the concentrations were low and not indicative of leaching substantial amounts of chemicals.

- Site #2:
  - Slight reductions in P. promelas survival in both phase 1 and 2 of the reference sample.
  - No impairment in survival seen in the two samples (at and down gradient).
  - Significant reductions in growth seen for both the reference sample and the other two site samples.
  - For *C. dubia*, > 80% mortality was seen in the leachate samples (phase 1); significant reductions in reproduction also seen but reductions in reproduction were also seen in the reference samples.
  - Elevated levels of some VOCs and metals (especially iron and manganese) indicated chemicals leach from shred fill; however, the leaching of iron is likely from the steel belts exposed on the cut edge.

Study Limitations:

- The type of infill used in road beds is quite different from the crumb rubber infill used in synthetic turf.
- The modeling estimates used numerous different scenarios to determine amount of filtration needed which is not applicable to studies investigating human exposure to chemicals synthetic turf.

4. Impact of tire debris on in vitro and in vivo systems

M. Gualteri, M. Andrioletti, P. Mantecca, C. Vismara, M. Camatini; *Particle and Fibre Toxicology*; **2005**.

The purpose of the study was to investigate tire debris effects on the development of *X. laevis* and on human cell lines.

Methods:

- Tire debris samples were obtained from laboratory processing using tire scrap materials.
- Eluates were obtained after soaking in water (pH 3); organic extracts obtained and used for the cell line test (A549) and the tests using *X. laevis* embryos
- Cell viability assay and Comet assay were used to determine toxicity, doses 10, 50, 60, 75 µg/mL
- in vivo: *X. laevis* embryos were exposed to 50,80,100, 120 µg/mL organic extracts

Study results and/or conclusions:

- A time-dependent increase of Zn in the human liver cell line was seen after treatment with 50µg/ml zinc at 2, 4, and 24 hours.
- An increase in cell death was seen at the higher doses (50, 60, 75 µg/ml) compared to controls.
- Cell proliferation was decreased in a time and dose-dependent manner.
- DNA damage increased at 50 and 60µg/mL as shown by the comet assay.
- Cell morphology was impacted after 72 hours treatment. The highest dose showed visible vacuolization in the cytoplasm and apoptotic nuclear images; present in 50% of cells at 72 hours with 75µg/ml treatment.
- Zn concentration of 44.73µg/ml (50 g/l tire debris) resulted in 80% mortality of embryos and a concentration of 35.28µg/ml (100 g/L tire debris) resulted in 26.8% mortality. Malformation was similar between the two doses. Dilutions of the organic extracts showed significant increases at 1% for 44.73 and at 10% for 35.28.
- The eluates had teratogenic effects for both doses.
- For *X. laevis* development, 80µg/ml and above resulted in significant mortality with 15.9% mortality at 120µg/mL.
- Increase in malformed larvae found at 80 and 100µg/mL; at 120 µg/mL, 37.8% of larvae were malformed.
- Most frequent malformation was gut roiling.

Study Limitations:

- The type of sample used in the analysis (tire debris) is not the same type of tire material as seen in crumb rubber infill.
- The analysis only looked at zinc and did not include other known contaminants of tire crumb/tire debris.
- No indication if the doses used in the laboratory analysis are similar to doses/exposure levels in the environment.

Appendix B - Literature review of microbial work done on tire crumb rubber artificial fields

Overall summary:
Most of the work in tire crumb rubber use in synthetic turf fields has focused on chemicals such as polycyclic aromatic hydrocarbons (PAH), metals, volatile organic carbons (VOCs), polychlorinated biphenyls (PCBs), or ecotoxicity work using sensitive bioindicators such as Pseudokirchneriella subcapitata and Daphnia magna. There is a very limited amount of literature on health risks from biological material (i.e., human pathogens) in tire crumb rubber artificial fields. Of the literature that does exist, most studies have been conducted by academia, or published in open access journals, or by state government/environmental groups, and thus have not undergone thorough peer review and therefore may show inherent bias. Regardless, most work has focused on quantifying total bacteria using non-selective agar, reporting colony forming units per gram (CFU/g) of infill material. Additional work has been done on the ability of opportunistic human pathogens (methicillin-resistant staphylococcus aureus (MRSA) and Burkholderia cepacia complex) to survive in tire crumb rubber leachate, including toxicity to these bacteria due to chemicals such as zinc. There has been no work published on enteric pathogens/risks from artificial turf fields.

1) Keller, Marcus. "The fate of methicillin-resistant staphylococcus aureus in a synthetic field turf system." (2013).
This study looked the survivability of methicillin-resistant staphylococcus aureus (MRSA) on turf infill (rubber, sand, organic, or polymer materials), and turf fibers (monofilament, slit-film or nylon turf blades), and the toxicity of infill materials to MRSA. MRSA was measured as the incubation time in which 50% of the inoculated MRSA are still viable (A50). MRSA persisted longer in infill (A50 = 13hr) vs turf fibers (A50 = 4hr, $p<0.05$). A50 for crumb rubber was 13hr. The role of infill toxicity to the MRSA A50 was assessed using a dialysis assay, which showed that 94% of MRSA cells remained viable following 6 h of exposure to organic infill, 91% for sands, 79% for polymer coated materials, 71% for crumb rubber, 68% for TPE rubber, and 17% for EPDM rubber.
Conclusion: MRSA survived less in crumb rubber materials than other fill materials such as sand/organic.

2) Miller, Suzanne CM, John J. LiPuma, and Jennifer L. Parke. "Culture-based and non-growth-dependent detection of the Burkholderia cepacia complex in soil environments." Applied and environmental microbiology 68.8 (2002): 3750-3758.
This study looked at Burkholderia cepacia complex (Bcc) – an opportunistic human pathogen, in a variety of soils and other surfaces, including turf athletic fields from 3 US cities (Philadelphia, Cleveland, Portland, OR). Bcc was not isolated from any turf samples (n=6).
Conclusion: using PCR, Bcc appears to be prevalent in soil from urban and suburban sites.

3) A Survey of Microbial Populations in Infilled Synthetic Turf Fields. McNitt, Andrew, and Petrunak, Dianne. A Draft Report by Faculty of the Center for Turfgrass Science at Penn State University. 2006.
Took samples from a couple of fields in PA, both crumb rubber and soil, specifically looking for MRSA and non-selective cultural bacteria on R2A agar over a 2-week period in 2006. Total number of samples not provided. Sampled areas included a "high use" and "low use" area of each field taking approx. 2-3mL sample of the crumb rubber, and cut fibers from synthetic fields. No samples were S. aureus positive via selective media, gram stain or latex agglutination tests. Of the 8 fields that were tested with crumb rubber only, total culturable bacteria from R2A agar averaged 3.97log10 CFU per gram of crumb rubber. Soil (silty loam and sand-based soil) samples (n=2) averaged 5.4log10 CFU/g soil. S. aureus was positively identified from other public areas and/or athletic facilities such as blocking pads, weight equipment, stretching tables, and used towels.
Conclusion: lower counts of microbes were found indoors as opposed to outdoors, and soil fields had over an order of magnitude more microbes than synthetic crumb-rubber fields.

4) Safety Study of Artificial Turf Containing Crumb Rubber Infill Made From Recycled Tires: Measurements of Chemicals and Particulates in the Air, Bacteria in the Turf, and Skin Abrasions Caused by Contact with the Surface. Report produced under contract by: Office of Environmental Health Hazard Assessment. Pesticide and Environmental Toxicology Branch. California Department of Resources Recycling and Recovery. 2010.

Chapter 3: Sampled 5 artificial turf (soccer) fields with crumb rubber mixed with sand and 2 natural fields in San Francisco, CA in September or October 2009 (all outdoor). 1-2g of material was sampled per event, and each field was sampled 3 times in various areas. The three most prominent species assay was used to quantify culturable bacteria in samples (agar not provided). Artificial turf (n=30) ranged from 0-50,000 CFU per gram crumb rubber compared to 637,000-305,000,000 CFU/g natural soil (n=12). 2/12 and 6/12 samples were positive for Staphylococci in crumb rubber and soil, respectively. No MRSA was detected in crumb rubber or synthetic blades of grass; one sample (n=12) was positive for MRSA from a blade from natural turf.
Conclusion: Synthetic turfs, including crumb rubber, harbor fewer bacteria than soil, which, according to authors, could be due to lower moisture content and high temperatures of artificial turf compared to natural turf.

Chapter 4: using a survey of 33 trainers from collegiate athletic programs in CA and NV, it was reported that athletes experienced ~2-3 times higher turf burn ratios compared to natural soil, but the severity of turf burns between soil and synthetic turfs remained similar.

5) Crampton, Mollee, et al. "Effects of leachate from crumb rubber and zinc in green roofs on the survival, growth, and resistance characteristics of Salmonella enterica subsp. enterica serovar typhimurium." Applied and environmental microbiology 80.9 (2014): 2804-2810.

This study investigated the impact of rainwater leachate from crumb rubber in green roofs on the growth of Salmonella enterica subsp. enterica serovar Typhimurium ATCC 14208S. S. Typhimurium was incubated for up to 48hr in crumb rubber leachate from synthetic rainwater (pH=4.3). When compared to a control of just synthetic rainwater incubation over the same time period, S. Typhimurium survived less in crumb rubber leachate than the control, leading the authors to suggest that crumb rubber contains compounds that are inhibitory to bacterial growth. Dilutions of the crumb rubber leachate showed increased survivability of the bacteria, supporting the idea that crumb rubber contains compounds that are toxic to S. Typhimurium. The same crumb rubber extract was washed 10 separate times with 10mL of synthetic rainwater. The leachate exhibited the same effects on microbial growth, with the authors concluding that the toxic effects that crumb rubber are not expected to decrease with time and additional rainfall/washing events.
Conclusion: crumb rubber leachate contains compounds that inhibit microbial growth and survivability.

6) Bass, Jason J., and David W. Hintze. "Determination of Microbial Populations in a Synthetic Turf System." Skyline-The Big Sky Undergraduate Journal 1.1 (2013): 1. – Open access journal

This study took samples from 2 infilled crumb rubber fields, one 1-year old field and one 6-year old field over a 14-week period in late fall/early winter in Ogden, Utah. Indoors/outdoors field information was not provided. Tryptic Soy Agar was used to determine total microbial load, Mannitol Salt Agar for Staphylococcus, and Eosin Methylene Blue Agar to count the number of enteric organisms such as Escherichia coli. Bacterial counts in the older field were up to 10,000 times higher than the newer field. Bacterial counts were highest on the sideline of the older field with average of 1.1x108 CFU/g soil infill compared to 2.5x105 CFU/g on the sideline of the newer field. A higher number of salt-tolerant organisms were able to grow on MSA, indicating possible staphylococci, with an average of 2.77x102 CFUs per gram on the new field and 6.58x103 CFUs per gram on the older field.
Conclusion: bacterial populations are much higher in older fields and newer fields, and the sideline near the 50-yd line contained the highest bacterial populations. This data suggests that microbial populations can accumulate from year to year in synthetic turf.

Below is less related to micro-related work, but focused on ecotoxicity of turf field leachates

7) Krüger, O., et al. "New approach to the ecotoxicological risk assessment of artificial outdoor sporting grounds." Environmental Pollution 175 (2013): 69-74.

Kruger et al., 2013 investigated growth inhibition (Pseudokirchneriella subcapitata) and acute toxicity tests (Daphnia magna) with leachates obtained from batch tests of granular infill material and column tests of complete sporting ground assemblies. Ethylene propylene diene monomer rubber (EPDM) leachate showed the highest effect on Daphnia magna (EC50 < 0.4% leachate) and the leachate of scrap tires made of styrene butadiene rubber (SBR) had the highest effect on P. subcapitata (EC10 ¼ 4.2% leachate; EC50 ¼ 15.6% leachate). No correlations between ecotoxicity of leachates and zinc or polycyclic aromatic hydrocarbons (PAH) was found.

Appendix C - EPA-NCEA Summary of Available Exposure and Health Risk Assessment Studies on Artificial Turf, Playgrounds and Tire Crumbs

Summary of Available Exposure and Health Risk Assessment Studies on Artificial Turf, Playgrounds and Tire Crumbs

Bulleted Summary

- Artificial turf is made of plastic blades that simulate grass and a layer of "infill" material made of recycled tire crumb or crumb rubber.
- There are benefits to using these materials, but concerns have been raised by the public and others regarding health issues associated with their use.
- EPA formed a workgroup in 2008; performed a scoping study and published a report in 2009.
- There are several studies found in the literature conducted by federal and state governments, academia, and industry.
- The studies varied in scope ranging from studies focused on environmental concentrations found in air; concentrations of the chemicals found in the bulk material; and health risk assessments. Some studies focused the inhalation pathway, while others considered other pathways including ingestion and dermal exposures. Chemicals studied included VOCs, SVOCs, PM_{10}, and metals. Other studies examine the potential for environmental impacts, including leaching of metal into waterways.
- Federal and state government studies include:
  - Norwegian Institute of Public Health (2006) "Artificial turf pitches – an assessment of the health risks for football players"
  - OEHHA 2007 "Evaluation of Health Effects of Recycled Waste Tires in Playground and Track Products"
  - CPSC 2008 "CPSC Staff Analysis and Assessment of Synthetic Turf Grass Blades"
  - New Jersey Department of Health and Senior Services (April 2008) "New Jersey Investigation of Artificial Turf and Human Health Concerns; Fact Sheet"
  - New York Department of Health (2008) "A Review of the Potential Health and Safety Risks From Synthetic Turf Fields Containing Crumb Rubber Infill"
  - New York City Department of Health and Mental Hygiene (March 2009) "Air Quality Survey of Synthetic Turf Fields Containing Crumb Rubber Infill"
  - New York State Department of Environmental Conservation (May 2009) "An Assessment of Chemical Leaching, Releases to Air, and Temperature at Crumb-Rubber Infilled Synthetic Turf Fields
  - EPA (2009) "A Scoping-Level Field Monitoring Study of Synthetic Turf Fields and Playgrounds"
  - Connecticut Department of Health (2010) "Human Health Risk Assessment of Artificial Turf Fields Based Upon Results from Five Fields in Connecticut"
  - New Jersey Department of Environmental Protection (July 2011) "An Evaluation of Potential Exposures to Lead and Other Metals as the Result of Aerosolized Particulate Matter from Artificial Turf Playing Fields"
- These studies concluded that there is no or limited health risk associated with the use of these materials. However, the studies were limited in scope and not all of them carried out a complete exposure/risk assessment. There are uncertainties associated with the assumptions used to derive these conclusions.
- Some potential future activities can be undertaken including: reviewing additional reports and scientific literature; examining the available data more closely; reviewing exposure assumptions; determine if an exposure/risk assessment can be conducted with the available data; studying other factors that may influence exposure; identify key data gaps; and assess the potential for microbiological exposures.

Background

Artificial turf is made of plastic blades that simulate grass and a layer of "infill" material to keep the blades upright. This "infill" is made of recycled "tire crumb" or "crumb rubber" material. This artificial or synthetic turf is often used to cover the surfaces of athletic field. Tire crumbs and crumb rubber are also used as groundcover under playground equipment, running track material, and as a soil additive on sports and playing fields. Although use of these materials has been recognized as beneficial (e.g., recycling, reduction of sports injuries), concerns have been raised by the public and others regarding health issues associated with these materials.

In 2005, EPA Region 8 Pediatric Environmental Health Specialty Unit (PEHSU) received telephone inquiries from parents concerned about health risks to children exposed to a recycled tire crumb product used in fields and school playgrounds. EPA Region 8 requested that the Agency consider this issue and a workgroup was formed and charged to consider the state of science and make recommendations for future research. A second science workgroup was formed to consider available methods to study the situation, and they recommended conducting a scoping study to assess approaches and methods, and to provide limited measurement data for consideration. The workgroup produced a report entitled "Scoping-level Field Monitoring Study of Synthetic Turf Fields and Playgrounds" published in 2009.

Over the years, there have been several published articles on the health concerns resulting from exposures to the materials used in artificial turf. In October of 2014, a soccer coach reportedly suggested an association between cancer cases found in soccer players and exposures to artificial turf. A list of 38 American soccer players (34 of them goalies) had been diagnosed with cancer (http://www.nbcnews.com/news/investigations/how-safe-artificial-turf-your-child-plays-n220166). In response to the news report, a representative from FieldTurf, an artificial field turf company, requested a meeting with EPA to present their views with regard to the safety of turf fields. A conference call was hosted by Michael Firestone of OCHP. FieldTurf stated that scientific research from academia, federal and state governments has failed to find any link between synthetic turf and cancer. More recently, in March 16, 2015, another news article in claimed that the federal government is promoting artificial turf despite health concerns (http://www.usatoday.com/story/news/2015/03/15/artificial-turf-health-safety-studies/24727111/).

Several studies have been conducted on artificial turf and the use of tire crumb materials. Some focused primarily on obtaining concentration data for various compounds that may off-gas from recycled tire materials, while others attempted to estimate health risks associated with their use. There are also several studies that focus on characterizing the compounds contained in bulk samples of artificial turf. Summarized below are the studies conducted by EPA, CPSC, and the states of New York, Connecticut, and California. Included also is a study conducted in Norway. It is important to note that this list is not comprehensive and focuses primarily on studies conducted by federal and state governments.

Norwegian Institute of Public Health (NIPH) and the Radium Hospital 2006

NIPH conducted a health risk assessment of football players that played in artificial turf fields. They examined 9 scenarios including: inhalation, dermal, and ingestion exposures (only for children) for adults, juniors, older children and children. The assessment included various constituents in the tire crumb: VOCs, PAHs, phthalates, PCBs, PM_{10}, and alkyl phenols. The study was limited because of the absence of toxicity data. The study concluded that the use of artificial turf does not cause any elevated health risk. The estimated Margins of Safety (MOS) were no cause for concern.
http://www.isss.de/conferences/Dresden%202006/Technical/FHI%20Engelsk.pdf

OEHHA California study 2007

Office of Environmental Health Hazard Assessment (OEHHA) conducted a risk assessment of the recycled waste tires in playgrounds and track products in 2007. Their study included VOCs, SVOCs and metals. The pathways included in the risk assessment were the ingestion of the tire crumbs via hand to mouth or surface to mouth and dermal contact. They concluded that risk levels were below the *di minim*is level of 1×10^{-6}.
http://www.calrecycle.ca.gov/publications/Documents/Tires%5C62206013.pdf

CPSC 2008

The U.S. Consumer Product Safety Commission investigated the potential hazards from lead in some artificial turf sports fields across the country. The study focused on ingestion of lead from the material that transfers to the mouth from the skin after contact with the lead containing turf. The study concluded that exposure to children playing on the field would not exceed 15 µg of lead/day.
http://www.cpsc.gov//PageFiles/104716/turfassessment.pdf

New Jersey Department of Health and Senior Services 2008

NJDHSS collected samples of artificial turf fibers from 12 fields. Ten fields with polyethylene fibers had very low Pb levels. Two fields with nylon fibers had 3,400 to 4,100 mg/kg of Pb. In addition, they collected artificial turf samples from consumer products that are used for residential lawns and play surfaces. Two of the products that were nylon or nylon/polyethylene contained Pb at 4,700 and 3,500 mg/Kg. These concentrations higher than the Residential Direct Contact Soil Cleanup Criteria (which is 400 mg/kg). "There is a need for a comprehensive and coordinated approach to evaluating the public health risks and benefits of artificial turf fields." http://www.nj.gov/dep/dsr/publications/artificial-turf-report.pdf

New York Department of Health Study 2008

In 2008, the NY Department of Health conducted a study where they reviewed data from 11 different risk assessments found in the literature on exposures to artificial turf and concluded that the levels found of the contaminants of concern did not result in an increased risk for human health effects as a result of ingestion, dermal or inhalation exposure to crumb rubber. They stated, however, that additional air studies at synthetic turf fields as well as background air measurements would

provide more representative data for characterizing potential exposures related to synthetic field use in NYC, particularly among children.
http://www.nyc.gov/html/doh/downloads/pdf/eode/turf_report_05-08.pdf

New York City Department of Health and Mental Hygiene March 2009
NYCDHMH conducted field sampling for VOCs, SVOCs, metals, particulate matter (PM2.5) in two synthetic fields, one grass field. They used stationary samplers on field during simulate playing conditions. The sampling was conducted during the summer under simulated playing conditions. Eight of the 69 VOC were detected, but concentrations were similar between upwind background and turf fields. None of the SVOCs were detected, including benzothiozole a "chemical marker" for synthetic rubber. Two of 10 metals were detected, but similar concentrations were found in upwind and grass field. PM was within background levels upwind and at grass field. The report concluded that air in the breathing zones of children above synthetic turf fields did not show appreciable levels from contaminants of potential concern contained in the crumb rubber and that a risk assessment from exposure through the inhalation route was not warranted.
http://www.nyc.gov/html/doh/downloads/pdf/eode/turf_aqs_report0409.pdf

New York State Department of Environmental Conservation May 2009
In 2008, NYDEC conducted a laboratory evaluation of four types of tire-derived crumb rubber to assess the release of chemicals using the simulated precipitation leaching procedure. Results indicated that zinc, aniline, phenol, and benzothiazole can potentially be release to ground water. Zinc, aniline, phenol were all below standards; there are no standards for benzothiazole. Lead concentration in the crumb rubber was below federal hazard standard for soil. Risk assessment for aquatic life indicated that zinc may be a problem for aquatic life. Air samples were collected above fields at two locations. Many of the analytes detected (e.g., benzene, 1,2,4-trimethylbenzene, ethyl benzene, carbon tetrachloride) are commonly found in an urban environment. A number of analytes found were detected at low concentrations (e.g., 4-methyl-2-pentanone, benzothiazole, alkane chains. Public health evaluation at the two fields tested concluded measured air levels do not raise a concern for non-cancer or cancer human health Indicators. PM concentrations were not different from concentrations upwind from the fields. http://www.dec.ny.gov/docs/materials_minerals_pdf/crumbrubfr.pdf

EPA 2009
The overall objectives of EPA's study were to evaluate the methodology and protocols for monitoring and analyzing data needed to characterize the contribution of tire crumb constituents to environmental concentrations and to collect limited environmental data from playgrounds and synthetic turf fields. EPA analyzed air samples for 56 volatile organic compounds (VOCs), air particulate matter (PM_{10}) for selected metals and the relative contribution of tire crumb particles to the overall particle mass, wet surface wipe samples for metals including Pb, Cr, Zn, and others, and turf field tire crumb infill granules, turf blades, and playground tire crumb materials for metals. The study protocol was implemented at two synthetic turf fields and one playground. Conclusions: "On average, concentrations of components monitored in the study were below levels of concern." Concentrations for many of the analytes were close to background levels. Due to the limitations of the study, the authors concluded that "it is not possible to reach any more comprehensive conclusions without the consideration of additional data." The study did not evaluate semivolatile organic compounds such as PAHs because of resource limitations. No exposure or risk assessment was conducted by EPA. Potential exposure pathways include: ingestion of loose tire crumbs via hand to mouth or surface to mouth; dermal contact; and inhalation exposures of VOCs and PM_{10}.
http://www.epa.gov/nerl/features/tire_crumbs.html

Connecticut Department of Public Health study 2010
Connecticut Department of Public Health conducted a human health risk assessment of artificial turf in 2010. They collected data from one indoor and four outdoor artificial turf fields. The study focused on two pathways, inhalation of offgassed and particle-bound chemicals. The study included 27 chemicals (VOCs, SVOCs, lead and PM_{10}). Using conservative assumptions, Connecticut Department of Public Health Program found that cancer risks are slightly above *de minimis* in all scenarios, and two fold higher at the indoor field compared to outdoors and being higher for children than adults. The non-cancer risk estimate is below unity for all analytes in all scenarios.
http://www.ct.gov/deep/lib/deep/artificialturf/dph_artificial_turf_report.pdf

New Jersey Department of Environmental Protection 2011
In 2009, NJDEP tested 5 artificial turf fields. They tested for PM and metals including Pb using wipe samples as well as stationary sampling and mobile robot sampling. In addition, a 12 year old boy was recruited to simultaneously collect a personal breathing zone sample. The age of the fields ranged between 1 and 8 years. The testing was done during the summer time. No levels exceeded guidance or NAAQS values; robot air Pb value on one field was 71 ng/m^3 (approx 50% of NAAQS), remainder below 10 ng/m^3

Potential Future Activities

- Review additional reports and scientific literature that may provide information on the chemical constituents in artificial turf, and their bioavailability and toxicity, exposure pathways and factors, and potential human health risks.
- Examine more closely all the available data, especially for indoor fields where inhalation exposures may be higher.
- Determine if sufficient data exist to conduct an exposure/risk assessment with the available data. Given the uncertainties with some of the exposure factors assumptions (e.g., amount of material ingested, exposure frequency), several "what if" scenarios can be developed to determine for example the amount of material that would need to be ingested to exceed some health level. If an assessment cannot be done, identify key data gaps.
- Examine the exposure factor assumptions used by the studies in the literature to evaluate their "reasonableness."
- Study other factors that may influence exposure levels; for example; the age of the fields, uncertainties about the amount of material that can be inadvertently ingested, potential for dermal exposures, and exposure frequency and duration.
- Examine the literature for microbiological exposures and risks from exposures to the materials in these fields and playgrounds.

Other Potentially Useful Sources (not yet reviewed; not based on a comprehensive search)

Reports

CDEP (2010) (Connecticut Department of Environmental Protection). Artificial Turf Study: leachate and stormwater characteristics. http://www.ct.gov/deep/lib/deep/artificialturf/dep_artificial_turf_report.pdf

EHHI (2007) (Environment and Human Health, Inc.). Artificial Turf: exposures to ground-up rubber tires. http://www.ehhi.org/reports/turf/turf_report07.pdf

FDEP (1999) (Florida Department of Environmental Protection) Study of the suitability of ground rubber tire as a parking lot surface. http://www.dep.state.fl.us/waste/quick_topics/publications/shw/tires/FCCJstudy.pdf

NYDEC (2008) (New York Department of Environmental Conservation) A study to assess potential environmental impacts from the use of crumb runner as infill material in synthetic turf fields. http://www.dec.ny.gov/docs/materials_minerals_pdf/tirestudy.pdf

News, Websites, and Fact Sheets

CDEP (2010) (Connecticut Department of Environmental Protection). Recent news concerning artificial turf fields. http://www.fieldturf.com/sites/fieldturf/assets/Circular%20Ltr%202015-02%20Connecticut%20Reaffirms%20Safety%20of%20Artificial%20Turf.pdf

CPSC. CPSC Staff1 Analysis and Assessment of Synthetic Turf "Grass Blades" http://www.cpsc.gov//PageFiles/104716/turfassessment.pdf

CPSC (2008) Press release: CPSC Staff Finds Synthetic Turf Fields OK to Install, OK to Play On.

European Tyre and Rubber Association (2008) Rubber infilled artificial turf environmental and health risk assessment. http://tools.etrma.org/public/Pdf%20from%20July/PR/20080305_ETRMA_-_Synthesis_on_synthetic_turf_studies_-_final.pdf

PEER.org. (2013) EPA retracts synthetic turf safety assurances. http://www.peer.org/news/news-release/2013/12/23/epa-retracts-synthetic-turf-safety-assurances

Soccer America (2015) Are tire crumbs on fields a cancer threat? http://www.socceramerica.com/article/62922/are-tire-crumbs-on-fields-a-cancer-threat.html

USA Today (2014) Ground up tires give new meaning to synthetic turf. January 9, 2014. http://www.usatoday.com/story/sports/nfl/2014/01/09/ground-up-tires-synthetic-turf-metlifestadium/4395673/

USA Today (2015) Fed promote artificial turf as safe despite health concerns. March 17, 2015. http://www.usatoday.com/story/news/2015/03/15/artificial-turf-health-safety-studies/24727111/

US Army. Guidance on Lead in Artificial Turf Including Child Care Centers. http://phc.amedd.army.mil/PHC%20Resource%20Library/LeadArtificialTurfw-child%20care%20centers%20Mar%2010.pdf
US EPA. Health and Environmental Concerns: Common wastes and materials: Playgrounds and synthetic turf fields. http://www.epa.gov/solidwaste/conserve/materials/tires/health.htm

Scientific papers

Birkholz, DA; Belton, KL; Guidotti, TL (2003) Toxicological evaluation for the hazard assessment of tire crumb for use in public playgrounds. J Air & Waste Manage Assoc 53:903-907. http://www.tandfonline.com/doi/pdf/10.1080/10473289.2003.10466221

Bocca, B; Forte, G; Petrucci, F; Costantini, S; Izzo, P (2009) Metals contained and leached from rubber granulates used in synthetic turf areas. Sci Total Environ 407:2183-2189. http://ac.els-cdn.com/S0048969708012904/1-s2.0-S0048969708012904-main.pdf?_tid=70225ce6-cf0b-11e4-91f5-00000aab0f01&acdnat=1426861056_50bfc390c1da7ac3d8644667757ce9d2

Cheng, H; Hu, Y; Reinhard, M (2014) Environmental and health impacts of artificial turf: a review. Environ Sci Technol 48(4): 2114-2129. http://pubs.acs.org/doi/pdf/10.1021/es4044193

Claudio, L (2008) Synthetic turf: health debate takes root. Environ Health Persp 116(3): A116-A122. http://www.ncbi.nlm.nih.gov/pmc/articles/PMC2265067/pdf/ehp0116-a00116.pdf

Ginsberg, G; Toal, B; Simcox, N; Bracker, A; Golembiewski, B; Kurland, T; Hedman, C (2011a) Human Health Risk Assessment of Synthetic Turf Fields Based Upon Investigation of Five
Fields in Connecticut, Journal of Toxicology and Environmental Health, Part A: Current Issues, 74:17, 1150-1174, DOI:10.1080/15287394.2011.586942; http://dx.doi.org/10.1080/15287394.2011.586942

Ginsberg, G; Toal, B; Kurland, T (2011b) Benzothiazole Toxicity Assessment in Support of Synthetic Turf Field Human Health Risk Assessment, Journal of Toxicology and Environmental Health, Part A: Current Issues, 74:17, 1175-1183, DOI: 10.1080/15287394.2011.586943; http://dx.doi.org/10.1080/15287394.2011.586943

Kim, S; Yang, J; Kim, H; Yeo, Y; Shin, D; Lim, Y (2005) Health Risk Assessment of Lead Ingestion Exposure by Particle Sizes in Crumb Rubber on Artificial Turf Considering Bioavailability. Environmental Health and Toxicology, Volume: 27, Article ID: e2012005: 10 pages http://dx.doi.org/10.5620/eht.2012.27.e2012005 eISSN 2233-6567 http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3278598/pdf/eht-27-e2012005.pdf

Li, X; Berger, W; Musante, C; Incorvia Mattina, MJ (2010) Characterization of substances released from crumb rubber material used on artificial turf fields. Chemosphere 80: 279-285.

Menichini, E; Abate, V; Attias, L; De Luca, S; di Domenico, A; Fochi, I; Forte, G; Iacovella, N; Iamiceli, L; Izzo, P; Merli, F; Bocca, B (2011) Artificial-turf playing fields: Contents of metals, PAHs, PCBs, PCDDs and PCDFs, inhalation exposure to PAHs and related preliminary risk assessment. Sci Total Environ 409(23):4950-4957. http://ac.els-cdn.com/S0048969711007601/1-s2.0-S0048969711007601-main.pdf?_tid=1b9c79f6-cf09-11e4-a4eb-00000aab0f6c&acdnat=1426860055_3ac179a31ccd83f208b1390edfd80c15

Pavilonis, BT; Weisel, CP; Buckley, B; Lioy, PJ (2014) Bio-accessibility and Risk of Exposure to Metals and SVOCs in Artificial Turf Field Fill Materials and Fibers. Risk Analysis. http://www.ncbi.nlm.nih.gov/pmc/articles/PMC4038666/pdf/nihms565643.pdf

Schiliro, T; Traversi, D; Degan, R; Pignata, C; Alessandria, L; Scozia, D; Bono, R.; Gilli, G(2012) Artificial turf football fields: environmental and mutagenicity assessment. Arch Environ Contam Toxicol. 64(1):1-11. doi: 10.1007/s00244-012-9792-1. Epub 2012 Sep 25 http://www.ncbi.nlm.nih.gov/pubmed/23007896

Simcox, NJ; Bracker, A; Ginsberg, G; Toal, B; Golembiewski, B; Kurland, T; Hedman, C (2011) Synthetic Turf Field Investigation in Connecticut, Journal of Toxicology and Environmental Health, Part A: 74:17, 1133-1149, DOI: 10.1080/15287394.2011.586941; http://dx.doi.org/10.1080/15287394.2011.586941

Zhang, J; Han, I; Zhang, L; Crain, W (2008) Hazardous chemicals in synthetic turf materials and their bioaccessibility in digestive fluids. J Exposure Sci Environ Epidemiol 18:600-607. http://www.nature.com/jes/journal/v18/n6/pdf/jes200855a.pdf

Websites

http://www.nycgovparks.org/news/reports/synthetic-turf-tests

Literature Search Results

February 2016

Summary

Subject: Health effects associated with exposure to tire crumbs or artificial turf fields

Databases searched: ProQuest Environmental Science Collection, Web of Science, ScienceDirect, Google Scholar

Number of citations: 55

Search terms:

"crumb rubber" OR "tire crumb"

AND

(field or infill or turf)

AND

(exposure or risk or toxic*)

Anderson, M. E., et al. (2006). "A Case Study of Tire Crumb Use on Playgrounds: Risk Analysis and Communication When Major Clinical Knowledge Gaps Exist." Environmental Health Perspectives **114**(1): 1-3.
Physicians and public health professionals working with the U.S. Environmental Protection Agency's Region 8 Pediatric Environmental Health Specialty Unit (PEHSU) received several telephone calls requesting information regarding the safety of recycled tire crumb as a playground surface constituent placed below children's play structures. There were no reported symptoms or adverse health effects in exposed children. The literature available on the safety and risk of exposure to crumb rubber constituents was limited and revealed no information quantifying exposures associated with product use. Callers were informed by the PEHSU that no evidence existed suggesting harm from intended use of the product, but gaps in knowledge about the product were identified and communicated. Here the case of crumb rubber on playgrounds is used as a model to present an approach to similar environmental medicine questions. From defining the question, to surveying traditional

and nontraditional resources for information, synthesis of findings, and risk communication, the case provides a model to approach similar questions. ***Already on our list.***

Aoki, T. (2011). "Current State and Perspective for Artificial Turf as Sport Environment: Focusing on Third-generation Artificial Turf as Football Playing Surface." – ***This paper was added to our list.***

Beausoleil, M., et al. (2009). "Chemicals in outdoor artificial turf: a health risk for users." Public Health Branch, Montreal Health and Social Services Agency.[accessed 2015 April 22]. http://www. ncceh. ca/sites/default/files/Outdoor_Artificial_Turf. pdf. ***Already on our list.***

Birkholz, D. A., et al. (2003). "Toxicological evaluation for the hazard assessment of tire crumb for use in public playgrounds." Journal of the Air & Waste Management Association **53**(7): 903-907.
Disposal of used tires has been a major problem in solid waste management. New uses will have to be found to consume recycled tire products. One such proposed use is as ground cover in playgrounds. However, concern has been expressed regarding exposure of children to hazardous chemicals and the environmental impact of such chemicals. We designed a comprehensive hazard assessment to evaluate and address potential human health and environmental concerns associated with the use of tire crumb in playgrounds. Human health concerns were addressed using conventional hazard analyses, mutagenicity assays, and aquatic toxicity tests of extracted tire crumb. Hazard to children appears to be minimal. Toxicity to all aquatic organisms (bacteria, invertebrates, fish, and green algae) was observed; however, this activity disappeared with aging of the tire crumb for three months in place in the playground. We conclude that the use of tire crumb in playgrounds results in minimal hazard to children and the receiving environment. ***Already on our list.***

Bocca, B., et al. (2009). "Metals contained and leached from rubber granulates used in synthetic turf areas." Science of the Total Environment **407**(7): 2183-2190.
The aim of this study was to quantify metals contained in and leached from different types of rubber granulates used in synthetic turf areas. To investigate the total content of metals, ca 0.5 g of material was added with HNO_3, HF and $HClO_4$ and microwave digested with power increasing from 250 W to 600 W. Leachates were prepared by extraction of about 5.0 g of material at room temperature for 24 h in an acidic environment (pH 5). Leaching with deionized water was also performed for comparison. Aluminium, As, Ba, Be, Cd, Co, Cr, Cu, Hg, Fe, Li, Mg, Mn, Mo, Ni, Pb, Rb, Sb, Se, Sn, Sr, Tl, V, W and Zn were quantified by high-resolution inductively coupled plasma mass spectrometry (HR-ICP-MS) and ICP optical emission spectrometry (ICP-OES). Results indicated that the developed method was accurate and precise for the multi-element characterization of rubber granulates and leachates. The total amount and the amount leached during the acidic test varied from metal to metal and from granulate to granulate. The highest median values were found for Zn (10,229 mg/kg), Al (755 mg/kg), Mg (456 mg/kg), Fe (305 mg/kg), followed by Pb, Ba, Co, Cu and Sr. The other elements were present at few units of mg/kg. The highest leaching was observed for Zn (2300 μg/l) and Mg (2500 μg/l), followed by Fe, Sr, Al, Mn and Ba. Little As, Cd, Co, Cr, Cu, Li, Mo, Ni, Pb, Rb, Sb and V leached, and Be, Hg, Se, Sn, Tl and W were below quantification limits. Data obtained were compared with the maximum tolerable amounts reported for similar materials, and only the concentration of Zn (total and leached) exceeded the expected values. ***Already on our list.***

Brown, D. "Artificial Turf: Exposures to Ground-up Rubber Tires." - ***This is the same as EHHI 2007 which is already on our list.***

Cheng, H., et al. (2014). "Environmental and Health Impacts of Artificial Turf: A Review." Environmental Science & Technology **48**(4): 2114-2129.
With significant water savings and low maintenance requirements, artificial turf is increasingly promoted as a replacement for natural grass on athletic fields and lawns. However, there remains the question of whether it is an environmentally friendly alternative to natural grass. The major concerns stem from the infill material that is typically derived from scrap tires. Tire rubber crumb contains a range of organic contaminants and heavy metals that can volatilize into the air and/or leach into the percolating rainwater, thereby posing a potential risk to the environment and human health. A limited number of studies have shown that the concentrations of volatile and semivolatile organic compounds in the air above artificial turf fields were typically not higher than the local

background, while the concentrations of heavy metals and organic contaminants in the field drainages were generally below the respective regulatory limits. Health suggested that users of artificial turf fields, even professional athletes, were not exposed to elevated risks. Preliminary life cycle assessment suggested that the environmental impacts of artificial turf fields were lower than equivalent grass fields. Areas that need further research to better understand and mitigate the potential negative environmental impacts of artificial turf are identified. ***Already on our list.***

Claudio, L. (2008). "Synthetic Turf Health Debate Takes Root." Environmental Health Perspectives **116**(3): A116-122. ***Already on our list.***

Dorsey, M. J., et al. (2015). "Mutagenic Potential of Artificial Athletic Field Crumb Rubber at Increased Temperatures." The Ohio Journal of Science **115**(2). ***This paper was added to our list.***

Drakes, M. C., et al. (2013). "Synthetic playing surfaces and athlete health." Journal of the American Academy of Orthopaedic Surgeons **21**(5): 293-302. – ***This paper was added to our list, but it is not suitable. It addresses injuries to athletes.***

Ginsberg, G., et al. (2011). "BENZOTHIAZOLE TOXICITY ASSESSMENT IN SUPPORT OF SYNTHETIC TURF FIELD HUMAN HEALTH RISK ASSESSMENT." Journal of Toxicology and Environmental Health-Part a-Current Issues **74**(17): 1175-1183.

Synthetic turf fields cushioned with crumb rubber may be a source of chemical exposure to those playing on the fields. Benzothiazole (BZT) may volatilize from crumb rubber and result in inhalation exposure. Benzothiazole has been the primary rubber-related chemical found in synthetic turf studies. However, risks associated with BZT have not been thoroughly assessed, primarily because of gaps in the database. This assessment provides toxicity information for a human health risk assessment involving BZT detected at five fields in Connecticut. BZT exerts acute toxicity and is a respiratory irritant and dermal sensitizer. In a genetic toxicity assay BZT was positive in Salmonella in the presence of metabolic activation. BZT metabolism involves ring-opening and formation of aromatic hydroxylamines, metabolites with mutagenic and carcinogenic potential. A structural analogue 2-mercaptobenzothiazole (2-MBZT) was more widely tested and so is used as a surrogate for some endpoints. 2-MBZT is a rodent carcinogen with rubber industry data supporting an association with human bladder cancer. The following BZT toxicity values were derived: (1) acute air target of 110 mu g/m(3) based upon a BZT RD(50) study in mice relative to results for formaldehyde; (2) a chronic noncancer target of 18 mu g/m(3) based upon the no-observed-adverse-effect level (NOAEL) in a subchronic dietary study in rats, dose route extrapolation, and uncertainty factors that combine to 1000; (3) a cancer unit risk of 1.8E-07/mu g-m(3) based upon a published oral slope factor for 2-MBZT and dose-route extrapolation. While there are numerous uncertainties in the BZT toxicology database, this assessment enables BZT to be quantitatively assessed in risk assessments involving synthetic turf fields. However, this is only a screening-level assessment, and research that better defines BZT potency is needed. ***Already on our list.***

Ginsberg, G., et al. (2011). "HUMAN HEALTH RISK ASSESSMENT OF SYNTHETIC TURF FIELDS BASED UPON INVESTIGATION OF FIVE FIELDS IN CONNECTICUT." Journal of Toxicology and Environmental Health-Part a-Current Issues **74**(17): 1150-1174.

Questions have been raised regarding possible exposures when playing sports on synthetic turf fields cushioned with crumb rubber. Rubber is a complex mixture with some components possessing toxic and carcinogenic properties. Exposure is possible via inhalation, given that chemicals emitted from rubber might end up in the breathing zone of players and these players have high ventilation rates. Previous studies provide useful data but are limited with respect to the variety of fields and scenarios evaluated. The State of Connecticut investigated emissions associated with four outdoor and one indoor synthetic turf field under summer conditions. On-field and background locations were sampled using a variety of stationary and personal samplers. More than 20 chemicals of potential concern (COPC) were found to be above background and possibly field-related on both indoor and outdoor fields. These COPC were entered into separate risk assessments (1) for outdoor and indoor fields and (2) for children and adults. Exposure concentrations were prorated for time spent away from the fields and inhalation rates were adjusted for play activity and for children's greater ventilation than adults. Cancer and noncancer risk levels were at or below de minimis levels of concern. The scenario with the highest exposure was children playing on the indoor field. The acute hazard index (HI) for this scenario approached unity, suggesting a potential concern, although there was great uncertainty with this estimate. The main contributor was benzothiazole, a rubber-related semivolatile organic chemical (SVOC) that was 14-fold higher indoors than outdoors. Based upon these findings, outdoor and indoor synthetic turf fields are not associated with elevated adverse health risks. However, it would be prudent for building operators to provide adequate ventilation to prevent a buildup of rubber-related volatile organic chemicals (VOC) and SVOC at indoor fields. The current results are generally consistent with the findings from studies conducted by New York City, New York State, the U. S. Environmental Protection Agency (EPA), and Norway, which tested different kinds of fields and under a variety of weather conditions. ***Already on our list.***

Gomes, J., et al. (2010). "Toxicological Assessment of Coated versus Uncoated Rubber Granulates Obtained from Used Tires for Use in Sport Facilities." Journal of the Air & Waste Management Association **60**(6): 741-746.
Reuse of tire crumb in sport facilities is currently a very cost-effective waste management measure. Considering that incorporation of the waste materials in artificial turf would be facilitated if the rubber materials were already colored green, coatings were specifically developed for this purpose. This paper presents an experimental toxicological and environmental assessment aimed at comparing the obtained emissions to the environment in terms of polycyclic aromatic hydrocarbons (PAHs), heavy metals, and ecotoxicity for coated and noncoated rubber granulates. This study is a comprehensive evaluation of the major potential critical factors related with the release of all of these classes of pollutants because previous studies were not systematically performed. It was concluded that between the two types of coatings tested, one is particularly effective in reducing emissions to the environment, simultaneously meeting the requirements of adherence and color stability. ***Already on our list.***

Groenevelt, P. H. and P. E. Grunthal (1998). "Utilisation of crumb rubber as a soil amendment for sports turf." Soil and Tillage Research **47**(1–2): 169-172.
In Canada, the Province of Ontario generates about ten million waste tires per year. According to 1991 government statistics less than 20% of these tires are recycled, some of which are granulated to produce crumb rubber. An innovation application for this secondary resource is as an efficient, economical and environmentally sound soil amendment. A rubber crumb-based soil amendment can enhance the physical properties of soils susceptible to the negative effects of compaction. Highly compacted sports fields require constant aeration to maintain a healthy and safe playing surface. Rubber crumb adds resiliency to sports turf. Standard United States Golf Association tests revealed that admixtures containing 20% or less crumb rubber maintained recommended total porosity values. Field tests showed that 10–20% crumb rubber significantly reduced surface hardness. Analysis of metals, VOC's and BNA extractable compounds from admixture leachate revealed no deleterious effects to the environment due to inclusion of rubber crumb in turfgrass root zones. ***This paper was added to our list.***

Haering, S. A. (2012). "Alexandria Health Department."
This memorandum provides information regarding the infill material used in synthetic turf fields in the City of Alexandria – ***This is a memo; not suitable for this effort.***

Johns, D. M. (2008). "Initial evaluation of potential human health risks associated with playing on synthetic turf fields on Bainbridge Island." Windward Environmental LLC. ***Already on our list.***

Johns, D. M. and T. Goodlin (2008). "Evaluation of Potential Environmental Risks Associated with Installing Synthetic Turf Fields on Bainbridge Island." Seattle, Washington: Windward Environmental LLC. ***This paper was added to our list.***

Kim, H.-H., et al. (2012). "Health Risk Assessment for Artificial Turf Playgrounds in School Athletic Facilities: Multi-route Exposure Estimation for Use Patterns." Asian Journal of Atmospheric Environment **6**(3): 206-221. ***This paper was added to our list.***

Kim, S., et al. (2012). "Health risk assessment of lead ingestion exposure by particle sizes in crumb rubber on artificial turf considering bioavailability." Environmental health and toxicology **27**: e2012005-e2012005.

OBJECTIVES: The purpose of this study was to assess the risk of ingestion exposure of lead by particle sizes of crumb rubber in artificial turf filling material with consideration of bioavailability. METHODS: This study estimated the ingestion exposure by particle sizes (more than 250 um or less than 250 um) focusing on recyclable ethylene propylene diene monomer crumb rubber being used as artificial turf filling. Analysis on crumb rubber was conducted using body ingestion exposure estimate method in which total content test method, acid extraction method and digestion extraction method are reflected. Bioavailability which is a calibrating factor was reflected in ingestion exposure estimate method and applied in exposure assessment and risk assessment. Two methods using acid extraction and digestion extraction concentration were compared and evaluated. RESULTS: As a result of the ingestion exposure of crumb rubber material, the average lead exposure amount to the digestion extraction result among crumb rubber was calculated to be 1.56*10(-4) mg/kg-day for low grade elementary school students and 4.87*10(-5) mg/kg-day for middle and high school students in 250 um or less particle size, and that to the acid extraction result was higher than the digestion extraction result. Results of digestion extraction and acid extraction showed that the hazard quotient was estimated by about over 2 times more in particle size of lower than 250 μm than in higher than 250 μm. There was a case of an elementary school student in which the hazard quotient exceeded 0.1. CONCLUSIONS: Results of this study confirm that the exposure of lead ingestion and risk level increases as the particle size of crumb rubber gets smaller. ***Already on our list.***

Krüger, O., et al. (2013). "New approach to the ecotoxicological risk assessment of artificial outdoor sporting grounds." Environmental Pollution **175**: 69-74.
Artificial surfaces for outdoor sporting grounds may pose environmental and health hazards that are difficult to assess due to their complex chemical composition. Ecotoxicity tests can indicate general hazardous impacts. We conducted growth inhibition (Pseudokirchneriella subcapitata) and acute toxicity tests (Daphnia magna) with leachates obtained from batch tests of granular infill material and column tests of complete sporting ground assemblies. Ethylene propylene diene monomer rubber (EPDM) leachate showed the highest effect on Daphnia magna (EC50 & lt; 0.4% leachate) and the leachate of scrap tires made of styrene butadiene rubber (SBR) had the highest effect on P. subcapitata (EC10 = 4.2% leachate; EC50 = 15.6% leachate). We found no correlations between ecotoxicity potential of leachates and zinc and PAH concentrations. Leachates obtained from column tests revealed lower ecotoxicological potential. Leachates of column tests of complete assemblies may be used for a reliable risk assessment of artificial sporting grounds. ***Already on our list.***

Li, X., et al. (2010). "Characterization of substances released from crumb rubber material used on artificial turf fields." Chemosphere **80**(3): 279-285.
Crumb rubber material (CRM) used as infill on artificial turf fields can be the source of a variety of substances released to the environment and to living organisms in the vicinity of the CRM. To assess potential risks of major volatilized and leached substances derived from CRM, methods were developed to identify organic compounds and elements, either in the vapor phase and/or the leachate from CRM. A qualitative method based on solid phase micro-extraction (SPME) coupled with gas chromatography/mass spectrometry (GC–MS) was developed to identify the major volatile and semi-volatile organic compounds out-gassing from CRM samples under defined laboratory conditions. Direct vapor phase injection into the GC–MS was applied for the quantitative analysis. Ten organic compounds were identified in the vapor phase by the SPME method. Volatile benzothiazole (BT) was detected at the highest level in all commercial CRM samples, in the range 8.2–69 ng g^{-1} CRM. Other volatile PAHs and antioxidants were quantified in the vapor phase as well. A decrease of volatile compounds was noted in the headspace over CRM samples from 2-years-old fields when compared with the virgin CRM used at installation. An outdoor experiment under natural weathering conditions showed a significant reduction of out-gassing organic compounds from the CRM in the first 14 d; thereafter, values remained consistent up to 70 d of observation. Zinc was the most abundant element in the acidified leachate (220–13 000 μg g^{-1}), while leachable BT was detected at relatively low amounts. ***Already on our list.***

Li, X., et al. (2010). "Corrigendum to "Characterization of substances released from crumb rubber material used on artificial turf fields" [Chemosphere 80 (3) (2010) 279–285]." Chemosphere **80**(11): 1406-1407. ***Already on our list.***

Lioy, P. J., et al. "UMDNJ-EOHSI Crumb Infill and Turf Report–October 31, 2011." ***Already on our list.***

Lioy, P. J. and C. P. Weisel (2008). "Artificial turf: safe or out on ball fields around the world." Journal of Exposure Science and Environmental Epidemiology **18**(6): 533-534. ***Already on our list.***

Llompart, M., et al. (2013). "Hazardous organic chemicals in rubber recycled tire playgrounds and pavers." Chemosphere **90**(2): 423-431. ***Already on our list.***

Marsili, L., et al. (2015). "Release of Polycyclic Aromatic Hydrocarbons and Heavy Metals from Rubber Crumb in Synthetic Turf Fields: Preliminary Hazard Assessment for Athletes." Journal of Environmental & Analytical Toxicology **5**(2): 1-8.
Synthetic turf, made with an infill of rubber crumb from used tyres or virgin rubber, is now common in many sporting facilities. It is known that it contains compounds such as polycyclic aromatic hydrocarbons (PAH) and heavy metals. The researchers evaluated in nine samples of rubber crumb the total content of some heavy metals (Zn, Cd, Pb, Cu, Cr, Ni, Fe) normally found in tyres by microwave mineralization and the levels of the 14 US EPA priority PAHs by Soxhlet extraction and HPLC analysis. The results showed high levels of PAHs and zinc in all rubber crumb samples compared to rubber granulate limits set by Italian National Amateur League. Finally, the aim of this study was to estimate the hazard for athletes inhaling PAHs released at the high temperatures this synthetic turf may reach. Then a sequence of proofs was carried out at 60 degrees Celsius, a temperature that this rubber crumb can easily reach in sporting installations, to see whether PAH release occurs. ***Already on our list.***

Mattina, M. I., et al. (2007). "Examination of crumb rubber produced from recycled tires." The Connecticut Agricultural Experiment Station, New Haven, CT. Available online at: http://www. ct. gov/caes/lib/caes/documents/publications/fact_sheets/examinationofcru mbrubberac005. pdf. Accessed on **12**(10): 07. ***Already on our list as Incorvia Mattina.***

Menichini, E., et al. (2011). "Artificial-turf playing fields: Contents of metals, PAHs, PCBs, PCDDs and PCDFs, inhalation exposure to PAHs and related preliminary risk assessment." Science of the Total Environment **409**(23): 4950-4957.
The artificial-turf granulates made from recycled rubber waste are of health concern due the possible exposure of users to dangerous substances present in the rubber, and especially to PAHs. In this work, we determined the contents of PAHs, metals, non-dioxin-like PCBs (NDL-PCBs), PCDDs and PCDFs in granulates, and PAH concentrations in air during the use of the field. The purposes were to identify some potential chemical risks and to roughly assess the risk associated with inhalation exposure to PAHs. Rubber granulates were collected from 13 Italian fields and analysed for 25 metals and nine PAHs. One further granulate was analysed for NDL-PCBs, PCDDs, PCDFs and 13 PAHs. Air samples were collected on filter at two fields, using respectively a high volume static sampler close to the athletes and personal samplers worn by the athletes, and at background locations outside the fields. In the absence of specific quality standards, we evaluated the measured contents with respect to the Italian standards for soils to be reclaimed as green areas. Zn concentrations (1 to 19 g/kg) and BaP concentrations (0.02 to 11 mg/kg) in granulates largely exceeded the pertinent standards, up to two orders of magnitude. No association between the origin of the recycled rubber and the contents of PAHs and metals was observed. The sums of NDL-PCBs and WHO-TE PCDDs + PCDFs were, respectively, 0.18 and 0.67 × 10− 5 mg/kg. The increased BaP concentrations in air, due to the use of the field, varied approximately from < 0.01 to 0.4 ng/m3, the latter referring to worst-case conditions as to the release of particle-bound PAHs. Based on the 0.4 ng/m3 concentration, an excess lifetime cancer risk of 1 × 10− 6 was calculated for an intense 30-year activity. ***Already on our list.***

Moretto, R. (2007). "Environmental and health assessment of the use of elastomer granulates (virgin and from used tyres) as filling in third-generation artificial turf." EEDEMS (Ademe, Aliapur, Fieldturf Tarkett. ***Already on our list.***

Mota, H., et al. (2009). "Coated rubber granulates obtained from used tyres for use in sport facilities: A toxicological assessment." Ciência & Tecnologia dos Materiais **21**(3-4): 26-30. ***This paper was added to our list.***

Pavilonis, B. T., et al. (2014). "Bioaccessibility and Risk of Exposure to Metals and SVOCs in Artificial Turf Field Fill Materials and Fibers." Risk Analysis **34**(1): 44-55.

To reduce maintenance costs, municipalities and schools are starting to replace natural grass fields with a new generation synthetic turf. Unlike Astro-Turf, which was first introduced in the 1960s, synthetic field turf provides more cushioning to athletes. Part of this cushioning comes from materials like crumb rubber infill, which is manufactured from recycled tires and may contain a variety of chemicals. The goal of this study was to evaluate potential exposures from playing on artificial turf fields and associated risks to trace metals, semi-volatile organic compounds (SVOCs), and polycyclic aromatic hydrocarbons (PAHs) by examining typical artificial turf fibers (n = 8), different types of infill (n = 8), and samples from actual fields (n = 7). Three artificial biofluids were prepared, which included: lung, sweat, and digestive fluids. Artificial biofluids were hypothesized to yield a more representative estimation of dose than the levels obtained from total extraction methods. PAHs were routinely below the limit of detection across all three biofluids, precluding completion of a meaningful risk assessment. No SVOCs were identified at quantifiable levels in any extracts based on a match of their mass spectrum to compounds that are regulated in soil. The metals were measurable but at concentrations for which human health risk was estimated to be low. The study demonstrated that for the products and fields we tested, exposure to infill and artificial turf was generally considered de minimus, with the possible exception of lead for some fields and materials. ***Already on our list.***

Rhodes, E. P., et al. (2012). "Zinc leaching from tire crumb rubber." Environmental Science & Technology **46**(23): 12856-12863. ***Already on our list.***

Ruffino, B., et al. (2013). "Environmental-sanitary risk analysis procedure applied to artificial turf sports fields." Environmental Science and Pollution Research International **20**(7): 4980-4992.
Owing to the extensive use of artificial turfs worldwide, over the past 10 years there has been much discussion about the possible health and environmental problems originating from styrene-butadiene recycled rubber. In this paper, the authors performed a Tier 2 environmental-sanitary risk analysis on five artificial turf sports fields located in the city of Turin (Italy) with the aid of RISC4 software. Two receptors (adult player and child player) and three routes of exposure (direct contact with crumb rubber, contact with rainwater soaking the rubber mat, inhalation of dusts and gases from the artificial turf fields) were considered in the conceptual model. For all the fields and for all the routes, the cumulative carcinogenic risk proved to be lower than 10^sup -6^ and the cumulative non-carcinogenic risk lower than 1. The outdoor inhalation of dusts and gases was the main route of exposure for both carcinogenic and non-carcinogenic substances. The results given by the inhalation pathway were compared with those of a risk assessment carried out on citizens breathing gases and dusts from traffic emissions every day in Turin. For both classes of substances and for both receptors, the inhalation of atmospheric dusts and gases from vehicular traffic gave risk values of one order of magnitude higher than those due to playing soccer on an artificial field. [PUBLICATION ABSTRACT] ***Already on our list.***

Schiliro, T., et al. (2013). "Artificial Turf Football Fields: Environmental and Mutagenicity Assessment." Archives of Environmental Contamination and Toxicology **64**(1): 1-11.
The public has recently raised concerns regarding potential human health and environmental risks associated with tire crumb constituents in the artificial turf of football fields. The aim of the present study was to develop an environmental analysis drawing a comparison between artificial turf football fields and urban areas relative to concentrations of particles (PM10 and PM2.5) and related polycyclic aromatic hydrocarbons (PAHs), aromatic hydrocarbons (BTXs), and mutagenicity of organic extracts from PM10 and PM2.5. No significant differences were found between PM10 concentrations at an urban site and on a turf football field, both during warm and in cold seasons, either with or without on-field activity. PM2.5 concentrations were significantly greater at the urban site in the cold season as was the ratio of PM2.5 to PM10. BTXs were significantly greater at urban sites than on turf football fields on both on warm and cold days. The ratio of toluene to benzene (T/B ratio) was always comparable with that of normal urban conditions. The concentration of PAHs on the monitored football fields was comparable with urban levels during the two different sampling periods, and the contribution of PAHs released from the granular material was negligible. PM10 organic extract mutagenicity for artificial turf football fields was greater, whereas PM2.5 organic extract mutagenicity was lower, compared with the urban site studied. However, both organic extract mutagenicity values were comparable with the organic extract mutagenicity reported in the literature for urban sites. On the basis of environmental monitoring, artificial turf football fields present no more exposure risks than the rest of the city. ***Already on our list.***

Simcox, N. J., et al. (2011). "SYNTHETIC TURF FIELD INVESTIGATION IN CONNECTICUT." Journal of Toxicology and Environmental Health-Part a-Current Issues **74**(17): 1133-1149.
The primary purpose of this study was to characterize the concentrations of volatile organic compounds (VOC), semivolatile organic compounds (SVOC), rubber-related chemicals such as benzothiazole (BZT) and nitrosamine, and particulate matter (PM(10)) in air at synthetic turf crumb rubber fields. Both new and older fields were evaluated under conditions of active use. Three types of fields were targeted: four outdoor crumb rubber fields, one indoor facility with crumb rubber turf, and an outdoor natural grass field. Background samples were collected at each field on grass. Personal air sampling was conducted for VOC, BZT, nitrosamines, and other chemicals. Stationary air samples were collected at different heights to assess the vertical profile of release. Air monitoring for PM(10) was conducted at one height. Bulk samples of turf grass and crumb rubber were analyzed, and meteorological data were recorded. Results showed that personal concentrations were higher than stationary concentrations and were higher on turf than in background samples for certain VOC. In some cases, personal VOC concentrations from natural grass fields were as high as those on turf. Naphthalene, BZT, and butylated hydroxytoluene (BHT) were detected in greater concentration at the indoor field compared to the outdoor fields. Nitrosamine air levels were below reporting levels. PM(10) air concentrations were not different between on-field and upwind locations. All bulk lead (Pb) samples were below the public health target of 400 ppm. More research is needed to better understand air quality at indoor facilities. These field investigation data were incorporated into a separate human health risk assessment. ***Already on our list.***

Simon, R. (2010). "Review of the impacts of crumb rubber in artificial turf applications." University of California, Berkeley, Laboratory for Manufacturing and Sustainability, prepared for The Corporation for Manufacturing Excellence (Manex). – ***This paper was added to our list.***

Sullivan, J. P. (2006). "An assessment of environmental toxicity and potential contamination from artificial turf using shredded or crumb rubber." Ardea Consulting **43**. ***Already on our list.***

van Rooij, J. G. and F. J. Jongeneelen (2010). "Hydroxypyrene in urine of football players after playing on artificial sports field with tire crumb infill." International Archives of Occupational and Environmental Health **83**(1): 105-110.
Artificial sports fields are increasingly being used for sports. Recycled rubber from automotive and truck scrap rubber tires are used as an infill material for football grounds. There are concerns that football players may be at risk due to exposure from released compounds from rubber infill. Compounds from crumb infill may be inhaled and dermal exposure may occur. A study was performed to assess the exposure of football players to polycyclic aromatic hydrocarbons due to sporting on synthetic ground with rubber crumb infill. In this study, football players were trained and had a match on the artificial turf pitch during 2.5 h. They had an intensive skin contact with rubber infill. All urine of seven nonsmoking football players was collected over a 3-day period, the day before sporting, the day of sporting and the day after sporting. Urine samples were analyzed for 1-hydroxypyrene. Confounding exposure from environmental sources and diet was controlled for. The individual increase of the amount of excretion over time was used as a measure to assess the uptake of PAH. It appeared that the baseline of excreted 1-hydroxypyrene in 4 of 7 volunteers was sufficient stable and that 1 volunteer out of 4 showed after the 2.5-h period of training and match on the playground an increase in hydroxypyrene in urine. However, concomitant dietary uptake of PAH by this volunteer was observed. This study provides evidence that uptake of PAH by football players active on artificial grounds with rubber crumb infill is minimal. If there is any exposure, than the uptake is very limited and within the range of uptake of PAH from environmental sources and/or diet. [PUBLICATION ABSTRACT] ***Already on our list.***

Zhang, J., et al. (2008). "Hazardous chemicals in synthetic turf materials and their bioaccessibility in digestive fluids." Journal of Exposure Science and Environmental Epidemiology **18**(6): 600-607.
Many synthetic turf fields consist of not only artificial grass but also rubber granules that are used as infill. The public concerns about toxic chemicals possibly contained in either artificial (polyethylene) grass fibers or rubber granules have been escalating but are based on very limited information available to date. The aim of this research was to obtain data that will help assess potential health risks associated with chemical exposure. In this small-scale study, we collected seven samples of rubber granules and one sample of artificial grass fiber from synthetic turf fields at different ages of the fields. We analyzed these samples to determine the contents

(maximum concentrations) of polycyclic aromatic hydrocarbons (PAHs) and several metals (Zn, Cr, As, Cd, and Pb). We also analyzed these samples to determine their bioaccessible fractions of PAHs and metals in synthetic digestive fluids including saliva, gastric fluid, and intestinal fluid through a laboratory simulation technique. Our findings include: (1) rubber granules often, especially when the synthetic turf fields were newer, contained PAHs at levels above health-based soil standards. The levels of PAHs generally appear to decline as the field ages. However, the decay trend may be complicated by adding new rubber granules to compensate for the loss of the material. (2) PAHs contained in rubber granules had zero or near-zero bioaccessibility in the synthetic digestive fluids. (3) The zinc contents were found to far exceed the soil limit. (4) Except one sample with a moderate lead content of 53 p.p.m., the other samples had relatively low concentrations of lead (3.12-5.76 p.p.m.), according to soil standards. However, 24.7-44.2% of the lead in the rubber granules was bioaccessible in the synthetic gastric fluid. (5) The artificial grass fiber sample showed a chromium content of 3.93 p.p.m., and 34.6% and 54.0% bioaccessibility of lead in the synthetic gastric and intestinal fluids, respectively. ***Already on our list.***

Appendix E - List of Literature Reviewed

Ref #	Title	Author
01	A Case Study of Tire Crumb Use on Playgrounds: Risk Analysis and Communication When Major Clinical Knowledge Gaps Exist	Anderson et al.
02	A preliminary chemical examination of hydrophobic tire leachate components Note: This reference is part III of III. Parts I and II were not relevant and therefore, not reviewed	Anthony, D.H.J. and Latawiec
03	Determination of Microbial Populations in a Synthetic Turf System	Bass JJ, Hintze DW
04	Chemicals in outdoor artificial turf: a health risk for users?	Beausoleil M, Price K, Muller C
05	Toxicological Evaluation of Hazard Assessment of Tire Crumb for Use on Public Playgrounds	Birkholz et al.
06	Metals contained and leached from rubber granulates used in synthetic turf areas	Bocca B, Forte G., Petrucci F., Costantini S., Izzo P.
07	Evaluation of Health Effects of Recycled Waste Tires in Playground and Track Products	California Office of Environmental Health Hazard Assessment
08	Safety Study of Artificial Turf Containing Crumb Rubber Infill Made from Recycled Tires: Measurements of Chemicals and Particulates in the Air, Bacteria in the Turf, and Skin Abrasions Caused by Contact with the Surface	California Office of Environmental Health Hazard Assessment
09	Review of the Human Health & Ecological Safety of Exposure to Recycled Tire Rubber found at Playgrounds and Synthetic Turf Fields	Cardno Chem Risk
10	Assessment of exposure to chemical agents in infill material for artificial turf soccer pitches: development and implementation of a survey protocol	Castellano P, Proietto AR, Gordiani A, Ferrante R, Tranfo G, Paci E,
11	Emission characteristics of VOCs from athletic tracks	Chang, F; Lin, T.; Huang, C.; Chao, H.; Chang, T.; Lu, C.
12	Environmental and Health Impacts of Artificial Turf: A Review	Cheng H., Hu Y., Reinhard M.
13	Assessment of occupational health hazards in scrap-tire shredding facilities	Chien YC, Ton S, Lee MH et al.
14	Synthetic Turf: Health Debate Takes Root	Claudio L.
15	Human Health Risk Assessment of Artificial Turf Fields Based Upon Results from Five Fields in Connecticut	Connecticut Department of Public Health. (CDPH)
16	Artificial Turf Field Investigation in Connecticut Final Report	Connecticut: University of Connecticut Health Center (UCHC)
17	2009 Study of Crumb Rubber Derived from Recycled Tires, final report	Connecticut Agricultural Experiment Station (CAES)
18	Artificial Turf Study: leachate and stormwater characteristics	Connecticut Department of Environmental Protection (CDEP)
19	Peer Review of an Evaluation of the Health and Environmental Impacts Associated with Synthetic Turf Playing Fields	Connecticut Academy of Science and Engineering. (CASE)
20	CPSC Staff Analysis and Assessment of Synthetic Turf Grass Blades	CPSC
21	Effects of leachate from crumb rubber and zinc in green roofs on the survival, growth, and resistance characteristics of Salmonella enterica subsp. enterica serovar typhimurium	Crampton M, et al.
22	A Review of the Potential Health and Safety Risks from Synthetic Turf Fields Containing Crumb Rubber Infill Note: See reference #59	Denly E., Rutkowski K., Vetrano K.M.
23	Measurement of Air Pollution in Indoor Artificial Turf Halls	Dye C., Bjerke A, Schmidbauer N., Mano S.
24	Artificial Turf – Exposures to Ground-Up Rubber Tires – Athletic Fields – Playgrounds – Gardening Mulch	Environment & Human Health Inc. (EHHI)
25	Study of the suitability of ground rubber tire as a parking lot surface	Florida Department of Environmental Protection (FDEP)
26	Human Health Risk Assessment of Synthetic Turf Fields Based Upon Investigation of Five Fields in Connecticut	Ginsberg et al.
27	Benzothiazole Toxicity Assessment in Support of Synthetic Turf Field Human Health Risk Assessment	Ginsberg, G; Toal, B; Kurland, T.
28	Toxicological Assessment of Coated Versus Uncoated Rubber Granulates Obtained from Used Tires for Use in Sports Facilities	Gomes et al.

Ref #	Title	Author
29	Design of a New Test Chamber for Evaluation of the Toxicity of Rubber Infill	Gomes JF, Mota HI, Bordado JC, Baião M, Sarmento GM, Fernandes J, Pampulim VM, Custódio ML, Veloso I.
30	Impact of tire debris on in vitro and in vivo systems	Gualteri, M.; Andrioletti, M.; Mantecca, P.; Vismara, C.; Camatini; M.
31	Identification of Benzothiazole Derivatives and Polycyclic Aromatic Hydrocarbons as Aryl Hydrocarbon Receptor Agonists Present in Tire Extracts	He, G., Zhao, B., Denison, M.S.
32	A Scoping-Level Field Monitoring Study of Synthetic Turf and Playgrounds	U.S. Environmental Protection Agency (U.S. EPA)
33	Environmental and Health Risks of Rubber Infill: Rubber crumb from car tyres as infill on artificial turf	Hofstra, U
34	Examination of Crumb Rubber Produced from Recycled Tires. Department of Analytical Chemistry	Incorvia Mattina, MJ; Isleyen, M; Berger, W; Ozdemir, S.
35	Initial evaluation of potential human health risks associated with playing on synthetic turf fields on Bainbridge Island	Johns, DM
36	Characterization and potential environmental risks of leachate from shredded rubber mulches	Kanematsu, M; Hayashi, A; Denison, MS; Young, TM.
37	The fate of methicillin-resistant staphylococcus aureus in a synthetic field turf system	Keller, M.
38	Synthetic turf from a chemical perspective--a status report	KemI (Swedish Chemicals Inspectorate)
39	Health Risk Assessment of Lead Ingestion Exposure by Particle Sizes in Crumb Rubber on Artificial Turf Considering Bioavailability	Kim, S; Yan, JY; Kim, HH; Yeo, IY; Shin, DC; Lim, YW.
40	New approach to the ecotoxicological risk assessment of artificial outdoor sporting grounds	Krüger, O; Kalbe, U; Richter, E; Egeler, P; Rombke, J; Berger, W.
41	Comparison of Batch and Column Tests for the Elution of Artificial Turf System Components	Krüger, O; Kalbe, U; Berger, W; Nordhauβ, K; Christoph, G; Walzel, HP.
42	Preliminary Assessment of the Toxicity from Exposure to Crumb Rubber: Its Use in Playgrounds and Artificial Turf Playing Fields	LeDoux, T.
43	Characterization of Substances Released from Crumb Rubber Material Used on Artificial Turf Fields	Li, X; Berger, W; Musante, C; Incorvia Mattina, MJ.
44	Artificial Turf: Safe or Out on Ball Fields Around the World	Lioy, P; Weisel, C.
45	Crumb Infill and Turf Characterization for Trace Elements and Organic Materials	Lioy, P; Weisel, C.
46	Hazardous organic chemicals in rubber recycled tire playgrounds and pavers	Llompart, M; Sanchez-Pardo, L; Lamas, J; Garcia-Jares, C; Roca, E.
47	Release of Polycyclic Aromatic Hydrocarbons and Heavy Metals from Rubber Crumb in Synthetic Turf Fields: Preliminary Hazard Assessment for Athletes	Marsili, L; Coppola, D; Bianchi, N; Maltese, S; Bianchi, M; Fossi, MC.
48	A Survey of Microbial Populations in Infilled Synthetic Turf Fields	McNitt, AS; Petrunak, D; Serensits, T.
49	Artificial-turf Playing Fields: Contents of Metals, PAHs, PCBs, PCDDs and PCDFs, Inhalation Exposure to PAHs and Related Preliminary Risk Assessment	Menichini, E; Abate, V; Attias, L; DeLuca, S; DiDomenico, A; Fochi, I; Forte, G; Iacovella, N; Iamiceli, AL, Izzo, P; Merli, F; Bocca, B.
50	~~Culture-based and non-growth-dependent detection of the Burkholderia cepacia complex in soil environments~~ Note: This reference is not relevant, therefore not reviewed.	~~Miller et al~~
51	Evaluation of the Environmental Effects of Synthetic Turf Athletic	Milone and MacBroom, Inc.
52	Environmental and Health Evaluation of the Use of Elastomer Granulates (Virgin and From Used Tyres) as Filling in Third-generation Artificial Turf	Moretto, R.
53	~~Emission and evaluation of health effects of PAHs and aromatic amines from tyres~~ Note: This study does not meet our search criteria (focuses on problematic substances in whole tires).	~~Nilsson, NH; Feilberg, A; Pommer, K. (2005).~~
54	Mapping Emissions and Environmental and Health Assessment of Chemical Substances in Artificial Turf	Nilsson, NH; Malmgren-Hansen, B; Thomsen, US.
55	Artificial Turf Pitches: An Assessment of the Health Risks for Football Players	Norwegian Institute of Public Health and the Radium Hospital
56	A study to assess potential environmental impacts from the use of crumb runner as infill material in synthetic turf fields	New York Department of Environmental Conservation (NYDEC)
57	An assessment of chemical leaching, releases to air and temperature at crumb-rubber infilled synthetic turf fields	New York Department of Environmental Conservation (NYDEC)

Ref #	Title	Author
58	New York City Department of Parks and Recreation: Synthetic Turf Lead Results (online)	New York City Department of Parks and Recreation
59	~~A Review of the Potential Health and Safety Risks From Synthetic Turf Fields Containing Crumb Rubber Infill~~ Note: Same as Denly et al. 2008. See reference # 22.	~~New York City Department of Health and Mental Hygiene (DOHMH)~~
60	Bioaccessibility and Risk of Exposure to Metals and SVOCs in Artificial Turf Field Fill Materials and Fibers	Pavilonis, BT; Weisel, CP; Buckley, B; Lioy, PJ.
61	Potential health and environmental effects linked to artificial turf systems-final report	Plesser, T; Lund, O.
62	Zinc Leaching From Tire Crumb Rubber	Rhodes, EP; Ren, Z; Mays, DC.
63	Environmental Sanitary Risk Analysis Procedure Applied to Artificial Turf Sports Fields	Ruffino, B; Fiore, S; Zanetti, MC.
64	Used Tire Recycling to Produce Granulates: Evaluation of Occupational Exposure to Chemical Agents	Savary, B; Vinvent, R.
65	Artificial Turf Football Fields: Environmental and Mutagenicity Assessment	Schilirò, T; Traversi, D; Degan, R; Pignata, C; Alessandria, L; Scozia, D; Bono R; Gilli, G.
66	Leaching of DOC, DN and inorganic Constituents from Scrap Tires	Selbes, M; Yilmaz, O;, Khan, AA; Karanfil, T.
67	Human health issues on synthetic turf in the USA	Serentis,T J; McNitt, AS; Petrunak, DM.
68	An Evaluation of Potential Exposures to Lead and Other Metals as the Result of Aerosolized Particulate Matter from Artificial Turf Playing Fields	Shalat, SL.
69	Evaluating the Risk to Aquatic Ecosystems Posed by Leachate from Tire Shred Fill in Roads Using Toxicity Tests, Toxicity Identification Evaluations, and Groundwater Modeling	Sheehan, PJ; Warmerdam, JM; Ogle, S; Humphrey, D; Patenaude, S.
70	Synthetic Turf Field Investigation in Connecticut	Simcox, NJ; Bracker, A; Ginsberg, G; Toal, B; Golembiewski, B; Kurland, T; Hedman, C
71	An Assessment of Environmental Toxicity and Potential Contamination from Artificial Turf using Shredded or Crumb Rubber	Sullivan, JP.
72	Environmental risk assessment of artificial turf systems	Torsten Kallqvist
73	Hydroxypyrene in Urine of Football Players After Playing on Artificial Sports Fields with Tire Crumb Infill	Van Rooij, JGM; Jongeneelen, FJ.
74	Evaluating and Regulating Lead in Synthetic Turf	Van Ulirsch, G; Gleason, K; Gerstenberger, S; Moffett, DB; Pulliam, G; Ahmed, T; Fagliano, J.
75	Leaching of Zinc from rubber infill in artificial turf (football pitches)	Verschoor, AJ.
76	Air Quality Survey of Synthetic Turf Fields Containing Crumb Rubber Infill	Vetrano, KM; Ritter, G.
77	Memo to Gloria Addo-Ayensu, Fairfax County Health Dept., from Dwight Flammia, Virginia Department of Health	Virginia Department of Health (VDH)
78	The RMA TCLP assessment project: Leachate from tire samples	Zelibor, J L.
79	Hazardous Chemicals in Synthetic Turf Materials and Their Bioaccessibility in Digestive Fluids	Zhang, J; Han, IK; Zhang, L; Crain, W.
80	~~Technical and environmental properties of tyre shreds focusing on ground engineering applications~~ Note: Not reviewed-not applicable.	~~Edeskar, T.~~
81	~~Expert Witness: Evaluation of health risks caused by skin contact with rubber granulates used in synthetic turf pitches~~ Note: Not a scientific study, expert opinion only; Not reviewed.	~~Hametner, C.~~
82	Investigation of PAH and other hazardous contaminant occurrence in recycled tyre rubber surfaces: case study: restaurant playground in an indoor shopping centre	Celeiro, M. et al.
83	~~Current State and Perspective for Artificial Turf as Sport Environment: Focusing on Third-generation Artificial Turf as Football Playing Surface~~ Note: This document reviews many of the documents already on this list that have been reviewed. Also includes information from Aoki 2008, see reference 91.	~~Aoki, T.~~
84	Mutagenic Potential of Artificial Athletic Field Crumb Rubber at Increased Temperatures	Dorsey et al.
85	~~Synthetic playing surfaces and athlete health~~ Note: Not suitable; it addresses injuries to athletes.	~~Drakos, M. C., et al.~~

Ref #	Title	Author
86	Utilisation of crumb rubber as a soil amendment for sports turf	Groenevelt, P. H. and P. E. Grunthal
87	Evaluation of Potential Environmental Risks Associated with Installing Synthetic Turf Fields on Bainbridge Island.	Johns, DM; Goodlin, T.
88	Health Risk Assessment for Artificial Turf Playgrounds in School Athletic Facilities: Multi-route Exposure Estimation for Use Patterns	Kim, HH et al.
89	Coated rubber granulates obtained from used tyres for use in sport facilities: A toxicological assessment	Mota, H., et al.
90	Review of the impacts of crumb rubber in artificial turf applications	Simon, R.
91	Leaching of heavy metals from infills on artificial turf by using acid solutions	Aoki, T.
92	~~Environmental and Health Evaluation of the use of Elastomer Granulates (Virgin and From Used Tyres) as Filling in Third-Generation Artificial Turf~~ Note: Same as Moretto et al 2007. See Study 52.	~~French National Institute for Industrial Environment and Risks~~
93	~~ACT Global Crumb Rubber Safety Study~~ Note: Summary only; no information on the types and source of materials studied	~~Tilford, RW~~
94	State of Knowledge Report for Tire Materials and Tire Wear Particles	ChemRisk, Inc.
95	Health Impact Assessment of the Use of Artificial Turf in Toronto	Toronto Public Health
96	Nitrosamines released from rubber crumb	van Bruggen et al.
97	FOLLOW-UP STUDY OF THE ENVIRONMENTAL ASPECTS OF RUBBER INFILL A lab study (performing weathering tests) and a field study rubber crumb from car tyres as infill on artificial turf	Hofstra et al.

Appendix F - Constituents List

Analyte	Synonym(s)	CAS#
Aluminum		7429-90-5
Antimony		7440-36-0
Arsenic		7440-38-2
Barium		7440-39-3
Beryllium		7440-41-7
Cadmium		7440-43-9
Calcium		7440-70-2
Chloride		16887-00-6
Chromium		7440-47-3; 16065-83-1 (CrIII); 18540-29-9 (CrVI)
Cobalt		7440-48-4
Copper		7440-50-8
Iron		7439-89-6
Lead		7439-92-1
Lithium		7439-93-2
Magnesium		7439-95-4
Manganese		7439-96-5
Mercury		7439-97-6
Molybdenum		7439-98-7
Nickel		7440-02-0
Phosphorous		7723-14-0
Potassium		7440-09-7
Rubidium		7440-17-7
Selenium		7782-49-2
Silver		7440-22-4
Sodium		7440-23-5
Strontium		7440-24-6
Sulfur		7704-34-9
Thallium		7440-28-0
Tin		7440-31-5
Titanium		7440-32-6
Tungsten		7440-33-7
Vanadium		7440-62-2
Zinc		7440-66-6
Cadmium and Zinc Soaps		
Acenaphthene		83-32-9
Acenaphthylene		208-96-8
Acetaldehyde	Ethanone	75-07-0
Acetamide, N-cyclohexyl-		1124-53-4
Acetone		67-64-1
Acetone-diphenylamine condensation product (ADPA)		
Acetonitrile		75-05-8
Acetophenone		98-86-2
6-Acetoxy-2,2-dimethyl-m-dioxane	Dimethoxane	828-00-2
Acrolein		107-02-8
Alcohols	Ethanol	64-17-5
Aldehydes		
Alkyl benzenes		
Alkyl dithiols		
Alkyl naphthalenes		
Alkyl phenols		
Alpha pinene	alpha-Pinene	80-56-8

Analyte	Synonym(s)	CAS#
Amine (N-dialkyl analine derivative)		
Amines		
Anathrene		
Aniline	Benzeneamine; aminobenzene	62-53-3
Anthanthrene		191-26-4
Anthracene		120-12-7
Aromatic oil		
9,10-Anthracenedione, 2-ethyl	2-Ethylanthracene-9,10-dione	84-51-5
Azobenzene		103-33-3
Benz(e)acenaphthylene	Acephenanthrylene	201-06-9
Benzaldehyde, 3-hydroxyl-4-methoxy	3-Hydroxy-4-methoxy-benzaldehyde	621-59-0
Benz(a)anthracene		56-55-3
Benzene		71-43-2
Benzene, 1,3-bis(1-methylethenyl)-	1,3-bis(1-methylethenyl)benzene; 1,3-Diisopropenylbenzene	3748-13-8
Benzene, 1,4-bis(1-methylethenyl)-	1,4-Bis(1-methylethenyl)benzene	1605-18-1
1,4-Benzenediamine, N,N'-diphenyl-	N,N'-Diphenyl-p-phenylenediamine	74-31-7
1,4-Benzendiamin, N-(1-methylethyl)-N'-phenyl-, (IPPD)	N-Isopropyl-N'-phenyl-p-phenylenediamine, Isopropylaminodephenylamine (IPPD)	101-72-4
Benzene, isocyanato-	Phenyl isocyanate	103-71-9
Benzenemethanol	Benzyl alcohol	100-51-6
Benzo(def)dibenzothiophene	Phenanthro[4,5-bcd]thiophene	30796-92-0
Benzo(g)dibenzothiophene		
Benzo(b)fluoranthene		205-99-2
Benzo(bjk)fluoranthene	2,11-(Metheno)benzo[a]fluorene	
Benzo(ghi)fluoranthene	Benzo[ghi]fluoranthene,	203-12-3
Benzo(i)fluoranthene	Benzo(j)fluoranthene	205-82-3
Benzo(k)fluoranthene		207-08-9
Benzo(mno)fluoranthene		
Benzo(a)fluorene	11H-Benzo[a]fluorene	238-84-6
Benzo(b)fluorene	2,3-Benzofluorene	243-17-4
Benzo(def)naphthobenzothiophene		
6H-Benzo[cd]pyren-6-one	6H-Benzo(cd)pyren-6-one	3074-00-8
Benzo(a)pyrene		50-32-8
Benzo(e)pyrene		192-97-2
Benzo(ghi)perylene	Benzo(g,h,i)perylene	191-24-2
Benzoic acid		65-85-0
Benzothiazole		95-16-9
Benzothiazole, 2-(methylthio)	2-(Methylthio)benzothiazole	615-22-5
Benzothiazole, 2-phenyl	2-Phenylbenzothiazole	883-93-2
Benzothiazolone	2-Hydroxybenzothiazole, 2(3H)-Benzothiazolone, 2(3H) benzothiazolone	934-34-9
Benzoyl and other peroxides		
Benzylbutyl phthalate	Butyl benzyl phthalate	85-68-7
Biphenyl	1,1'-Biphenyl	92-52-4
1,1'-Biphenyl, 4, 4', 5', 6'-tetramethoxy-		
(N,N`-Bis(1,4-dimethylpentyl)pphenylendiamine) (7PPD)	N,N'-Bis(1,4-dimethylpentyl)-4-phenylenediamine	3081-14-9
Bis(2-ethylhexyl) phthalate	Di(2-ethylhexyl) phthalate	117-81-7
Bis-(2,2,6,6-tetramethyl-4-piperidinyl)sebacate	Bis(2,2,6,6-tetramethyl-4-piperidyl) sebacate	52829-07-9
Bisthiol acids		
Black rubber		
Bromodichloromethane		75-27-4
Bromoform		75-25-2
Butadiene oligomers		
Butoxyethoxyethanol	2-(2-Butoxyethoxy)ethanol, diethylene glycol monobutyl ether	112-34-5
Butylated hydroxyanisole		25013-16-5
Butylated hydroxytoluene	2,6-Di-tert-butyl-4-methylphenol (BHT)	128-37-0
Butylbenzene		104-51-8
Caprolactam disulfide (CLD)	1,1'-Disulfanediyldiazepan-2-one	23847-08-7

Analyte	Synonym(s)	CAS#
Carbazole		86-74-8
Carbon Black	Furnace Black	1333-86-4
Carbon Disulfide		75-15-0
Carbon Tetrachloride		56-23-5
Chlorobenzene		108-90-7
Chloroform	Trichloromethane	67-66-3
Chloromethane	Methyl chloride	74-87-3
Chrysene		218-01-9
Coronene		191-07-1
o-Cyanobenzoic acid	2-Cyanobenzoic acid	3839-22-3
Cyclohexanamine	Cyclohexylamine	108-91-8
Cyclohexanamine, N-cyclohexyl-	Dicyclohexylamine	101-83-7
Cyclohexanamine, N-cyclohexyl-N-methyl-	N-Cyclohexyl-N-methylcyclohexanamine	7560-83-0
Cyclohexane		110-82-7
Cyclohexane, isocyanato	Isocyanatocyclohexane	3173-53-3
Cyclohexane, isothiocyanato-		1122-82-3
Cyclohexanone		108-94-1
N-Cyclohexyl-2-benzothiazolesulfenamide (CBS)	N-Cyclohexyl-2-benzothiazolesulfenamide	95-33-0
n-Cyclohexyl-formamide	N-Cyclohexylformamide; Formamide, N-cyclohexyl	766-93-8
Cycloninasiloxane, octadecamethyl-	Octadecamethylcyclononasiloxane	556-71-8
Cyclopenta[cd]pyrene		27208-37-3
4H-cyclopenta[def]phenanthren-4-one	4H-Cyclopenta(def)phenanthren-4-one	5737-13-3
4H-cyclopenta[def]-phenanthrene	4-H-Cyclopenta(d,e,f)phenanthrene	203-64-5
Cyclopentane, methyl-	Methylcyclopentane	96-37-7
Decane		124-18-5
Diazoaminobenzenes		
Dibenzo(a,h) anthracene	Dibenz(a,h)anthracene	53-70-3
Dibenzofurane	Dibenzofuran	132-64-9
Dibenzo(ae)pyrene	Naphtho(1,2,3,4-def)chrysene	192-65-4
Dibenzo(ai)pyrene	Dibenzo[a,i]pyrene	189-55-9
Dibenzo(ah)pyrene	Dibenzo[a,h]pyrene	189-64-0
Dibenzothiophene		132-65-0
Dibutyl phthalate		84-74-2
1,4-Dichlorobenzene	p-dichlorobenzene	106-46-7
Dichlorodifluoromethane	Freon 12	75-71-8
1,2-Dichloroethane	Ethylene dichloride	107-06-2
cis-1,2-Dichloroethene	(Z)-1,2-Dichloroethylene	156-59-2
1,2-Dichloropropane		78-87-5
N,N-Dicyclohexyl-2-benzothiazolesulfenamide (DCBS)	N,N-Dicyclohexyl-2-benzothiazolesulfenamide	4979-32-2
Dicyclohexylphthalate (DCHP)	Dicyclohexyl phthalate	84-61-7
1,3-Dicyclohexylurea	N,N'-Dicyclohexylurea	2387-23-7
Diethenylbenzene	Divinylbenzene	1321-74-0
Di(2-ethylhexyl) adipate	Hexanedioic acid, bis(2-ehtylhexyl); Bis(2-ethylhexyl)hexanedioic acid	103-23-1
Diethyl phthalate		84-66-2
Diethylthiourea (DETU)	N,N'-Diethylthiourea	105-55-5
Dihydrocyclopentapyrene	2,3-Acepyrene	25732-74-5
Diisobutyl phthalate		84-69-5
Diisodecylphthalate	bis(8-Methylnonyl) phthalate	89-16-7
Diisononyl phthalate	DINP	28553-12-0
9,l0-Dimethyl-1,2-Benzanthracene	7,12-Dimethylbenz(a)anthracene	57-97-6
(N-1,3-dimethyl-butyl)-N'- phenyl-p-phenylenediamine (6PPD)	N-(1,3-Dimethylbutyl)-N'-phenyl-p-phenylenediamine	793-24-8
Dimethyldiphenylthiuram disulfide (MPTD)	Dimethyldiphenylthiuram disulfide	53880-86-7
2,6-Dimethylnaphthalene		581-42-0
2,4-Dimethylphenol		105-67-9
Dimethyl phthalate		131-11-3
Dinitroarenes		
Di-n-octyl phthalate	Dioctyl phthalate	117-84-0
Di-ortho-tolylguanidine		97-39-2

Analyte	Synonym(s)	CAS#
Dipentamethylenethiuramtetrasulfide (DPTT)	Bis(pentamethylenethiuram)tetrasulfide	120-54-7
Diphenylamine		122-39-4
N,N'-Diphenylguanidine (DPG)	1,3-Diphenylguanidine	102-06-7
N,N'-Diphenyl-p-phenylenediamine (DPPD)	N,N'-Diphenyl-p-phenylenediamine	74-31-7
Disulfides		
Di-(2-ethyl)hexylphosphorylpolysulfide) (SDT)	Bis-(ethylhexylthiophosphoryl) polysulfide	
3,5-Di-tert-Butyl-4-hydroxybenzaldehyde		1620-98-0
2,2’-Dithiobis(benzothiazole)	2,2'-Dithiobisbenzothiazole	120-78-5
Dithiocarbamates		
Dithiomorpholine (DTDM)	4,4'-Dithiodimorpholine	103-34-4
Dithiophosphates		
N,N`-Ditolyl-p-phenylenediamine (DTPD)	N,N'-Ditolyl-p-phenylenediamine	27417-40-9
Docosanoic acid		112-85-6
Dodecanoic acid		143-07-7
Dotriacontane		544-85-4
Drometrizol	2-(2H-Benzotriazol-2-yl)-4-methylphenol	2440-22-4
Eicosane		112-95-8
Erucylamide	Erucamide	112-84-5
Esters		
Ethanol, 2-butoxy-	2-Butoxyethanol	111-76-2
Ethanol, 1-(2-butoxyethoxy)	1-(2-Butoxyethoxy)ethanol	54446-78-5
Ethanone, 1,1'-(1,3-phenylene)bis-	Benzene-1,3-bis(acetyl)	6781-42-6
Ethanone, 1,1'-(1,4-phenylene)bis-	1,1-(1,4-Phenylene)bis-ethanone	1009-61-6
Ethanone, 1-[4-(1-methylethenyl)phenyl]-	1-[4-(1-Methylethenyl)phenyl]ethanone	5359-04-6
Ethyl Acetate		141-78-6
Ethyl benzene	Ethylbenzene	100-41-4
Ethyl benzene aldehyde	Benzaldehyde, 2-ethyl-	22927-13-5
Ethylene thiourea (Ethylene thiourea)		96-45-7
2-Ethyl-1-hexanol		104-76-7
1-Ethyl-4-Methyl Benzene	4-Ethyltoluene	622-96-8
Fluoranthene		206-44-0
Fluorene		86-73-7
Formaldehyde		50-00-0
Furan, 2-methyl	2-Methylfuran	534-22-5
2(3H)-Furanone,dihydro-4-hydroxy-	Dihydro-4-hydroxy-2(3H)-furanone; beta-Hydroxybutyrolactone	5469-16-9
Guanidines		
Halocarbon 11	Trichlorofluoromethane, Trichloro-fluoromethane, Freon 11	75-69-4
Hemeicosane		
Heptadecane		629-78-7
Heptane		142-82-5
Heptanonitrile	Heptanenitrile	629-08-3
Hexacosane		630-01-3
Hexadecane		544-76-3
Hexa(methoxymethyl)melamine	N,N,N',N',N'',N''-Hexakis(methoxymethyl)-1,3,5-triazine-2,4,6-triamine	3089-11-0
Hexamethylenetetramine	Methenamine	100-97-0
Hexane	n-Hexane	110-54-3
Hexanedioic acid, methyl ester	Methyl hexanedioate	627-91-8
Hexanoic acid, 2-ethyl-	2-Ethylhexanoic acid	149-57-5
Hydrocarbon (olefin/aromatic)		
7-Hydroxybenzo[f]flavone	7-Hydroxy-3-phenyl-1H-naphtho[2,1-b]pyran-1-one	86247-95-2
1-Hydroxypyrene		5315-79-7
Indeno[l,2,3-cd]pyrene	o-Phenylenepyrene	193-39-5
1H-isoindole-1,3 (2H)-dione	Phthalimide	85-41-6
iso-nonylphenol	3-Nonylphenol	11066-49-2
Isophorone		78-59-1
Isopropyl Alcohol	2-Propanol, Isopropanol	67-63-0
Isopropylbenzene	Cumene	98-82-8

Analyte	Synonym(s)	CAS#
Isopropyltoluene	1-Methyl-2-(propan-2-yl)benzene	527-84-4
Ketones		
Latex protein		
Limonene		138-86-3
MEK	Methyl ethyl ketone	78-93-3
2-Mercaptobenzothiazole		149-30-4
Methane, diethoxy-cyclohexane	Diethoxycyclohexanemethane; Bis(cyclohexyloxy)methane	1453-21-0
Methyl Alcohol	Methanol	67-56-1
2-Methylanthracene		613-12-7
2-Methyl-Butane	2-Methylbutane	78-78-4
2,2-Methylene-bis-(4-methyl-6-tert-butylphenol) (BPH)		119-47-1
Methylene Chloride	Dichloromethane	75-09-2
5-Methyl-2-hexanone	Methyl isoamyl ketone	110-12-3
1-Methylnaphthalene		90-12-0
2-Methylnaphthalene		91-57-6
3-Methyl-Pentane	3-Methylpentane	96-14-0
4-Methyl-2-pentanone	MIBK	108-10-1
1-Methylphenanthrene	1-Methyl phenanthrene	832-69-9
2-Methylphenanthrene		2531-84-2
3-Methylphenanthrene		832-71-3
9-Methylphenanthrene		883-20-5
2-Methylphenol	o-Cresol	95-48-7
4-Methylphenol	p-Cresol	106-44-5
MES (special purified aromatic oil)		
2-(4-morpholino)benzothiazole	2-morpholinothio benzothiazole (MBS); Morpholinothio-benzothiazole; N-Oxydiethylenebenzothiazole-2-sulfenamide	102-77-2
2-Morpholinodithiobenzothiazole (MBSS)	2-(Morpholin-4-yldithio)-1,3-benzothiazole	95-32-9
Naphthalene		91-20-3
Naphthalene, 2-(bromomethyl)-	2-Bromomethylnaphthalene	939-26-4
Naphthalic Anhydride	1H,3H-Naphtho(1,8-cd)pyran-1,3-dione	81-84-5
Napthenic oil		
Nitro compound (isomer of major peak)		
Nitro compound (nitro-ether derivative)		
Nitrogen containing substances		
Nitrosodibutylamine (n-)	N-Nitrosodibutylamine	924-16-3
Nitrosodiethylamine (n-)	N-Nitrosodiethylamine	55-18-5
Nitrosodimethylamine (n-)	N-Nitrosodimethylamine	62-75-9
n-Nitrosodiphenylamine	N-Nitrosodiphenylamine	86-30-6
Nitrosodipropylamine (n-)	N-Nitrosodipropylamine	621-64-7
Nitrosomorpholine (n-)	N-Nitrosomorpholine	59-89-2
Nitrosopiperidine (n-)	N-Nitrosopiperidine	100-75-4
Nitrosopyrrolidine (n-)	N-Nitrosopyrrolidine	930-55-2
Nonadecane		629-92-5
Nonanale	Nonanal	124-19-6
Nonane		111-84-2
4-n-nonylphenol	4-Nonylphenol	104-40-5
Octadecanoic acid, methyl ester	Methyl stearate	112-61-8
Octane		111-65-9
4-t-octylphenol	4-(1,1,3,3-Tetramethylbutyl)phenol, 4-tert-(octyl)-phenol	140-66-9
Optadecane		
Organic thiola and sulfides		
Orthocarbonate - Carboxy compound)		
N-Oxydiethylenedithiocarbamyl-N`-oxydiethylenesulfenamide (OTOS)		13752-51-7
PAHs	Polycyclic aromatic hydrocarbons	
Parrafinic oils	Mineral oil	8012-95-1
PCB sum		

Analyte	Synonym(s)	CAS#
PCDD/F sum		
Pentacosane		629-99-2
Pentane		109-66-0
Perylene		198-55-0
Petroleum Naphtha	Naphtha	8030-30-6
Phenalone	Phenalen-1-one	548-39-0
Phenanthrene		85-01-8
1-Phenanthrenecarboxylic acid, 1,2,3,4,4	1,2,3,4,4-1-Phenanthrene carboxylic acid; Dehydroabietic acid	1740-19-8
Phenol	2,4-Di-tert-butylphenol	108-95-2
Phenolics		
Phenol, 2,4-bis(1,1-dimethylethyl)-		96-76-4
Phenol, 2,4-bis(1-methyl-1-phenylethyl)-	2,4-Bis(1-methyl-1-phenylethyl)phenol	2772-45-4
Phenol, m-tert-butyl-	3-tert-Butylphenol	585-34-2
Phenylbenzimidazole	2-Phenylbenzimidazole	716-79-0
p-Phenylenediamines		
Phenylenediamines		
2-(1-phenylethyl)-phenol	2-(1-Phenylethyl)phenol	26857-99-8
3-Phenyl-2-propenal	3-Phenylprop-2-enal	104-55-2
Phthalates		
PM 2.5		
PM10		
Poly- and di-nitrobenzenes		
Poly-p-dinitrosobenzene		
Propene	1-Propene; propylene	115-07-1
Propylbenzene		103-65-1
Pyrazole		288-13-1
Pyrene		129-00-0
Pyrimidine, 2-(4-pentylphenyl)-5-propyl-		94320-32-8
2-Pyrrolidinone. 1-methyl-	N-Methyl-2-pyrrolidone	872-50-4
Quinones		
Resorcinol		108-46-3
Rethene		
Siloxanes		
Styrene		100-42-5
Styrene oligomers		
Substituted p-Phenylenediamines		
Sulfur containing organics		
Sulfur Donors		
Sulphenamides		
TDAE (special purified aromatic oil)		
Tertbutylacetophenone	3,3-dimethyl-1-phenylbutan-1-one	31366-07-1
N-tert-Butyl-2-benzothiazolesulfenamide (TBBS)		95-31-8
4-tert butylphenol	4-tert-Butylphenol	98-54-4
Tetraalkylthiuram disulfides		
Tetrabenzylthiuram disulfide (TBZTD)		10591-85-2
Tetrabutylthiuram disulfide (TBTD)		1634-02-2
Tetrachloroethene	Tetrachloroethylene; perchloroethylene	127-18-4
Tetracosane		646-31-1
Tetraethylthiuram disulfide	Disulfiram	97-77-8
Tetrahydrofuran		109-99-9
Tetramethylthiuram disulfide	Thiram	137-26-8
Tetramethylthiuram monosulfide		97-74-5
Thiazoles		
Thioureas		
Thiurams		
Thiuram sulfides		
Toluene		108-88-3
Total petroleum hydrocarbons		
Trans trans-muconic acid	(E,E)-Muconic acid	3588-17-8

Analyte	Synonym(s)	CAS#
Trimethyl-1,2-dihydroquinoline (TMDQ)	1,2-Dihydro-2,2,4-trimethylquinoline, polymer	26780-96-1
1,1,1-Trichloroethane		71-55-6
Trichloroethylene		79-01-6
1,1,2-Trichloro-1,2,2-trifluoroethane		76-13-1
Trichloro-trifluoroethane	1,1,1-Trichloro-2,2,2-trifluoroethane	354-58-5
Tricosane		638-67-5
1,2,3-Trimethyl benzene	1,2,3-Trimethylbenzene	526-73-8
1,2,4-Trimethyl benzene	1,2,4-Trimethylbenzene	95-63-6
1,3,5-Trimethyl benzene	1,3,5-Trimethylbenzene	108-67-8
2,2,4-Trimethyl-1,2-dihydroquinoline (TMQ)	1,2-Dihydro-2,2,4-trimethylquinoline, polymer	26780-96-1
Vinyl Acetate		108-05-4
White gasoline	Natural gasoline	8006-61-9
o-Xylene		95-47-6
Xylenes		1330-20-7
Zn-Dibenzyldithiocarbamate (ZBEC)		136-23-2
Zn-Diethyldithiocarbamate (ZDEC)	Zinc diethyldithiocarbamate	14324-55-1
Zn-Dimethyldithiocarbamate (ZDMC)	Ziram	137-30-4
Zn-dibutyldithiocarbamate (ZDBC)		
ZnO	Zinc Oxide	1314-13-2

Appendix D
Standard Operating Procedure (SOP) Lists for Tire Crumb Rubber Characterization Research

Tables D1 and D2 list the standard operating procedures (SOPs) that were prepared or used for the tire crumb rubber characterization research activities by research area. The SOPs will also be made available in a separate EPA report. These are research-level SOPs. Descriptions in the table below are the SOP topic areas, not the formal SOP titles.

Table D-1. Summary of the Tire Crumb Rubber Field Collection Standard Operating Procedures (SOPs)

Type of Sample Collection	Associated SOPs
Tire Crumb Rubber from Tire Recycling Plants	D-EMMD-PHCB-038-SOP-01
Tire Crumb Rubber from Synthetic Turf Fields	D-SED-IEMB-001-SOP-01
Tire Crumb Rubber from Synthetic Turf Fields for Microbiome Analysis	D-SED-EFAB-009-SOP-01
Questionnaire for administrators of Synthetic Turf Fields on operations, turf history and maintenance, use	D-SED-EHCAB-002-SOP-01
iButton Temperature logging system to assure the integrity of samples collected for microbial analysis	D-SED-EFAB-010-SOP-01

Table D-2. Summary of the Tire Crumb Rubber Characterization Study Laboratory SOPs[a]

Sample or Analysis Type	Analytes	Type of Analysis	SOP Identification Number
Preparation of Sub-samples for Analysis	SVOCs, Metals	Preparation of Tire Crumb Rubber Substances for Multi-residue Characterization	D-EMMD-PHCB-040-SOP-1
Tire Crumb Rubber Particle Characterization	Particle Size Analysis (PSA)	Sieving Procedure for Tire Crumb Rubber Samples	D-EMMD-ECB-002-SOP-03
Tire Crumb Rubber Particle Characterization	Bulk samples-total element concentration	Innov-X XRF ANALYSIS PROCEDURES: For Tire Crumb Samples	D-EMMD-ECB-004-SOP-01
Tire Crumb Rubber Particle Characterization	Particle size & distribution	SEM Analysis of Tire Crumb Particles for Sizing and Metals	D-EMMD-ECB-001-SOP-01
Tire Crumb Rubber Particle Characterization	Particle Moisture	Determination of Moisture Content in Tire Crumb Rubber	D-EMMD-PHCB-041-SOP-01
Tire Crumb Emissions Experiments	VOCs	Setup and operation of small environmental chambers during testing	NRMRL MOP-802
Tire Crumb Emissions Experiments	VOCs	Setup and Operation of the Markes Micro-Chamber	NRMRL SOP AEMD-6401
Tire Crumb Emissions Experiments	VOCs	Operation of the OPTO Display Software Data Acquisition System in the small chamber laboratory	NRMRL MOP-803
Tire Crumb Emissions Experiments	VOCs	Chain of Custody Procedures for the Receipt and Transfer of Samples	NRMRL SOP AEMD-6402
Tire Crumb Emissions Experiments	VOCs	Operation of Clean Air System for the Small Chamber Laboratory	NRMRL MOP-806
Tire Crumb Emissions Experiments	VOCs	Sampling and extraction procedures for DNPH-Coated Silica gel cartridges used to determine air concentrations of formaldehyde and other aldehydes	NRMRL MOP-812
Tire Crumb Emissions Experiments	VOCs-Formaldehyde	Operation of the Agilent 1200 HPLC for Analysis of DNPH-Carbonyls	NRMRL MOP-826
Tire Crumb Emissions Experiments	VOCs-Formaldehyde	High Performance Liquid Chromatography (HPLC) Calibration Standard Preparation Procedure	NRMRL MOP-827

Table D-2 Continued

Sample or Analysis Type	Analytes	Type of Analysis	SOP Identification Number
Tire Crumb Emissions Experiments (Continued)	VOCs	Actively loading sorbent tubes with volatile organic compounds	D-EMMD-AQB-015-SOP-01
Tire Crumb Emissions Experiments	VOCs	Determination of Volatile Organic Compounds Desorbed from Sorbent Tubes Using the Markes International Bench ToF-Select ToF GC/MS System	D-EMMD-AQB-017-SOP-01
Tire Crumb Emissions Experiments	VOCs	Determination of Volatile Organic Compounds Desorbed from Sorbent Tubes Using the Markes International Ultra/Unity Thermal Desorption System	D-EMMD-AQB-018-SOP-01 Companion SOP to D-EMMD-AQB-017-SOP-01
Tire Crumb Emissions Experiments	VOCs	Collecting Air Samples from the Small Environmental Testing Chambers Using Carbopack™ X Sorbent Tubes	NRMRL-SOP-AEMD-6404
Tire Crumb Emissions Experiments	SVOCs	Collecting Air Samples from the Markes Micro-chambers Using PUF Plugs	NRMRL-SOP-AEMD-6403-01-0
Tire Crumb Emissions Experiments	Chamber clean-up	Glassware and Chamber Cleaning Procedure	NRMRL-SOP-AEMD-6405
Tire Crumb Emissions Experiments	SVOCs	Standard Operating Procedure for Preparation of Air Samples Collected on PUF Plugs for GC/MS Analysis	D-EMMD-PHCB-036-SOP-01
Organic Analysis	VOCs	Determination of Volatile Organic Compounds Desorbed from Sorbent Tubes Using the Markes International Bench ToF-Select ToF GC/MS System	D-EMMD-AQB-017-SOP-01
Organic Analysis	VOCs	Determination of Volatile Organic Compounds Desorbed from Sorbent Tubes Using the Markes International Ultra/Unity Thermal Desorption System	D-EMMD-AQB-018-SOP-01 Companion SOP to D-EMMD-AQB-017-SOP-01
Organic Analysis	Extraction of SVOCs and GC analysis	Extraction and Analysis of SVOCs in Tire Crumb Rubber Samples	D-EMMD- PHCB-033-SOP-01
Organic Analysis	SVOCs	Standard Operating Procedure for Preparation of Air Samples Collected on PUF Plugs for GC/MS Analysis	D-EMMD-PHCB-036-SOP-01
Organic Analysis	SVOCs LC/ToF/MS analysis	Analytical method for non-targeted and suspect screening in environmental and biological samples using Time of Flight Mass Spectrometry (TOFMS)	D-EMMD-PHCB-034-SOP-01
Metals Analysis	Extraction	Total Nitric Acid Extractable Metals from Solid Samples by Microwave Digestion	D-EMMD-ECB-003-SOP-01
Metals Analysis	ICP/MS analysis	Operation and Maintenance of the Element High-Resolution Inductively Coupled Plasma Mass Spectrometry Instrument	D-EMMD-PHCB-042-SOP-03
Microbial Analysis	Extraction	Extraction of microbes and DNA genomes from samples collected from artificial turf athletic fields	D-SED-EFAB-011-SOP-01
Microbial Analysis	PCR analysis	PCR, Library Preparation and MiSeq Sequencing of Samples for 16S microbiome analysis	D-SED-EFAB-012-SOP-01

Table D-2 Continued

Sample or Analysis Type	Analytes	Type of Analysis	SOP Identification Number
Microbial Analysis (Continued)	Genome analysis	16S rRNA Gene Sequence Analysis	D-SED-EIB-SOP-1907-0
Microbial Analysis	PCR	Droplet digital PCR (ddPCR) analysis of genomic targets;	D-SED-EFAB-014-SOP-01
Microbial Analysis	Data analysis	Analysis of data generated from the droplet digital PCR (ddPCR)	D-SED-EFAB-015-SOP-01

[a] SOP = standard operating procedure; SVOC = semivolatile organic compound; VOC = volatile organic compound; XRF = X-ray fluorescence spectrometry; SEM = Scanning electron microscopy; DNPH = 2, 4-dinitrophenylhydrazine; HPLC = High performance liquid chromatography; ToF = time of flight; GC/MS = gas chromatography/mass spectrometry; PUF = polyurethane foam; DNA = deoxyribonucleic acid; ICP/MS = inductively couple plasma/mass spectrometry; PCR = polymerase chain reaction; rRNA = ribosomal ribonucleic acid; ddPCR = digital droplet polymerase chain reaction

Appendix E

Quality Assurance and Quality Control

E.1 Quality Overview and Planning

The U.S. Environmental Protection Agency (EPA) requires that all data collected for the characterization of environmental processes and conditions are of the appropriate type and quality for their intended use. This is accomplished through an EPA-wide quality system for environmental data. Components of the EPA quality system can be found at http://www.epa.gov/quality/. EPA policy is based on ANSI/ASQ E4-2004 (an American National Standard). This standard recommends a tiered approach that includes the development and use of Quality Management Plans (QMPs). The organizational units in EPA that generate and/or use environmental data are required to have EPA-approved QMPs. Programmatic QMPs may also be written when program managers and their quality assurance (QA) staff decide a program is of sufficient complexity to benefit from a QMP.

A programmatic QMP was developed for the research conducted under the Federal Research Action Plan on Recycled Tire Crumb Used on Playing Fields and Playgrounds, described here as the Tire Crumb Research Study (TCRS). The TCRS QMP describes the program's organizational structure, defines and assigns QA and quality control (QC) responsibilities, and describes the processes and procedures used to plan, implement and assess the effectiveness of the quality system. The TCRS QMP is supported by project-specific QA project plans (QAPPs).

The TCRS QAPPs provide the technical details and associated QA/QC procedures for the research activities that address TCRS objectives as described in the TCRS Research Protocol, "Collections Related to Synthetic Turf Fields with Crumb Rubber Infill." Written sample collection and analysis research-level standard operating procedures (SOPs) were also prepared to support the QAPPs, when appropriate.

The EPA worked cooperatively with the Centers for Disease Control and Prevention/Agency for Toxic Substances and Disease Registry (CDC/ATSDR) on QA and QC activities across the TCRS research topic areas. Analyses conducted by CDC/ATSDR and/or their associates followed the QA/QC guidelines and protocols required and approved by their associated organizations. QC results for bioaccessibility measurements conducted by CDC are included in this QA/QC Appendix.

The following elements were critical for producing high-quality research results:

- Research projects comply with Agency requirements and guidance for QAPPs, including the use of systematic planning;
- Technical system audits (TSAs) and data quality reviews, as described in the QMP or project-specific QAPPs;
- QA review of all products that include environmental data; and
- Inclusion of a QA/QC section in the final study report.

This research was supported by a Program QA Manager (PQAM) who was independent of the technical work and who assisted the QA staff in the implementation of the TCRS quality program and QMP requirements. Requirements specified in the TCRS QMP and QAPPs were intended to ensure consistency in the QA approach for all participating organizations.

E.2 Quality Assurance Activities and Results

E.2.1 Quality Assurance Project Plans

As part of the QA processes implemented in this research study, QAPPs were prepared by research staff for several components of the TCRS, including the Literature Review/Gaps Analysis and the tire crumb rubber characterization. QAPPs were reviewed and approved by the respective research staff supervisors and QAMs. One QMP and four QAPPs (or QAPP addendums) were prepared for the TCRS (Table E-1).

Table E-1. Quality Management Plan and Quality Assurance Project Plans (QAPPs)/Addendums[a]

#	QMP/QAPP Title	Approval Date
1	QAPP for Literature Review and Data Gap Analysis for the EPA-ORD portion of the Tire Crumb Research Study	May 2016
2	QAPP for Characterization of the Microbiome and Occurrence of the Antibiotic Resistance Genes in Tire Crumb Rubber Artificial Turf Athletic Fields QAPP	July 2016
3	Quality Management Plan Tire Crumb Science Workgroup	August 2016
4	QAPP for Tire Crumb Research Study Sampling and Analyses	October 2016 (provisional approval for field study August 2016)
5	QAPP Addendum for the Tire Crumb Research Study – Statistical Analysis	February 2018

[a] EPA-ORD = U.S. Environmental Protection Agency-Office of Research and Development

E.2.2 Standard Operating Procedures

Research-level SOPs were developed for all sample collection, data collection and sample analysis activities. Prior to undertaking the activities covered by a SOP, the SOP was reviewed and approved by the respective researcher staff supervisors and QAMs. A list of research-level SOPs developed or applied in this study is provided in Appendix D. The research SOPs will also be published as part of an EPA research report.

E.2.3 Technical Systems Audits

The EPA Office of Research and Development (ORD) quality program requires at least one audit be conducted per project, at a minimum,. However, due to the high visibility and multi-component nature of the TCRS, a robust quality review process (including technical system audits and data quality reviews) was implemented to identify and correct issues immediately. Seven separate technical system audits (TSAs) were conducted of tire crumb rubber characterization activities and included audits on field sampling activities, field measurement activities and laboratory analyses. The purpose of each audit was to ensure that the research tasks prescribed within the QAPPs or SOPs were verified and documented. These audits are summarized in Table E-2. Most discrepancies/inconsistencies identified in the audits were minor and were classified as observations. Minor findings included lack of some field documentation, inadequate use of research notebooks or some researchers not using a research notebook, and outdated balance calibrations. Observations and findings were noted in audit reports and corrected during or shortly after each audit. **No significant findings were identified during the audits, and minor findings that were identified did not directly affect the integrity or quality of the data.**

Table E-2. Technical System Audits of Tire Crumb Rubber Characterization[a,b]

Date	Target	Description	Interviewed	Auditor
11/2/2016	Tire Crumb Characterization field sampling activities	TSA of field data collection activities and adherence to planned activities was conducted at two undisclosed recreational field locations near Concord, Missouri. The TSA was performed using the TCRS Sampling and Analysis QAPP and referenced field SOPs as the audit standard. Findings and observations identified included incomplete field documentation or inadequate information on the chain of custody. Corrective actions were addressed during exposure measurement field activities (reported in Part II of the TCRS).	CDC participants	Christine Alvarez
11/28/2016	SVOCs GC/MS	On-site TSA of laboratory sample receipt, storage, processing and analysis activities for GC/MS analysis of SVOCs. The audit standard used for the TSA was Appendix H of the TCRS Sampling and Analysis QAPP and ORD QA Policies and Procedures for Scientific Recordkeeping (Paper) and ORD Laboratory and Field-Based Research (PPM 13.2 and PPM 13.4). Minor observations included suggestions on improvement of 3-ring binder usage and documentation of lot numbers used for solvents.	Scott Clifton	Sania Tong-Argao and Christine Alvarez
11/28/2016 and 11/30/2016	ICP/MS	On-site TSA of laboratory sample receipt, storage, processing and analysis activities for ICP/MS analysis of metals. The audit standard used for the TSA was Appendix J of the TCRS Sampling and Analysis QAPP and ORD QA Policies and Procedures for Scientific Recordkeeping (Paper) and ORD Laboratory and Field-Based Research (PPM 13.2 and PPM 13.4). Observations included suggestions to improve how data information was shared between laboratories and improve documentation of where files were stored.	Kasey Kovalcik	Sania Tong-Argao and Christine Alvarez
2/9/2017 and 2/10/2017	VOCs	On-site TSA of laboratory sample receipt, storage, processing and analysis activities for TOF GC/MS analysis of VOCs. The audit standard used for the TSA was Appendix G of the TCRS Sampling and Analysis QAPP and ORD QA Policies and Procedures for Scientific Recordkeeping (Paper) and ORD Laboratory and Field-Based Research (PPM 13.2 and PPM 13.4). Minor observations included suggestions to improve research notebook documentation and management of project files.	Don Whitaker	Sania Tong-Argao and Christine Alvarez

Table E-2 Continued

Date	Target	Description	Interviewed	Auditor
11/14/2016	SVOCs LC/MS	On-site TSA of laboratory sample receipt, storage, processing and analysis activities for LC/MS analysis of SVOCs. The audit standard used for the TSA was Appendix I of the TCRS Sampling and Analysis QAPP and ORD QA Policies and Procedures for Scientific Recordkeeping (Paper) and ORD Laboratory and Field-Based Research (PPM 13.2 and PPM 13.4). Findings included a lack of refrigerator temperature monitoring for the refrigerator where samples were stored and the redundant backup system for data backup not being in operation at the time. Minor observations included sample preparation discrepancies that were not outlined in the cited SOP, lack of formal chain-of-custody forms (but documentation of sample tracking was readily available), labeling/documentation for solvents/solutions used, storage/expiration date of tuning solution, documentation of calibration file location, and file management recommendations.	Mark Strynar	Sania Tong-Argao and Christine Alvarez
10/4/2016	Microbiological activities	On-site TSA conducted at the NERL Cincinnati Laboratory of a variety of activities performed for this project, including project management, sample receipt, processing and analysis. Findings included balances that had exceeded their calibration date, insufficient or lack of documentation and inadequate storage of electronic files.	Nichole Brinkman	Brittany Stuart and Margie Vazquez
11/23/2016	TCRS particle characterization, metals digestion, and XRF analysis activities	On-site TSA conducted at the Las Vegas EPA laboratory to assess QA/QC procedures specified in the TCRS Quality Management Plan, TCRS Sampling and Analyses QAPP and Las Vegas SOPs. Findings included the need to update a laboratory SOP to describe how samples were being dried and outdated calibration of balances.	Steve Gardner, Georges-Marie Momplasir	Margie Vazquez

[a] Note: All documentation associated with these audits, including audit reports, corrective actions and email correspondence is documented and saved in the TCRS QA SharePoint, https://usepa.sharepoint.com/sites/ORD_Work/TCRS%20QA/SitePages/Home.aspx.

[b] TSA = technical system audit; TCRS = Tire Crumb Research Study; QAPP = quality assurance project plan; SOP = standard operating procedure; CDC = U.S. Centers for Disease Control and Prevention; RTP = Research Triangle Park; EPA = U.S. Environmental Protection Agency; NERL = National Exposure Research Laboratory; ICP/MS = inductively coupled plasma/mass spectrometry; ORD = Office of Research and Development; QA = quality assurance; VOC = volatile organic compound; SVOC = semivolatile organic compound; GC/MS = gas chromatography/mass spectrometry; TOF = time of flight; LC/MS = liquid chromatography/mass spectrometry; QC = quality control

E.2.4 Deviations from the QAPPs or SOPs

There were no significant deviations from the QAPPs and/or QAPP addendums listed in Table E-1. Deviations from SOPs identified during field or laboratory activities were documented in the researcher's research notebook and confirmed, if applicable, during field or laboratory audits. All SOPs unique to this project that deviated from the original procedure were amended and, if needed, reviewed by the QAM and approved by the analyst's supervisor. Minor changes related to specific samples or information collection were documented on the TCRS field forms and chain of custody.

E.2.5 Data Quality Reviews

Reviews of data quality were performed at several stages throughout the course of the research study (Table E-3). Data produced through field sample collection, data collection and sample analysis received data quality reviews by QAMs and/or secondary technical expert reviewers. Reviews were performed after data were produced and before they were submitted for data processing or included in data analysis.

Much of the analytical chemistry measurement data for the tire crumb rubber characterization was compiled, standardized and processed by data managers to prepare data analysis files. Data quality reviews were performed to verify that the data in the data analysis files were correct and complete and that all processing calculations were performed correctly.

Using the data analysis files, data were organized to prepare outputs for reporting, such as tables and figures. Statistical summaries of the data were prepared and in some cases, statistical testing was performed. Data quality reviews were performed to ensure that the data analysis outputs were complete and correct and that data calculations and analyses were performed correctly.

Finally, multiple data quality reviews were performed to verify that the outputs from the data analyses were correctly and completely compiled in report tables and figures. This set of data quality reviews is depicted in the last two rows of Table E-3, with no quantification of the number of reviews completed for data compilation and analysis; the completion date reflects the completion of the last data compilation and/or analysis reviews.

Table E-3. Data Quality Reviews of Tire Crumb Rubber Characterization[a]

Data/Information Type	Technical Lead	Reviewer	Completion Date
Synthetic field questionnaire	CDC used the forms, developed jointly by EPA and CDC	Kent Thomas	11/2016
Emissions chamber data	Xiaoyu Liu	Libby Nessley	01/26/2017
Formaldehyde emissions	Xiaoyu Liu	Libby Nessley	01/26/2017
Microbial targeted	Nichole Brinkman	Emily Annekan	04/04/2017
Microbial non-targeted	Scott Keely	Nichole Brinkman	04/04/2017
Microbial Analysis	Nichole Brinkman	Brittany Stuart	04/04/2017
Field sample data	Kent Thomas	Larry McMillian	05/03/2017
Moisture content	Kasey Kovalcik	Myriam Medina-Vera	05/08/2017
SVOC LC/MS extractions	Mark Strynar	James McCord	05/08/2017
SVOC LC/MS emissions	Mark Strynar	James McCord	05/08/2017
VOC & SVOC non-targeted data	Don Whitaker, Scott Clifton, Mark Strynar	James McCord	05/08/2017
SEM characterization	Ed Heithmar	Tammy Jones-Lepp	05/08/2017
Metals XRF	Steve Gardner	Tammy Jones-Lepp	05/18/2017
Metals ICP/MS digests	Kasey Kovalcik	Clay Nelson	06/20/2017
Particle size measurements	Steve Gardner	Tammy Jones-Lepp	08/20/2017
VOC emissions	Don Whitaker	Christine Alvarez	12/14/2017
SVOC GC/MS emissions	Scott Clifton	Elin Ulrich	12/20/2017
SVOC GC/MS extractions	Scott Clifton	Elin Ulrich	02/13/2018
Metals Determination by HR-ICPMS	Kasey D. Kovalcik	Georges-Marie Momplaisir	02/15/2018
Data Analysis	BJ George	Christine Alvarez	03/29/2018
Data Compilation	Carry Croghan	James Noel and Christine Alvarez	03/30/2018

[a] CDC = U.S. Centers for Disease Control and Prevention; EPA = U.S. Environmental Protection Agency; ICP/MS = inductively coupled plasma/mass spectrometry; XRF = x-ray fluorescence spectrometry; VOC = volatile organic compound; SVOC = semivolatile organic compound; GC/MS = gas chromatography/mass spectrometry; LC/MS = liquid chromatography/mass spectrometry; SEM = scanning electron microscopy; HR-ICPMS = high resolution magnetic sector inductively coupled plasma mass spectrometer

E.3 Quality Control Overview

Numerous quality control activities and analyses were performed over the course of the study and included, but were not limited to the following:

- Sample collection media and sample containers were pre-cleaned or purchased as certifiably clean, when appropriate;
- Whenever possible, media were evaluated prior to field deployment to ensure minimal background or interferences, and blank media were analyzed to assess potential background contamination;
- Chain of custody procedures were implemented for all samples;
- Field quality control samples, consisting of blank, spike, and duplicate samples, were taken when applicable; location-specific field blanks were taken to and handled in the field in the same manner as samples, including opening and closing of containers, where appropriate;

- Laboratory quality control samples were applied, as appropriate, for each analysis method and included one or more of the following: procedure or method blanks and spikes, matrix blanks and spikes where feasible, and replicate sample analysis;
- Reference standards were obtained from reputable and traceable sources, where available;
- Solvents used for device cleaning, media preparation, or sample extraction were HPLC-grade or better in purity;
- Appropriate methods were used to determine analytical detection or quantifiable limits and to quantify target chemical amounts in samples;
- Blank and recovery correction were applied, as appropriate;
- Research notebooks were maintained.

However, there were limitations in implementing quality control assessment approaches for the tire crumb rubber characterization due to the nature of the matrix and the lack of available quality control or quality assurance materials and standards. No reliable procedures were identified for preparing spiked field control or matrix recovery samples (i.e., for spiking tire crumb rubber with metal, VOC or SVOC target analytes). Extraction and digestion spikes were used to evaluate analyte recovery through analytical methods for tire crumb rubber.

Key quality control measures and their results are reported in this Appendix, including:

- *Completeness:* a measure of the amount of verified data obtained from a measurement system compared to the amount of data that was expected to be obtained under normal conditions.
- *Quantification Limits*: the lowest concentration or amount of analyte that can be measured in an analytical method to a known and acceptable degree of confidence and precision. This is determined in a manner that is appropriate and applicable for each type of measurement.
- *Background:* the amount of analyte or signal present that was not associated with the sample and can interfere with or inflate measurement results. Background is assessed by using unspiked field and/or laboratory media and analyses.
- *Precision:* a measure of mutual agreement among individual measurements of the same property, usually under prescribed similar conditions. Precision is best expressed in terms of the standard deviation.
- *Accuracy:* the degree of agreement of measurements (or an average of measurements) with an accepted reference or true value. Accuracy is a measure of the bias or systematic error in a system and was assessed by measuring recovery of target analytes through laboratory analysis and where applicable, through combined field and laboratory conditions and procedures.

Each of these general quality criteria and the process by which they were addressed were not universal throughout the study. Each analyst's technique, task and characterization process could differ substantially; therefore, it was impossible to have a standard operating procedure or consistent approach for addressing or validating all methods used in tire crumb rubber characterization. This Appendix describes how each method addressed the general quality controls described above.

Each analytical method had its own set of quality control measures appropriate for that method. In addition to the assessments listed above, the SOPs for the sample collection and sample analysis methods described quality control elements that were implemented for each method. Not all quality control procedures and results are reported here, however. For example, calibration procedures and acceptance criteria, mass spectrometer tuning check procedures and other quality-related activities related to quantitative analysis were described in the quantitative analysis SOPs. Quality control procedures for field sample collection were also described in their respective SOPs.

E.3.1 Tire Crumb Rubber Characterization Study Data Quality Indicators

Overall project-level data quality indicators (DQI) were developed for the tire crumb rubber characterization (Table E-4). Because the laboratories had limited experience analyzing the tire crumb rubber matrix, and because there are no standard methods for these analysis procedures, the DQI target values developed for tire crumb rubber characterization were considered to be objectives and were assessed as the work proceeded and following work completion. Additional data quality indicators were described, where applicable, in the technical SOPs for each experimental or analytical method.

Table E-4. Target Quantitative Data Quality Indicator Objectives for Tire Crumb Rubber Characterization[a]

Metric	Precision (%)	Accuracy (%)	% Completeness - Collection	% Completeness - Analysis
Metals ICP/MS	± 25	75 – 125	95	95
DNPH HPLC/UV	± 25	75 – 125	95	95
SVOC GC/MS/MS	± 25	70 – 130	95	95
VOC GC/TOFMS	± 25	70 – 130	95	95

[a] ICP/MS = inductively coupled plasma/mass spectrometry; DNPH = 2, 4-dinitrophenylhydrazine; HPLC/UV = High performance liquid chromatography/ultraviolet spectrometry; SVOC = semivolatile organic compound; GS/MS/MS = gas chromatography/tandem mass spectrometry; VOC = volatile organic compound; GC/TOFMS = gas chromatography/time-of-flight mass spectrometry

E.4 Tire Crumb Rubber Characterization Quality Control Results

Tire crumb rubber quality control measurement results are reported in the following subsections for:

- Metals analysis by inductively coupled plasma/mass spectrometry (ICP/MS) in tire crumb rubber digestion samples (Section E.4.1),
- Emission chamber experiments (Section E.4.2),
- Analysis of formaldehyde in chamber emission samples (Section E.4.3),
- Analysis of SVOCs by gas chromatography/tandem mass spectrometry (GC/MS/MS) in tire crumb rubber extract samples (Section E.4.4),
- Analysis of SVOCs by GC/MS/MS in chamber emission samples (Section E.4.5),
- Analysis of SVOCs by liquid chromatography/time-of-flight mass spectrometry (LC/TOFMS) in tire crumb rubber extract and chamber emission samples (Section E.4.6),
- Analysis of VOCs by gas chromatography/time-of-flight mass spectrometry (GC/TOFMS) in chamber emission samples (Section E.4.7),
- Microbiological analyses (Section E.4.8), and
- Bioaccessibility analyses for metals by ICP/MS (Section E.4.9).

E.4.1 Metals Analysis by ICP/MS

Completeness – All (100%) of the scheduled tire crumb rubber samples were successfully analyzed for metals by ICP/MS.

Quantification Limits – Table E-5 reports the minimum reporting limit for metal analytes in tire crumb rubber, when applied to the volume of tire crumb rubber typically digested.

Table E-5. ICP/MS Minimum Reportable Limits (MRL) for Metals in Crumb Rubber[a]

Chemical	Minimum Reportable Limit (mg/kg)
Aluminum	0.024
Antimony	0.0014
Arsenic	0.0020
Barium	0.011
Beryllium	0.0017
Cadmium	0.00076
Chromium	0.0018
Cobalt	0.00062
Copper	0.0018
Iron	0.0071
Lead	0.0013
Magnesium	0.018
Manganese	0.0012
Molybdenum	0.00058
Nickel	0.0012
Rubidium	0.0040
Selenium	0.040
Strontium	0.0022
Tin	0.00070
Vanadium	0.0029
Zinc	0.024

[a] ICP/MS = inductively coupled plasma/mass spectrometry

Blanks - Table E-6 reports average concentrations of metals in method blanks. One method blank was analyzed in each of nine digestion/analysis batches. Metals concentrations were adjusted for each sample by subtracting the method blank result for each metal analyte within each analysis batch.

Table E-6. Method Blank Quality Control Results for Metals in the Tire Crumb Matrix by ICP/MS[a,b]

Chemical	Tire Crumb Rubber Matrix Method Blanks Mean (µg/L)	Tire Crumb Rubber Matrix Method Blanks Standard Deviation (µg/L)
Aluminum	0.321	0.279
Antimony	< MRL	N/A
Arsenic	< MRL	N/A
Barium	0.591	1.647
Beryllium	0.011	0.007
Cadmium	< MRL	N/A

Table E-6 Continued

Chemical	Tire Crumb Rubber Matrix Method Blanks Mean (µg/L)	Tire Crumb Rubber Matrix Method Blanks Standard Deviation (µg/L)
Chromium	< MRL	N/A
Cobalt	0.020	0.033
Copper	< MRL	N/A
Iron	0.069	0.061
Lead	0.032	0.072
Magnesium	0.489	0.394
Molybdenum	0.011	0.011
Nickel	0.017	0.049
Rubidium	0.022	0.026
Selenium	< MRL	N/A
Strontium	0.020	0.018
Tin	0.020	0.027
Vanadium	0.026	0.024
Zinc	0.176	0.268

[a] Tire Crumb Rubber Matrix Method Blanks (n=9)

[b] ICP/MS = inductively coupled plasma/mass spectrometry; MRL = minimum reportable limit; N/A = not applicable

Recovery - Table E-7 reports method spike recovery results for each analyte. One method spike was analyzed for each digestion/analysis batch, with the exception of one batch. All analytes had average recoveries ranging from 80% to 118%, except for selenium at 72% recovery. No recovery adjustments were made in the sample analysis results.

Table E-7. Spike Recovery Quality Control Results for Metals in Crumb Microwave Digestion by ICP/MS[a,b]

Chemical	Tire Crumb Rubber Matrix Mean % Recovery	Tire Crumb Rubber Matrix % Recovery Standard Deviation
Aluminum	118	55
Antimony	98	12
Arsenic	80	5
Barium	90	3
Beryllium	90	3
Cadmium	89	4
Chromium	96	6
Cobalt	107	8
Copper	89	12
Iron	91	43
Lead	96	10
Magnesium	95	9
Molybdenum	93	4
Nickel	91	7
Rubidium	98	4

Table E-7 Continued

Chemical	Tire Crumb Rubber Matrix Mean % Recovery	Tire Crumb Rubber Matrix % Recovery Standard Deviation
Selenium	72	5
Strontium	100	5
Tin	98	12
Vanadium	92	6
Zinc	103	5

[a] ICP/MS = inductively coupled plasma/mass spectrometry

[b] Method Spikes (n=8); Spike = 250 microliters (µL); Spike solution from SCP Science (Champlain, NY)

Precision – Analysis precision was assessed by replicate analysis of tire crumb rubber digestion samples. Results are shown for selected metals in Section 4.9.1, Table 4-50 of the Volume 1 report (EPA/600/R-19/051a). Mean % relative standard deviations for 10 to 11 replicate analyses ranged from 0.47 to 1.3% for the selected metals.

DQI – Based on the quality control measurement results, all of the DQI objectives were met for metals ICP/MS analyses.

E.4.2 Chamber Emission Experiments

QA/QC procedures for the chamber emission experiments were implemented by following the guidelines and procedures detailed in the approved addendum to the overarching NERL QAPP for Tire Crumb Research Study Sampling and Analysis.

Data Quality Indicators Objectives - DQI objectives for critical chamber emission measurements in this study were based on historical data obtained in similar studies and from laboratory evaluations of chamber emissions sampling methods and analysis. DQI objectives for the measurement parameters and validation methods of chamber testing are listed in Tables E-8 and E-9.

Table E-8. Data Quality Indicator Objectives for 53-L Small Chamber Operating Parameters[a]

Measurement Parameters	Control Method	Target Point	% Relative Standard Deviation
Chamber temperature	Incubator	25/60 audit °C	5
Chamber RH	Water vapor generator/ dilution system	45% RH (25 °C) 7% RH (60 °C)	10
Chamber ACH	Mass flow controllers/meters	1.0 ACH	10

[a] °C = degrees Celsius; RH = relative humidity; ACH = air changes per hour

Table E-9. Data Quality Indicator Objectives for Micro-chamber Operating Parameters[a]

Measurement Parameters	Control Method	Target Point	% Relative Standard Deviation
Chamber temperature	Internal heater	25/60 °C	5
Chamber inlet air RH	Water vapor generator/dilution system	45% RH (25 °C) 7% RH (60 °C)	10
ACH for 44 mL chambers (µ-CTE™ system)	Mass flow controllers/meters	82 ACH (25 °C)[b] / 72 ACH (60 °C)[b]	10
ACH for 114 mL chambers (M-CTE250™ system)	Mass flow controllers/meters	32 ACH (25 °C)[b] / 28 ACH (60 °C)[b]	10

[a] °C = degrees Celsius; RH = relative humidity; ACH = air changes per hour; µ = micro; CTE = Chamber/Thermal Extractor
[b] Based on a 60 mL/min air flow through each micro-chamber.

Instrument Calibration – Calibration of the system components was conducted prior to collection of the reportable data. The small test chamber environmental system components operated by the OPTO 22 data acquisition system (DAS), including temperature sensors, relative humidity (RH) sensors, and mass flow controllers were calibrated between May and July 2016 by the Air and Energy Management Division (AEMD) Metrology Laboratory. The chamber testing started on August 16, 2016. Any equipment received after testing had begun was either calibrated by the AEMD Metrology Laboratory or received from the manufacturer with a valid calibration certificate. The thermocouple and RH probes for micro-chamber operation were calibrated by the AEMD Metrology Laboratory between April and May 2016. The Gilibrator primary flow calibrators used to measure sampling air flows were calibrated between April and June 2016 by the manufacturer. The balances were calibrated between April and July 2016 by the AEMD Metrology Laboratory.

Temperature sensors were calibrated by comparison to a National Institute for Standards and Technology (NIST)-traceable reference device. RH sensors were calibrated using aqueous salt solutions at 11% and 75% (nominal). Mass flow controllers were calibrated using a Molbloc mass flow rate calibration system reference device (DH Instruments, Phoenix, AZ, USA). The balances were calibrated using NIST-traceable weights. In addition, before and after a subsample was weighed, the balance was checked with NIST-traceable weights.

Data Quality: Environmental Parameters of Small Chamber Tests - Environmental conditions in the small chambers, such as temperature and RH, were recorded by the OPTO 22 DAS continuously during the tests (about 103 data points for a 24-hour test). The air exchange rate of the small chamber was calculated in air changes per hour (ACH) based on the average flow rate of outlet air measured with a Gilibrator at the start and end of each test. Overall, the test conditions under 25 °C, 45% RH, and 1 ACH were much more stable than the test conditions under 60 °C, 7% RH, and 1 ACH (Table E-10 and Table E-11). For the 25 °C tests, one test had % relative standard deviation (%RSD) for temperature above the 5% DQI objective and two tests had %RSD for % RH above the 10% DQI objective (Table E-10). The majority of 60 °C tests failed to meet DQI objectives for both temperature and % RH (Table E-11). One reason for these failures under 60 °C test conditions was that the tire crumb rubber samples were at room temperature before they were placed into the 60 °C testing chamber, so it took minutes to reach equilibrium at 60 °C. In addition, moisture was observed in the tested tire crumb samples. When the samples were heated up to 60 °C, the moisture coming off the samples affected the RH measurement in the chamber.

Table E-10. Summary of 53-L Small Chamber Operating Parameters at 25 °C (88 tests)[a]

Parameters	Temperature (°C)	% RH	ACH
Average	25.04	46.09	1.00
Minimum	24.93	43.61	0.97
Maximum	25.42	48.76	1.03
% Out of DQI	1	2	0

[a] °C = degrees Celsius; % RH = percent relative humidity; ACH = air changes per hour; DQI = data quality indicator listed in Table E-8. If any of those criteria failed for the parameter measured during the course of each chamber test, that parameter is marked out of DQI for the test.

Table E-11. Summary of 53-L Small Chamber Operating Parameters at 60 °C (88 tests)[a]

Parameters	Temperature (°C)	% RH	ACH
Average	59.10	6.59	0.99
Minimum	57.36	4.78	0.90
Maximum	61.51	8.32	1.03
% Out of DQI	72	97	7

[a] °C = degrees Celsius; % RH = percent relative humidity; ACH = air changes per hour; DQI = data quality indicator listed in Table E-8. If any of those criteria failed for the parameter measured during the course of each chamber test, that parameter is marked out of DQI for the test.

Data Quality: Environmental Parameters of Micro-chamber Tests - Micro-chamber environmental parameters were measured and recorded manually prior to the start of a test during chamber setup, prior to and after the collection of chamber background samples, immediately following introduction of the tire crumb test material into the chambers, and prior to and following polyurethane foam (PUF) air sampling. Micro-chamber temperatures were measured using the Omega HH-KC25 digital thermometer with a type K thermocouple inserted directly into the micro-chamber pots to the approximate center of the chamber's volume. Micro-chamber RH measurements were collected at the micro-chambers' exhaust port outlets using the handheld Hanna Instruments HI 9565 dewpoint hygrometer unit included in the Markes Humidifier Accessory for the micro-chambers. A correction calculation was used to determine the micro-chamber's %RH based on this direct measurement at the exhaust ports (Vaisala Oyj, Humidity Conversion Formulas: Calculating Formulas for Humidity. 2013. Helsinki, Finland.).

Overall, temperature and air exchange rates were stable at 25 °C and 60 °C (Table E-12 and Table E-13) for all tests with the exception of three that had %RSD of temperature above the 5% DQI objective. The % RH varied more due to the same reasons noted for the small chamber tests.

Table E-12. Summary of Micro-chamber Operating Parameters at 25 °C[a]

Parameters	Temperature (°C)	% RH	ACH - 44mL	ACH - 114mL
Average	24.61	46.06	80.65	31.76
Minimum	23.42	41.46	75.68	30.88
Maximum	25.21	57.69	87.24	33.37
N (tests)	88	88	67	21
% Out of DQI	3	14	0	0

[a] °C = degrees Celsius; % RH = percent relative humidity; ACH = air changes per hour; DQI = data quality indicator listed in Table E-9. If any of those criteria failed for the parameter measured during the course of each chamber test, that parameter is marked out of DQI for the test.

Table E-13. Summary of Micro-chamber Operating Parameters at 60 °C[a]

Parameters	Temperature (°C)	% RH	ACH - 44mL	ACH - 114mL
Average	60.13	8.43	71.34	27.86
Minimum	58.54	6.74	67.08	27.26
Maximum	62.15	15.85	76.72	28.62
N (tests)	88	88	67	21
% Out of DQI	0	43	0	0

[a] °C = degrees Celsius; % RH = percent relative humidity; ACH = air changes per hour; DQI = data quality indicator listed in Table E-9. If any of those criteria failed for the parameter measured during the course of each chamber test, that parameter is marked out of DQI for the test.

E.4.3 Formaldehyde Analysis in Chamber Emission Samples by HPCL/UV

Data Quality Indicators Goals - The formaldehyde-DNPH (2,4-dinitrophenylhydrazine) air samples were collected from small chamber tests. DQI goals for critical measurements during this study were based on historical data obtained in similar studies and from laboratory evaluations of sampling methods and analysis. To the extent possible, standardized methods were followed. The DQI objectives for the measurement parameters and validation methods of formaldehyde-DNPH analysis were 100 ± 25% for the recoveries of daily calibration checks (DCCs) and internal audit program (IAP) standards and ± 25% for the %RSD of duplicates.

HPLC Calibration - The Agilent 1200 High Performance Liquid Chromatography (HPLC) with diode array detector (DAD) was calibrated on August 3, 2016 at six concentration levels with triplicate injections in the concentration range of 0.03 to 15 µg/mL. The stock solution of calibration standards was Aldehyde/Ketone-DNPH Stock Standard-15 (Cerilliant Corporation, Round Rock, TX, USA). The calibration was performed by using the response factor. The %RSD of the response factor was less than 6% and thus met the DQI goal of ±25% RSD.

E.4.3.1 Data Quality

Internal Audit Program (IAP) - The IAP standard was instituted to assess the accuracy and precision of the HPLC/DAD system. The IAP standard was prepared by someone other than the person who prepared the calibration standards, using a formaldehyde standard (TO11/IP-6A Aldehyde/Ketone-DNPH Mix, Supelco) obtained from a second source (Sigma Aldrich, St. Louis, MO, USA). The IAP standard was submitted to the analyst for calibration verification without stating its concentration. The percentage recovery of IAP standard was 95% and the %RSD of triplicate injections was 0.3%. They all met the criteria for IAP analysis, which were 100 ± 25% recoveries and % RSD of triplicate analyses within ± 25%.

Detection Limit - The method detection limit (MDL) was not investigated for this study. After the calibration, the instrument detection limit (IDL), 0.008 µg/mL, was determined by analyzing the lowest calibration standard seven times and then calculating three standard deviations from the measured concentrations of the standard. The practical quantification limit (PQL), the lowest calibration concentration in the calibration (0.03 µg/mL), was used in analysis, as well.

E.4.3.2 Quality Control Samples

Quality control samples consisted of chamber background samples, field blanks, duplicate samples, daily calibration checks and solvent blanks.

Chamber Background - For each chamber test, chamber background samples were collected prior to the tire crumb test material being loaded into the chambers. The duration and sampling volume of the background samples were the same as the duration and sampling volume of tire crumb emission samples. A typical background sample included the contribution of the contamination in the empty chamber, the sampling device, and the clean air supply. In the 25 °C tests, concentrations of formaldehyde detected in small chamber background samples were all less than the PQL. In the 60 °C small chamber tests, two chamber background samples were above the PQL. The background concentration was subtracted when the formaldehyde emission rate was calculated for each test.

Field Blanks - Field blanks accompanied every batch of background and tire crumb test samples. The field blank samples were DNPH cartridges that were unopened and handled and stored in the same manner as the formaldehyde-DNPH samples. They were stored with the samples in the same way the samples were stored. Field blank samples were used to determine background contamination on the sampling media due to media preparation, handling, and storage.

A total of 46 field blank samples were collected for all small chamber tests. Thirty-one (31) of the field blanks had no detectable formaldehyde. Fourteen (14) field blanks had formaldehyde concentrations below the PQL, and one (1) field blank sample had a formaldehyde concentration slightly above the PQL, with an on-column concentration of 0.033 µg/mL or 0.165 µg/cartridge.

Duplicates - Duplicate samples were used to estimate the precision of the sampling and analysis methods. A total of 38 duplicate DNPH samples were collected for the formaldehyde emission tests, of which 6 duplicates had formaldehyde concentrations above the lowest calibration concentration. The results of these 6 duplicates are summarized in Table E-14, which shows that the %RSDs of all duplicate samples were less than 25%, meeting the data quality indicator objective. Overall, the precision of the sampling and analysis methods were very good when formaldehyde concentrations were above the PQL.

Table E-14. Summary of Percent Relative Standard Deviation of Analyses of Duplicate Formaldehyde-DNPH Samples[a]

Statistic	Value
N[b]	6 duplicates
Minimum	1.77 %RSD
Maximum	10.62 %RSD
Average	7.31 %RSD
% Out of DQI	0

[a] DNPH = 2,4-dinitrophenylhydrazine; DQI = data quality indicators

[b.]32 duplicate samples with concentration below the practical quantification limit (PQL) were not included.

Twelve duplicate small chamber tests were conducted for this study. All formaldehyde emissions from those tests were below the lowest HPLC calibration level.

E.4.3.3 Daily Calibration Check

A daily calibration check (DCC) sample was analyzed to document the performance of the HPLC/DAD analysis. DCC samples were analyzed at the beginning and during the analysis sequence on each analysis day. Table E-15 summarizes the average recovery of DCCs for the analysis of formaldehyde-DNPH samples from the emission tests. The recoveries met the DQI acceptance criterion of 75 – 125% recovery.

Table E-15. Summary of the Recoveries of DCCs for Formaldehyde-DNPH Analysis[a]

Statistic	Value
Average	98.87% recovery
% Relative Standard Deviation	4.42
Minimum	111.84% recovery
Maximum	87.26% recovery
N	56 DCCs
% Out of DQI	0

[a] DCC = daily calibration check; DNPH = 2,4-dinitrophenylhydrazine; DQI = data quality indicators

E.4.3.4 Daily Solvent Blank Check

Two acetonitrile solvent blanks were also analyzed daily with every HPLC sample sequence, one before and the other after the sequence. The solvent blanks were free of formaldehyde-DNPH for all the samples.

E.4.3.5 Confirmation by LC/TOFMS

A calibration standard and several samples were analyzed by LC/TOFMS. Mass spectral confirmation was made confirming the presence of the DNPH derivative of formaldehyde in chamber emission samples.

E.4.4 SVOC Analysis by GC/MS/MS in Tire Crumb Rubber Extract Samples

Completeness – All (100%) of the scheduled tire crumb rubber samples were successfully analyzed for SVOCs by GC/MS/MS.

Quantification Limits – Table E-16 reports the minimum quantitation levels (MQLs) for SVOC analytes in tire crumb rubber extracts. There was variability in the MQLs across extraction/analysis batches.

Table E-16. Minimum Quantitation Level (MQL) Ranges for SVOCs in Tire Crumb Rubber Extracts by GC/MS/MS[a]

Chemical	MQL Range (mg/kg)
Aniline	0.001 – 0.0025
n-Butylbenzene	0.00025 – 0.0025
Naphthalene	0.0001 – 0.0005
Benzothiazole	0.001 – 0.01
Cyclohexylisothiocyanate	0.0005 – 0.0025
2-Methylnaphthalene	0.0001 – 0.001
1-Methylnaphthalene	0.0001 – 0.05
Dimethyl Phthalate	0.00025 – 0.0025
Acenaphthalene	0.0001 – 0.001
2,6-Di-tert-butyl-p-cresol	0.0001 – 0.05

Table E-16 Continued

Chemical	MQL Range (mg/kg)
Diethyl phthalate	0.0001 – 0.025
n-Hexadecane	0.0005 – 0.01
Fluorene	0.00025 – 0.005
4-tert-octylphenol	0.0025 – 0.025
2-Bromomethylnaphthalene	0.0001 – 0.025
2-Hydroxybenzothiazole	0.0025 – 0.05
Dibenzothiophene	0.0001 – 0.0025
Phenanthrene	0.0001 – 0.05
Anthracene	0.00025 – 0.001
Diisobutyl phthalate	0.00025 – 0.005
3-Methylphenanthrene	0.00025 – 0.0025
2-Methylphenanthrene	0.0005 – 0.025
1-Methylphenanthrene	0.0001 – 0.0025
Dibutyl phthalate	0.00025 – 0.005
Fluoranthene	0.00025 – 0.0025
Pyrene	0.00025 – 0.001
Di-N-hexylphthalate (2)13C2[b]	0.0001
Benzyl butyl phthalate	0.0001 – 0.0025
bis(2-ethylhexyl) adipate	0.0025 – 0.05
Benz(a)anthracene	0.00025 – 0.0025
Chrysene	0.0001 – 0.0025
Bis(2-ethylhexyl)phthalate	0.0005 – 0.005
Di-n-octyl phthalate	0.0001 – 0.05
Benzo(b)fluoranthene	0.001 – 0.005
Benzo(k)fluoranthene	0.001 – 0.005
Benzo(e)pyrene	0.001 – 0.0025
Benzo(e)pyrene d12[b]	0.0001 – 0.001
Benzo[a]pyrene	0.0001 – 0.0025
Benzo[a]pyrene d12[b]	0.0005
Bis(2,2,6,6-tetramethyl-4-piperidyl) sebacate	0.005 – 0.05
Indeno(1,2,3-cd)pyrene d12[b]	0.0005
Dibenz(a,h)anthracene d14[b]	0.0025
DBA + ICDP[c]	0.0005 – 0.025
Benzo[ghi]perylene d12[b]	0.00025 – 0.005
Benzo[ghi]perylene	0.0005 – 0.01
Coronene	0.00025 – 0.025

[a] SVOC = semivolatile organic compound; GC/MS/MS = gas chromatography/tandem mass spectrometry

[b] Added internal standard and surrogate recovery compounds

[c] DBA + ICDP = Dibenz(a,h)anthracene + Indeno(1,2,3-cd)pyrene

Blanks - Table E-17 reports average concentrations of SVOCs in reagent blanks. Groups of samples were prepared as 'batches' for extraction on the same date and subsequent analysis together. One reagent blank was analyzed in each of nine extraction/analysis batches. Cyclohexylisothiocyanate had the highest analyte background level, an average of 169 ng/g (equivalent to 0.169 mg/kg) in the reagent blanks. Sample concentrations were adjusted by subtracting the average reagent blank result for each SVOC analyte from the measured SVOC concentration.

Table E-17. Blanks Quality Control Results for SVOCs in Tire Crumb Rubber Extraction by GC/MS/MS[a,b]

Chemical	Reagent Blank Mean ng/g (equivalent)	Reagent Blank Standard Deviation ng/g (equivalent)
Aniline	6.9	5.3
n-Butylbenzene	0.1	0.4
Naphthalene	0	0.1
Benzothiazole	3.5	5.2
Cyclohexylisothiocyanate	169.1	43.2
2-Methylnaphthalene	0	0
1-Methylnaphthalene	0	0
Dimethyl Phthalate	0	0
Acenaphthalene	0	0
2,6-Di-tert-butyl-p-cresol	8.3	12.9
Diethyl phthalate	14	23.2
n-Hexadecane	19.2	31.6
Fluorene	0.1	0.3
4-tert-octylphenol	1.2	3.6
2-Bromomethylnaphthalene	0	0
2-Hydroxybenzothiazole	0	0
Dibenzothiophene	0	0
Phenanthrene	0.1	0.2
Anthracene	0	0
Diisobutyl phthalate	23.5	8.3
3-Methylphenanthrene	3.1	9.2
2-Methylphenanthrene	0	0
1-Methylphenanthrene	0	0
Dibutyl phthalate	17	11.5
Fluoranthene	0	0
Pyrene	0	0
Di-N-hexylphthalate (2)13C2[c]	53.4	5.7
Benzyl butyl phthalate	5.2	3.9
bis(2-ethylhexyl) adipate	0	0
Benz(a)anthracene	0	0
Chrysene	0.2	0.4
Bis(2-ethylhexyl)phthalate	11.1	7.5
Di-n-octyl phthalate	0.3	0.9

Table E-17 Continued

Chemical	Reagent Blank Mean ng/g (equivalent)	Reagent Blank Standard Deviation ng/g (equivalent)
Benzo(b)fluoranthene	0	0
Benzo(k)fluoranthene	0	0
Benzo(e)pyrene	0	0
Benzo(e)pyrene d12[c]	25.7	13.4
Benzo[a]pyrene	0	0
Benzo[a]pyrene d12[c]	38.2	10.1
Bis(2,2,6,6-tetramethyl-4-piperidyl) sebacate	5.5	8.4
Indeno(1,2,3-cd)pyrene d12[c]	44	38.4
Dibenz(a,h)anthracene d14[c]	27.4	7.7
DBA + ICDP[d]	0	0
Benzo[ghi]perylene d12[a]	39.2	12.7
Benzo[ghi]perylene	0	0
Coronene	0	0

[a] SVOC = semivolatile organic compound; GC/MS/MS = gas chromatography/tandem mass spectrometry

[b] Reagent Blank (n=9)

[c] Added internal standard and surrogate recovery compounds

[d] DBA + ICDP = Dibenz(a,h)anthracene + Indeno(1,2,3-cd)pyrene

Recovery - Table E-18 reports reagent spike and calibration check recovery results for each analyte. One reagent spike was analyzed for each extraction/analysis batch. For the calibration checks, most analytes had average recoveries in the 70% to 130% DQI objective range. For reagent spikes, about half of the average recovery values were outside the 70% to 130% range. Variability in recoveries was observed across the extraction/analysis batches. Therefore, batch-specific recovery adjustments were performed by multiplying the measurement result by the average reagent spike result across all batches divided by that batch's reagent spike result, using the following formula:

$$\text{Analyte Conc}_{adj} = \text{Analyte Conc}_{batch,i} \text{ x } (\text{Average Reagent Spike}_{batch,1\text{-}9}/\text{Reagent Spike}_{batch,i})$$

Table E-18. Recovery Quality Control Results for SVOCs in Tire Crumb Rubber Extracts by GC/MS/MS[a,b]

Chemical	Reagent Spike % Recovery Mean	Reagent Spike % Recovery Standard Deviation	Calibration Checks % Recovery Mean	Calibration Checks % Recovery Standard Deviation
Aniline	77.2	7.7	91.3	14
n-Butylbenzene	122.1	13.9	104.2	8.9
Naphthalene	107.3	11.5	103.8	9.4
Benzothiazole	57.8	26.1	98.5	15.8
Cyclohexylisothiocyanate	168	38.2	112.4	17.2
2-Methylnaphthalene	104.6	24.9	103.1	15
1-Methylnaphthalene	137.9	34.4	112.7	15.1
Dimethyl Phthalate	125.7	28.4	97.7	14.5
Acenaphthalene	90.6	6.1	95.6	4.1
2,6-Di-tert-butyl-p-cresol	294.3	85.5	122.9	49

Table E-18 Continued

Chemical	Reagent Spike % Recovery Mean	Reagent Spike % Recovery Standard Deviation	Calibration Checks % Recovery Mean	Calibration Checks % Recovery Standard Deviation
Diethyl phthalate	104.4	27.3	67.5	52.5
n-Hexadecane	85.3	12.8	93.1	10.1
Fluorene	99.8	3	101.1	4.3
4-tert-octylphenol	37.8	23.8	141.2	25
2-Bromomethylnaphthalene	31.6	33.9	144.7	87.3
2-Hydroxybenzothiazole	0.5	1.4	86.7	86.3
Dibenzothiophene	94.8	6.6	100.5	5.5
Phenanthrene	78.3	12	93.3	6.8
Anthracene	99.4	13.4	101.1	8.9
Diisobutyl phthalate	104.9	25.8	123.8	26.4
3-Methylphenanthrene	66.1	23.1	90.3	14
2-Methylphenanthrene	82.8	52.6	97.3	37.1
1-Methylphenanthrene	116.8	23.7	103.2	11.6
Dibutyl phthalate	105.8	32.3	129.2	35.6
Fluoranthene	97.8	10.7	96.5	7.8
Pyrene	95.1	6.6	96.2	7.8
Di-N-hexylphthalate (2)13C2[c]	111.9	19.9	100.9	6.1
Benzyl butyl phthalate	92	18.5	95.6	8.7
bis(2-ethylhexyl) adipate	154.7	161	85.4	47.8
Benz(a)anthracene	96.5	12.8	92.1	8.4
Chrysene	104.3	7	98.9	6.8
Bis(2-ethylhexyl)phthalate	102.7	20.4	97.4	10.8
Di-n-octyl phthalate	103.8	18.8	89.5	24.4
Benzo(b)fluoranthene	106.5	31.4	102.5	31.8
Benzo(k)fluoranthene	98.6	17.2	105.6	14.6
Benzo(e)pyrene	54.8	12.4	100.8	25.8
Benzo(e)pyrene d12[c]	44.4	15.7	105.5	19.9
Benzo[a]pyrene	65.9	10.4	101.8	28
Benzo[a]pyrene d12[c]	59.9	8.9	98.7	19
Bis(2,2,6,6-tetramethyl-4-piperidyl) sebacate	42.3	25.4	56	30
Indeno(1,2,3-cd)pyrene d12[c]	78.4	65.9	171.8	127.5
Dibenz(a,h)anthracene d14[c]	46	4	97.1	25.9
DBA + ICDP[d]	58.1	25	110.9	45.2
Benzo[ghi]perylene d12[c]	59.7	15	87.9	24
Benzo[ghi]perylene	64.2	24.2	94.3	30.6
Coronene	64.7	48.7	95.4	46.4

[a] SVOC = semivolatile organic compound; GC/MS/MS = gas chromatography/tandem mass spectrometry

[b] Reagent Spike (n=9), Spike = 500 nanograms (ng); Calibration Checks (n=70), Spike = 5-500 ng

[c] Added internal standard and surrogate recovery compounds

[d] DBA + ICDP = Dibenz(a,h)anthracene + Indeno(1,2,3-cd)pyrene

Precision – Analysis precision was assessed by the replicate analysis of tire crumb rubber sample extracts and by the analysis of duplicate portions of tire crumb rubber samples. Results are shown for select SVOCs in Section 4.9.1, Table 4-51 of the Volume 1 report (EPA/600/R-19/051a). Mean %RSDs for seven replicate analyses ranged from 13 to 63% for the select SVOCs. Except for 4-tert-octylphenol, all average %RSDs were ≤ 34%. In addition, duplicate extractions and analyses were performed for 100% of the tire crumb rubber samples. These duplicate measurements assess a homogeneity component in addition to the measurement precision. Mean %RSDs for 101 duplicate sample analyses ranged from 4.8% to 20% for the select SVOCs. Overall, the duplicate sample analyses showed a higher degree of precision than the replicate extract analyses. It is not clear why this level of precision was not reflected in the replicate extract analysis results.

Table E-19 shows results for the repeated analysis of a composite tire crumb rubber matrix that was prepared by adding and mixing portions of tire crumb rubber collected from all nine recycling plants. The purpose of this analysis was to assess whether a standard control material could be prepared and used to evaluate performance over time. In order to be a suitable standard, the material would need to be very homogeneous with regard to the target analytes. A portion of the mixed reference standard was extracted and analyzed along with each tire crumb rubber sample extraction/analysis batch. The results in Table E-19 show a fairly high degree of variability. At this time, it is not clear whether this variability is related to non-homogeneity in the prepared standard material or whether it reflects the batch-to-batch differences in analyte recoveries described above. (The reference standard results were not adjusted for recovery on a batch-wise basis as the samples were.) More work would need to be performed to confirm this approach for preparing a standard material for quality control assessment use.

Table E-19. Precision Quality Control Results for SVOCs in Tire Crumb Rubber Extracts by GC/MS/MS[a,b]

Chemical	Replicate Extract Injection Range of Relative Percent Difference (RPD)	Reference Samples Mean ± Standard Deviation (% RSD) (ng/g)
Aniline	2.9 - 21.2	2259.3 ± 424.3 (18.8)
n-Butylbenzene	0 - 100	129.6 ± 14.9 (11.5)
Naphthalene	3.2 - 3.7	1313.4 ± 227.8 (17.3)
Benzothiazole	4.2 - 17	42247 ± 20377.7 (48.2)
Cyclohexylisothiocyanate	0.8 - 17.6	763.2 ± 182.7 (23.9)
2-Methylnaphthalene	12.8 - 26.6	1571.2 ± 446.6 (28.4)
1-Methylnaphthalene	8.1 - 8.3	1625.8 ± 516.8 (31.8)
Dimethyl Phthalate	1.2 - 16	47.7 ± 68 (142.6)
Acenaphthalene	6.1 - 7.5	370.3 ± 34.3 (9.3)
2,6-Di-tert-butyl-p-cresol	2.7 - 7	8714.1 ± 5201 (59.7)
Diethyl phthalate	1 - 2.4	60.8 ± 27.9 (45.9)
n-Hexadecane	1.2 - 7.7	2760.9 ± 645.1 (23.4)
Fluorene	12.1 - 15	407.8 ± 67 (16.4)
4-tert-octylphenol	0.9 - 17	20920.8 ± 6862.7 (32.8)
2-Bromomethylnaphthalene	0 - 0	0
2-Hydroxybenzothiazole	14.6 - 20.7	5854.8 ± 4849.7 (82.8)
Dibenzothiophene	4.8 - 8.5	473.9 ± 76.2 (16.1)
Phenanthrene	5.3 - 10	3711.4 ± 628.5 (16.9)
Anthracene	1.3 - 37.9	662.5 ± 241.8 (36.5)

Table E-19 Continued

Chemical	Replicate Extract Injection Range of Relative Percent Difference (RPD)	Reference Samples Mean ± Standard Deviation (% RSD) (ng/g)
Diisobutyl phthalate	4.4 - 4.9	538.9 ± 267.4 (49.6)
3-Methylphenanthrene	2.1 - 9.2	2327.9 ± 770.1 (33.1)
2-Methylphenanthrene	2.5 - 8.4	2128.7 ± 1107.6 (52)
1-Methylphenanthrene	1.2 - 9.7	1566.5 ± 490.9 (31.3)
Dibutyl phthalate	4.2 - 8.2	1036.1 ± 837.5 (80.8)
Fluoranthene	9.9 - 10.8	5731.8 ± 810.2 (14.1)
Pyrene	10.9 – 11.6	17065.9 ± 2064.1 (12.1)
Di-N-hexylphthalate (2)13C2[c]	13.9 - 14.1	53 ± 9.5 (17.9)
Benzyl butyl phthalate	11.4 - 12.1	652.7 ± 147.2 (22.6)
bis(2-ethylhexyl) adipate	3.5 - 8.5	8190.8 ± 7160.9 (87.4)
Benz(a)anthracene	18 - 25.5	2068 ± 935.8 (45.3)
Chrysene	9.7 - 29.2	3023.8 ± 1280.9 (42.4)
Bis(2-ethylhexyl)phthalate	2.4 - 6.1	6250.5 ± 2657.8 (42.5)
Di-n-octyl phthalate	38.2 - 112.6	140.2 ± 135 (96.3)
Benzo(b)fluoranthene	8 - 23	1304.1 ± 692.4 (53.1)
Benzo(k)fluoranthene	9.3 - 15.5	462.2 ± 124.6 (27)
Benzo(e)pyrene	1.3 - 18.4	1303.4 ± 518.9 (39.8)
Benzo(e)pyrene d12[c]	11.3 - 15.5	34.1 ± 7 (20.5)
Benzo[a]pyrene	24.4 - 36.3	753.4 ± 153.1 (20.3)
Benzo[a]pyrene d12[c]	12.8 - 25.6	34.6 ± 7.9 (22.8)
Bis(2,2,6,6-tetramethyl-4-piperidyl) sebacate	2.6 - 19.6	547.8 ± 557.6 (101.8)
Indeno(1,2,3-cd)pyrene d12[c]	9 - 19.7	39.6 ± 36.6 (92.4)
Dibenz(a,h)anthracene d14[c]	9.6 - 19.7	22.9 ± 7.2 (31.4)
DBA + ICDP[d]	31.5 - 46.9	372.5 ± 153.5 (41.2)
Benzo[ghi]perylene d12[c]	12.3 - 17.2	15.3 ± 4.3 (28.1)
Benzo[ghi]perylene	11.9 - 20	1022.3 ± 280.9 (27.5)
Coronene	29.1 - 30.6	422.5 ± 165.8 (39.2)

[a] SVOC = semivolatile organic compound; GC/MS/MS = gas chromatography/tandem mass spectrometry; RPD = Relative percent difference; % RSD = percent relative standard deviation

[b] Replicate Extract Injection (n = 7); Reference Samples (n = 9)

[c] Added internal standard and surrogate recovery compounds

[d] DBA + ICDP = Dibenz(a,h)anthracene + Indeno(1,2,3-cd)pyrene

DQI – Completeness DQI objectives were met for SVOC extract analyses. Precision DQI objectives were met for most SVOC extract analytes based on the quality control measurement results, with a particular focus on the mean %RSD duplicate sample extraction/analysis across 101 samples. However, analyte recovery variability was observed across batches, and recovery adjustments were performed. In addition to the quality control measures, the lead analyst evaluated the chromatography of the analytes. As a result of the overall review of quality control and a review of the chromatographic performance by the lead analyst, 2-hydroxybenzothiazole and bis(2-ethylhexyl) adipate were not included in data reporting for tire crumb rubber extract analysis. It should be noted that selecting only one extraction and analysis method for the varied analyte types in this study presented challenges for method performance. It is also important to note that many non-target chemicals were present in the extracts, creating further challenges for successful and consistent target analyte identification and quantitation.

E.4.5 SVOCs in Chamber Emission Samples Analyzed by GC/MS/MS

Completeness – All (100%) of the scheduled tire crumb rubber chamber emission samples collected at 25 °C and 60 °C were successfully analyzed for SVOC emissions by GC/MS/MS.

Quantification Limits – Table E-20 reports the minimum quantitation levels for SVOC analytes in tire crumb rubber emission samples. The values were calculated as nominal emission factors using typical chamber operation and sampling conditions. There was variability across the analysis batches.

Table E-20. Minimum Quantitation Level (MQL) for SVOCs in Emissions Samples by GC/MS/MS[a]

Chemical	Lowest Nominal Minimum Quantitation Level (ng/g/h)	Highest Nominal Minimum Quantitation Level (ng/g/h)
Aniline	0.034	0.085
n-Butylbenzene	0.003	0.017
Naphthalene	0.003	0.085
Benzothiazole	0.003	0.170
Cyclohexylisothiocyanate	0.009	0.017
2-Methylnaphthalene	0.009	0.034
1-Methylnaphthalene	0.003	0.017
Dimethyl Phthalate	0.003	0.034
Acenaphthalene	0.017	0.034
2,6-Di-tert-butyl-p-cresol	0.085	0.085
Diethyl phthalate	0.003	0.341
n-Hexadecane	0.017	0.341
Fluorene	0.003	0.017
4-tert-octylphenol	0.034	0.085
2-Bromomethylnaphthalene	0.085	0.085
2-Hydroxybenzothiazole	0.085	3.409
Dibenzothiophene	0.003	0.034
Phenanthrene	0.017	0.034
Anthracene	0.009	0.085
Diisobutyl phthalate	0.003	0.034
3-Methylphenanthrene	0.034	0.085
2-Methylphenanthrene	0.003	0.341
1-Methylphenanthrene	0.003	0.034
Dibutyl phthalate	0.003	0.034
Fluoranthene	0.009	0.034
Pyrene	0.009	0.034
Benzyl butyl phthalate	0.009	0.017
bis(2-ethylhexyl) adipate	0.009	0.341
Benz(a)anthracene	0.009	0.034

Table E-20 Continued

Chemical	Lowest Nominal Minimum Quantitation Level (ng/g/h)	Highest Nominal Minimum Quantitation Level (ng/g/h)
Chrysene	0.009	0.085
Bis(2-ethylhexyl)phthalate	0.009	0.034
Di-n-octyl phthalate	0.009	0.034
Benzo(b)fluoranthene	0.017	0.085
Benzo(k)fluoranthene	0.003	0.085
Benzo(e)pyrene	0.009	0.085
Benzo[a]pyrene	0.009	0.085
Bis(2,2,6,6-tetramethyl-4-piperidyl) sebacate	0.170	1.705
DBA + ICDP[b]	0.034	1.705
Benzo[ghi]perylene	0.009	0.085
Coronene	0.009	0.170

[a] SVOC = semivolatile organic compound; GC/MS/MS = gas chromatography/tandem mass spectrometry

[b] DBA + ICDP = Sum of Dibenz[a,h]anthracene and Indeno(1,2,3-cd)pyrene

Blanks - Table E-21 reports average concentrations of SVOCs in method blanks, which were extracts of unused PUF filters. One method blank was prepared for each of the 19 emission sample analysis batches. Several analytes had average method blank levels ranging from approximately 430 to 670 ng/sample, including benzothiazole, n-hexadecane, 2-hydrocybenzothiazole, and bis(2-ethylhexyl)phthalate. But very high average levels of cyclohexylisothiocyanate (approximately 12,000 ng/sample) were observed. For the first 10 chamber experiment batches, the PUF filter sampling media was used directly from the supplier. While the filters were sold as precleaned material, they were found to have higher background levels of some target analytes in this study. (In initial testing of solvent cleaning in the laboratory, it was found that drying the filter media in a drying oven with rubber door seals resulted in contamination of the filters with benzothiazole. Upon finding this, an alternate drying approach was used.) The PUF filters used for chamber experiment batches 11 – 19 were solvent cleaned in the research laboratory, which provided filter media with much lower background levels for most target analytes.

Table E-21. Blanks Quality Control Results for SVOCs in PUF for Emissions Testing by GC/MS/MS[a,b]

Chemical	Method Blank Mean (ng/sample)	Method Blank Standard Deviation (ng/sample)
Aniline	30.7	111.7
n-Butylbenzene	7.9	29.4
Naphthalene	2.5	2.9
Benzothiazole	665.3	1054.7
Cyclohexylisothiocyanate	11843.4	51220.4
2-Methylnaphthalene	16.5	64.1
1-Methylnaphthalene	8.8	34.5
Dimethyl Phthalate	0.5	0.6

Table E-21 Continued

Chemical	Method Blank Mean (ng/sample)	Method Blank Standard Deviation (ng/sample)
Acenaphthalene	0.9	1.6
2,6-Di-tert-butyl-p-cresol	172.6	425.2
Diethyl phthalate	43.5	112.5
n-Hexadecane	427.3	1493.5
Fluorene	0.9	2.1
4-tert-octylphenol	6.7	18.3
2-Bromomethylnaphthalene	1.3	2.3
2-Hydroxybenzothiazole	473.2	1638.2
Dibenzothiophene	0.3	0.3
Phenanthrene	2.7	5.2
Anthracene	1.7	6.5
Diisobutyl phthalate	23.6	14.8
3-Methylphenanthrene	0.9	0.7
2-Methylphenanthrene	0.5	0.5
1-Methylphenanthrene	0.4	0.4
Dibutyl phthalate	38.3	38.9
Fluoranthene	0.7	0.6
Pyrene	2	2.1
Di-N-hexylphthalate (2)13C2[c]	0	0
Benzyl butyl phthalate	83.1	95.4
bis(2-ethylhexyl) adipate	28.7	36.5
Benz(a)anthracene	0.9	3.3
Chrysene	0.2	0.2
Bis(2-ethylhexyl)phthalate	485.6	609.6
Di-n-octyl phthalate	4.8	8.4
Benzo(b)fluoranthene	0.2	0.2
Benzo(k)fluoranthene	0	0.1
Benzo(e)pyrene	0	0
Benzo[a]pyrene	0.3	0.5
Bis(2,2,6,6-tetramethyl-4-piperidyl) sebacate	0.8	2.1
DBA + ICDP[d]	0.6	0.5
Dibenz(a,h)anthracene	0.4	0.7
Benzo[ghi]perylene	0.2	0.2
Coronene	0.1	0.1

[a] SVOC = semivolatile organic compound; PUF = polyurethane foam; GC/MS/MS = gas chromatography/ tandem mass spectrometry

[b] Method Blank (n=19)

[c] Added internal standard compound

[d] DBA + ICDP = Dibenz(a,h)anthracene + Indeno(1,2,3-cd)pyrene

Chamber Background Samples – Table E-22 reports chamber background sample measurement results for chamber emission tests performed at 25 °C and 60 °C. One chamber background sample was collected prior to the test performed for each tire crumb rubber sample. Relatively high average chamber background levels were observed for cyclohexylisothiocyanate, n-hexadecane, and diethyl phthalate. Lower chamber background levels were observed for benzothiazole and several other phthalates. There was considerable variability in chamber background levels across chamber experiment batches. In some cases, the variability was associated with the differences in PUF media for batches 1 – 10 and 11 – 19, as described above. For diethyl phthalate, very high levels were measured in three of the early chamber test sets. There were also differences in chamber background measurements at 25 °C and 60 °C. Sample emission results were adjusted by subtracting the average chamber background measurement result for each batch from the sample VOC measurement results for samples in that batch. Each batch was conducted at either 25 °C or 60 °C, so the chamber background adjustments were effectively made on a temperature-specific basis.

Table E-22. Emission Test Chamber Background Sample Quality Control Results for SVOCs by GC/MS/MS[a,b]

Chemical	Emission Chamber Background at 25 °C Mean (ng/sample)	Emission Chamber Background at 25 °C Standard Deviation (ng/sample)	Emission Chamber Background at 60 °C Mean (ng/sample)	Emission Chamber Background at 60 °C Standard Deviation (ng/sample)
Aniline	4.9	3.8	5.1	4.7
n-Butylbenzene	2.2	8.7	1.4	0.92
Naphthalene	6.2	6.2	12	18
Benzothiazole	29	31	36	24
Cyclohexylisothiocyanate	240	430	360	490
2-Methylnaphthalene	4.0	2.7	4.6	3.4
1-Methylnaphthalene	2.0	1.4	2.3	1.7
Dimethyl Phthalate	0.50	0.55	0.67	0.84
Acenaphthalene	0.62	0.79	0.59	0.55
2,6-Di-tert-butyl-p-cresol	17	33	16	14
Diethyl phthalate	662	2600	1300	3800
n-Hexadecane	170	170	210	200
Fluorene	0.87	0.63	1.0	0.82
4-tert-octylphenol	3.8	4.2	4.5	6.7
2-Bromomethylnaphthalene	0.65	1.0	0.61	0.95
2-Hydroxybenzothiazole	25	160	7.6	10
Dibenzothiophene	0.30	0.19	0.35	0.25
Phenanthrene	3.1	3.2	3.7	4.3
Anthracene	1.2	3.6	2.1	5.3
Diisobutyl phthalate	22	13	23	13
3-Methylphenanthrene	1.2	1.9	1.7	3.6
2-Methylphenanthrene	0.59	1.2	0.75	1.8
1-Methylphenanthrene	0.63	1.7	0.88	2.6
Dibutyl phthalate	29	14	30	15
Fluoranthene	0.46	0.51	0.40	0.26

Table E-22 Continued

Chemical	Emission Chamber Background at 25 °C Mean (ng/sample)	Emission Chamber Background at 25 °C Standard Deviation (ng/sample)	Emission Chamber Background at 60 °C Mean (ng/sample)	Emission Chamber Background at 60 °C Standard Deviation (ng/sample)
Pyrene	0.38	0.24	0.44	0.52
Benzyl butyl phthalate	55	59	48	34
bis(2-ethylhexyl) adipate	20	25	23	59
Benz(a)anthracene	0.13	0.13	0.10	0.11
Chrysene	0.14	0.20	0.19	0.25
Bis(2-ethylhexyl)phthalate	39	51	45	48
Di-n-octyl phthalate	3.3	11	1.2	2.2
Benzo(b)fluoranthene	0.12	0.23	0.11	0.21
Benzo(k)fluoranthene	0.03	0.09	0.01	0.04
Benzo(e)pyrene	0	0	0	0
Benzo[a]pyrene	0.27	0.52	0.27	0.51
Bis(2,2,6,6-tetramethyl-4-piperidyl) sebacate	0.5	3.7	0.92	4.3
DBA + ICDP[c]	0.38	0.52	0.46	0.48
Dibenz(a,h)anthracene	0.45	0.95	0.41	0.90
Benzo[ghi]perylene	0.06	0.07	0.07	0.08
Coronene	0.01	0.04	0	0.01

[a] SVOC = semivolatile organic compound; GC/MS/MS = gas chromatography/tandem mass spectrometry; °C = degrees Celsius

[b] Emission Chamber Background at 25 °C (n=96), at 60 °C (n=100)

[c] DBA + ICDP = Dibenz(a,h)anthracene + Indeno(1,2,3-cd)pyrene

Recovery - Table E-23 reports recovery results for method spikes (spiked unused PUF filters), recovery spikes (spiked extraction solvent), and calibration check standards. Recovery values were not corrected for PUF or chamber background values. Average recoveries for most target analytes fell within the 75% to 130% range. Benzothiazole, cyclohexylisothiocyanate, dibutyl phthalate, and bis(2-ethylhexyl) phthalate had average recoveries between 150% and 200% in the method spikes. However, had they been corrected for background, the recoveries would have been lower. The average recovery for 2-hydroxybenzothiazole in method spikes was 290%. No recovery adjustments were made in the emission sample analysis results.

Table E-23. Recovery Quality Control Results for SVOCs in PUF for Emissions Testing by GC/MS/MS[a,b]

Chemical	Method Spike % Recovery Mean	Method Spike % Recovery Standard Deviation	Recovery Spike % Recovery Mean	Recovery Spike % Recovery Standard Deviation	Calibration Check % Recovery Mean	Calibration Check % Recovery Standard Deviation
Aniline	75.5	27.5	85.5	26.9	93.5	8.4
n-Butylbenzene	99.6	14.2	101.1	13.2	98.6	12.1
Naphthalene	72.7	21.3	107.1	20.3	140.6	62.3
Benzothiazole	202.3	101.3	141.7	33.2	95.1	7.6
Cyclohexylisothiocyanate	195	111.8	156.6	123.6	96.1	4.9
2-Methylnaphthalene	119.2	15.3	99	17.6	101.4	7.4
1-Methylnaphthalene	116.6	15.4	98.5	18.3	102.2	7
Dimethyl Phthalate	83.9	11.5	88.8	18.4	93.3	5.6
Acenaphthalene	88.7	8.1	99	11.5	90.9	10.8
2,6-Di-tert-butyl-p-cresol	107.4	89.5	177.7	69.4	97.6	19
Diethyl phthalate	102.9	15.7	100.9	18.8	79.5	18.3
n-Hexadecane	114.8	18.4	121	20.9	91.4	8.8
Fluorene	100.2	10.7	90.7	16.7	100.8	8.2
4-tert-octylphenol	125.4	34.3	118.3	39.7	101	15
2-Bromomethylnaphthalene	107.1	35.6	97.9	54.5	73.8	26.2
2-Hydroxybenzothiazole	290.9	340.8	241.8	260.6	65.3	65.5
Dibenzothiophene	102.9	7.5	104.5	10.9	96.2	5
Phenanthrene	102.6	7.3	102.8	11.1	91.2	9.1
Anthracene	97.6	10.3	106	13.4	96.4	14.9
Diisobutyl phthalate	137.8	28.4	118	23.2	98.4	14.7
3-Methylphenanthrene	125	11.6	115.9	16	91.9	18.6
2-Methylphenanthrene	110.8	17.3	102.5	17.2	97.1	12.6
1-Methylphenanthrene	118.9	16.3	108.1	15.8	97.5	11
Dibutyl phthalate	155.1	42.1	126.7	31.9	99.2	20.5
Fluoranthene	103	9.6	102.9	15.1	93.1	11.9
Pyrene	103.8	9	104.1	14.1	92.2	11.7
Di-N-hexylphthalate (2)13C2[c]	38.1	47.8	37	44.7	75.6	56.8
Benzyl butyl phthalate	127.6	16.8	128	21.3	94.7	12.5
bis(2-ethylhexyl) adipate	133.6	44.4	124.3	34.7	97.7	35.8
Benz(a)anthracene	104.2	16.2	102.6	20.3	93.8	17.6
Chrysene	102.3	8.4	104.4	9.6	100.7	25.9
Bis(2-ethylhexyl)phthalate	191.6	95.5	194	104.7	95	11.4
Di-n-octyl phthalate	97.7	19.8	97.5	25.7	90.6	11.6
Benzo(b)fluoranthene	104.3	10.7	100	25.8	91.9	27.9
Benzo(k)fluoranthene	108.4	9.6	190.9	347.1	102.4	25.3
Benzo(e)pyrene	115.7	11.8	107.7	10.7	98	8.5
Benzo[a]pyrene	123.6	33	111.5	32.4	89.7	33
Bis(2,2,6,6-tetramethyl-4-piperidyl) sebacate	43.3	48.4	105.2	60.4	42.1	31
DBA + ICDP[d]	102.2	15.3	103.9	17.9	83.9	14.7

Table E-23 Continued

Chemical	Method Spike % Recovery Mean	Method Spike % Recovery Standard Deviation	Recovery Spike % Recovery Mean	Recovery Spike % Recovery Standard Deviation	Calibration Check % Recovery Mean	Calibration Check % Recovery Standard Deviation
Dibenz(a,h)anthracene	104.8	33.2	113.3	25.6	96.4	53.1
Benzo[ghi]perylene	107.6	7.6	109.4	10.3	97.4	8.3
Coronene	97.9	17	98.2	16.7	89.8	11.4

[a] SVOC = semivolatile organic compound; PUF = polyurethane foam; GC/MS/MS = gas chromatography/tandem mass spectrometry

[b] Method Spike (Spike=500 ng; n=19); Recovery Spike (Spike=500 ng; n=19); Calibration Check (Spike=5–500 ng; n=93)

[c] Added internal standard compound

[c] DBA + ICDP = Dibenz(a,h)anthracene + Indeno(1,2,3-cd)pyrene

Precision – Analysis precision was assessed by the replicate analysis of emission sample PUF extracts. Results are shown for select SVOCs in Section 4.9.1, Table 4-52 of the Volume 1 report (EPA/600/R-19/051a). For these select analytes, average %RSDs ranged from <0.1% to 31%. Table E-24 shows the range of relative percent differences (RPDs) for SVOC measurements without any PUF background adjustments. Several analytes had relatively high RPDs. It is likely that the relatively poor precision for some analytes is due to measurements near or below the minimum quantifiable limits.

Table E-24. Precision Quality Control Results for SVOCs in Chamber Emission Sample PUF Extracts by GC/MS/MS[a,b]

Chemical	Duplicate Injections Range of RPD
Aniline	67 - 218.5
n-Butylbenzene	32 - 59.3
Naphthalene	4.8 - 4.9
Benzothiazole	14.8 - 20.9
Cyclohexylisothiocyanate	2.2 - 26.2
2-Methylnaphthalene	2.3 - 2.4
1-Methylnaphthalene	3.7 - 4.4
Dimethyl Phthalate	6.4 - 17.7
Acenaphthalene	5.4 - 10.1
2,6-Di-tert-butyl-p-cresol	12.9 - 31.7
Diethyl phthalate	12 - 16.3
n-Hexadecane	5.9 - 24
Fluorene	5.3 - 11.5
4-tert-octylphenol	23 - 23.7
2-Bromomethylnaphthalene	4.2 - 7.3
2-Hydroxybenzothiazole	14.8 - 99.1
Dibenzothiophene	6.1 - 17.9
Phenanthrene	4.7 - 5.4
Anthracene	8.5 - 28.5
Diisobutyl phthalate	4.5 - 22.3
3-Methylphenanthrene	5.2 - 9.5

Table E-24 Continued

Chemical	Duplicate Injections Range of RPD
2-Methylphenanthrene	5.2 - 125.3
1-Methylphenanthrene	71.7 - 97.7
Dibutyl phthalate	3.6 - 18.4
Fluoranthene	7.4 - 7.8
Pyrene	5.2 - 7.7
Di-N-hexylphthalate (2)13C2[c]	3 - 13.1
Benzyl butyl phthalate	2.4 - 4.3
bis(2-ethylhexyl) adipate	35.7 - 39
Benz(a)anthracene	12.5 - 36.2
Chrysene	21.6 - 29.4
Bis(2-ethylhexyl)phthalate	0.9 - 14.4
Di-n-octyl phthalate	100 - 115.9
Benzo(b)fluoranthene	14.5 - 14.8
Benzo(k)fluoranthene	0 - 13.6
Benzo(e)pyrene	0 - 1.9
Benzo[a]pyrene	14.7 - 100
Bis(2,2,6,6-tetramethyl-4-piperidyl) sebacate	5.2 - 113.6
DBA + ICDP[d]	17.5 - 307
Dibenz(a,h)anthracene	0 - 0
Benzo[ghi]perylene	21.6 - 23.3
Coronene	3 - 105.3

[a] SVOC = semivolatile organic compound; PUF = polyurethane foam; GC/MS/MS = gas chromatography/ tandem mass spectrometry; RPD = Relative percent difference

[b] Duplicate Injections (n=16)

[c] Added internal standard compound

[d] DBA + ICDP = Dibenz(a,h)anthracene + Indeno(1,2,3-cd)pyrene

DQI – Most DQI objectives were met for most SVOC emission samples based on the quality control measurement results. Recovery and precision DQI values were not met for some analytes, likely as a result of relatively high PUF and/or chamber background levels, or due to measurements below or near the method detection limits. Due to high recoveries and poor chromatographic peak shape, 2-hydroxybenzothiazole and bis(2-ethylhexyl) adipate were not included in the reported results. Due to the high and highly variable chamber background and/or PUF background levels of diethyl phthalate, n-hexadecane, bis(2-ethylhexyl) phthalate, benzyl butyl phthalate, cyclohexylisothiocyanate, and 2,6-di-tert-butyl-p-cresol, we elected not to report emission results for these chemicals.

E.4.6 Analysis of SVOCs by LC/TOFMS in Tire Crumb Rubber Extract and Chamber Emission Samples

Completeness – All (100%) of the scheduled tire crumb rubber extraction samples were analyzed for SVOCs by LC/TOFMS. All (100%) of the scheduled tire crumb rubber chamber emission samples collected at 60 °C were analyzed for SVOC emissions by LC/TOFMS, as well. However, only a portion of the chamber emission samples collected at 25 °C were analyzed. A decision was made not to complete those analyses since target analytes were not being observed above chamber background levels.

Quantification Limits – The SVOC analyses by LC/TOFMS were not performed as quantitative analyses, so no quantification limits were determined.

Blanks - Method blanks were analyzed for the SVOC extract samples. The average method blank chromatographic peak intensity was subtracted from the intensity measured for each target analyte in each sample.

Chamber Background - Chamber background samples were analyzed for the 60 °C emission tests. Sample emission measurement chromatographic peak intensity results were adjusted by subtracting the average chamber background measurement result for each chamber experiment batch from the sample measurement results for samples in that chamber experiment batch. Relatively high amounts of diisononyl phthalate and diisodecyl phthalate were observed in the chamber background samples, and the amounts were variable across the chamber experiment batches.

Recoveries - The SVOC analyses by LC/TOFMS were not performed as quantitative analyses, so no recovery values were determined.

Precision - The SVOC analyses by LC/TOFMS were not performed as quantitative analyses, so no precision values were determined.

DQIs - The SVOC analyses by LC/TOFMS were not performed as quantitative analyses, so measurement results were not evaluated against the data quality indicators. While no quantitative analyses were performed, known standards were analyzed to confirm target analyte retention times and mass spectra. Two target analytes, diisononyl phthalate and diisodecyl phthalate, were not included in measurement reporting for chamber emission sample results due to relatively high and variable amounts of those analytes found in the chamber background samples.

E.4.7 VOC Analysis in Chamber Emission Samples by GC/TOFMS

Completeness – All (100%) of the scheduled tire crumb rubber samples collected from recycling plants were successfully analyzed for VOC emissions by GC/TOFMS. Two synthetic turf field infill composite 25 °C emission samples and three 60 °C emission samples did not result in usable data. The overall completeness rate was 97% (159 of 164 planned sample analyses were completed).

Quantification Limits – Table E-25 reports the method detection limits for VOC analytes in tire crumb rubber emission samples. The values were calculated as nominal emission factors using typical chamber operation and sampling conditions.

Table E-25. Method Detection Limits (MDLs) for VOCs Measured in Recycling Plant and Synthetic Turf Field Tire Crumb Rubber Chamber Emission Samples[a]

Chemical	Nominal Field Tire Crumb Rubber Infill Chamber Emission Samples MDL (ng/g/h)	Nominal Recycling Plant Tire Crumb Rubber Chamber Emission Samples MDL (ng/g/h)
Freon 12	0.029	0.035
1,3-Butadiene	0.081	0.185
trans-2-Butene	0.064	0.029
cis-2-Butene	0.081	0.035
Freon 11	0.052	0.035
1,1-Dichloroethene	0.144	0.324
Freon 113	0.040	0.144
1,1-Dichloroethane	0.208	0.116
cis-1,2-Dichloroethene	0.428	0.092
1,2-Dichoroethane	0.208	0.202
1,1,1-Trichloroethane	0.445	0.456
Benzene	0.485	0.352
Carbon tetrachloride	0.347	1.046
1,2 -Dichloropropane	0.289	0.341
Trichloroethene	0.797	0.312
Methyl isobutyl ketone	0.630	2.773
Toluene	0.144	0.092
Tetrachloroethene	0.023	0.058
Chlorobenzene	0.017	0.035
Ethylbenzene	0.046	0.092
m,p-Xylene	0.092	0.127
Styrene	0.139	0.202
o-Xylene	0.052	0.081
4-Ethyltoluene	0.300	0.173
1,3,5-Trimethylbenzene	0.196	0.110
m-Dichlorobenzene	0.058	0.104
p-Dichlorobenzene	0.092	0.110
o-Dichlorobenzene	0.052	0.092
Benzothiazole	6.876	1.294

[a] MDL= method detection limit; VOC = volatile organic compound

Blanks - Tables E-26 and E-27 report average concentrations of VOCs in field blanks (Fenceline monitor [FLM] tubes taken to the chamber facility, but not used) and run blanks (FLM tubes that stayed unopened in the analysis laboratory).

Table E-26. Blanks Quality Control Results for VOCs in Recycling Plant Tire Crumb Rubber Characterization Chamber Emission Samples[a,b]

Chemical	FLM Field Blank Mean (ng/tube)	FLM Field Blank Standard Deviation (ng/tube)	FLM Run Blank Mean (ng/tube)	FLM Run Blank Standard Deviation (ng/tube)
Freon 12	0.00	0.00	0.00	0.00
1,3-Butadiene	0.32	0.34	0.11	0.18
trans-2-Butene	0.12	0.07	0.04	0.07
cis-2-Butene	0.12	0.08	0.05	0.07
Freon 11	0.09	0.05	0.09	0.06
1,1-Dichloroethene	0.00	0.00	0.00	0.00
Freon 113	0.05	0.05	0.02	0.05
1,1-Dichloroethane	-0.01	0.02	0.00	0.00
cis-1,2-Dichloroethene	0.00	0.00	0.00	0.00
1,2-Dichoroethane	0.00	0.00	0.00	0.00
1,1,1-Trichloroethane	0.00	0.00	0.00	0.00
Benzene	1.29	0.92	0.67	0.19
Carbon tetrachloride	0.00	0.00	0.00	0.00
1,2 -Dichloropropane	0.00	0.00	0.00	0.00
Trichloroethene	0.05	0.00	0.04	0.02
Methyl isobutyl ketone	1.85	2.82	0.34	0.40
Toluene	0.37	0.04	0.31	0.05
Tetrachloroethene	0.15	0.00	0.08	0.08
Chlorobenzene	0.13	0.03	0.12	0.04
Ethylbenzene	0.11	0.01	0.10	0.01
m,p-Xylene	0.56	0.02	0.55	0.02
Styrene	0.28	0.01	0.27	0.03
o-Xylene	0.07	0.04	0.09	0.01
4-Ethyltoluene	0.06	0.01	0.04	0.02
1,3,5-Trimethylbenzene	0.10	0.06	0.05	0.03
m-Dichlorobenzene	0.10	0.06	0.10	0.05
p-Dichlorobenzene	0.11	0.02	0.10	0.04
o-Dichlorobenzene	0.11	0.01	0.09	0.04
Benzothiazole	5.42	3.18	23.01	22.96

[a] VOC = volatile organic compound; FLM = fence line monitor

[b] FLM Field Blank (n=4); FLM Run Blank (n=23)

Table E-27. Blanks Quality Control Results for VOCs in Synthetic Turf Field Tire Crumb Rubber Characterization Chamber Emission Samples[a,b]

Chemical	FLM Field Blank Mean (ng/tube)	FLM Field Blank Standard Deviation (ng/tube)	FLM Run Blank Mean (ng/tube)	FLM Run Blank Standard Deviation (ng/tube)
Freon 12	0.01	0.01	0.00	0.01
1,3-Butadiene	-0.04	0.10	0.07	0.53
trans-2-Butene	0.05	0.03	0.05	0.05
cis-2-Butene	0.05	0.03	0.05	0.05
Freon 11	0.05	0.06	0.04	0.05
1,1-Dichloroethene	0.00	0.00	0.00	0.00
Freon 113	0.08	0.05	0.03	0.05
1,1-Dichloroethane	0.00	0.00	0.00	0.00
cis-1,2-Dichloroethene	-0.02	0.15	0.00	0.00
1,2-Dichoroethane	0.00	0.00	0.00	0.00
1,1,1-Trichloroethane	0.00	0.00	0.00	0.00
Benzene	1.26	0.35	1.28	0.39
Carbon tetrachloride	0.05	0.11	0.05	0.11
1,2 -Dichloropropane	0.00	0.00	0.00	0.00
Trichloroethene	-0.20	0.07	-0.18	0.09
Methyl isobutyl ketone	0.12	0.18	0.35	1.35
Toluene	0.29	0.19	0.29	0.23
Tetrachloroethene	0.08	0.02	0.07	0.03
Chlorobenzene	0.07	0.02	0.07	0.03
Ethylbenzene	0.07	0.02	0.07	0.02
m,p-Xylene	0.16	0.04	0.16	0.07
Styrene	0.14	0.15	0.15	0.10
o-Xylene	0.06	0.03	0.07	0.07
4-Ethyltoluene	0.00	0.03	0.01	0.07
1,3,5-Trimethylbenzene	0.01	0.05	0.02	0.11
m-Dichlorobenzene	-0.04	0.05	-0.04	0.10
p-Dichlorobenzene	-0.09	0.06	-0.08	0.10
o-Dichlorobenzene	-0.21	0.10	-0.22	0.15
Benzothiazole	4.73	4.79	4.36	3.89

[a] VOC = volatile organic compound; FLM = fence line monitor

[b] FLM Field Blank (n=43); FLM Run Blank (n=49)

Chamber Background Samples – Table E-28 reports chamber background sample measurement results for chamber emission tests performed at 25 °C and 60 °C. One chamber background sample was collected prior to the test performed for each tire crumb rubber sample. Sample emission results were adjusted by subtracting the average chamber background measurement result for each batch from the sample VOC measurement results for samples in that batch. Each batch was at either 25 °C or 60 °C, so the chamber background adjustments were effectively made on a temperature-specific basis.

Table E-28. Emission Test Chamber Background Sample Quality Control Results for VOCs[a,b]

Chemical	Mean Emission Chamber Background at 25 °C (ng/sample)	Emission Chamber Background at 25 °C Standard Deviation (ng/sample)	Mean Emission Chamber Background at 60 °C (ng/sample)	Emission Chamber Background at 60 °C Standard Deviation (ng/sample)
Benzene	0.3009	0.5352	0.9733	1.0122
Benzothiazole	0.7958	11.5077	6.1112	21.0472
Carbon tetrachloride	0.00973	0.0935	0.0608	0.1199
Chlorobenzene	0.0108	0.0289	0.0606	0.0385
Freon 11	0.4539	0.0843	0.4481	0.0795
Ethylbenzene	0.0431	0.0264	0.6647	0.5250
Freon 113	0.0633	0.0458	0.0628	0.0488
Methyl isobutyl ketone	0.3006	0.4819	1.9614	2.1588
Styrene	0.1240	0.4953	1.0900	0.5634
Tetrachloroethene	0.0347	0.0381	0.0553	0.0370
Toluene	0.1280	0.3020	0.7423	0.5505
Trichloroethene	0.00603	0.0723	-0.0197	0.0320
Freon 12	1.2034	0.9950	1.2079	1.0174
1,1,1-Trichloroethane	0	0	-0.00211	0.0199
1,1-Dichloroethane	-0.00093	0.0259	0.000639	0.0298
1,1-Dichloroethene	0.00306	0.0289	0.00255	0.0241
1,2-Dichoroethane	0	0	0	0
1,2 -Dichloropropane	0.000440	0.000323	0.000447	0.000321
1,3,5-Trimethylbenzene	0.0238	0.0656	0.0406	0.0497
1,3-Butadiene	0.0171	0.2626	0.0315	0.2610
4-Ethyltoluene	0.0308	0.0209	0.1591	0.1267
cis-1,2-Dichloroethene	-0.0214	0.1420	-0.0115	0.1090
cis-2-Butene	0.0995	0.0595	0.9517	0.5326
m-Dichlorobenzene	0.0203	0.0607	0.0363	0.0342
m,p-Xylene	0.1489	0.1000	2.6777	2.2244
o-Dichlorobenzene	0.0269	0.0954	0.0192	0.0560
o-Xylene	0.1367	0.1051	1.9389	1.8241
p-Dichlorobenzene	0.0405	0.0717	0.3271	0.2666
trans-2-Butene	0.0973	0.0568	1.0360	0.5871

[a] VOC = volatile organic compound; °C = degrees Celsius

[b] Emission Chamber Background samples at 25 °C (n=89), at 60 °C (n=89)

Recovery - Table E-29 reports tube matrix spike recovery results for each analyte and Table E-30 reports recovery results for FLM run calibration checks. Recoveries ranged from 77% to 108%. No recovery adjustments were made in the sample analysis results.

Table E-29. Recovery Quality Control Results for VOCs in Tube Matrix Spike Samples [a,b,c]

Chemical	Tube Matrix Spikes Mean % Recovery	Tube Matrix Spikes % Recovery Standard Deviation
Freon 12	92	16
1,3-Butadiene	92	18
trans-2-Butene	90	18
cis-2-Butene	90	17
Freon 11	94	16
1,1-Dichloroethene	95	19
Freon 113	101	9
1,1-Dichloroethane	108	12
cis-1,2-Dichloroethene	104	20
1,2-Dichoroethane	110	16
1,1,1-Trichloroethane	102	14
Benzene	99	5
Carbon tetrachloride	97	30
1,2 -Dichloropropane	99	11
Trichloroethene	97	18
Methyl isobutyl ketone	91	44
Toluene	98	3
Tetrachloroethene	100	3
Chlorobenzene	100	2
Ethylbenzene	99	2
m,p-Xylene	99	3
Styrene	102	4
o-Xylene	100	3
4-Ethyltoluene	103	8
1,3,5-Trimethylbenzene	102	4
m-Dichlorobenzene	106	4
p-Dichlorobenzene	107	4
o-Dichlorobenzene	108	4
Benzothiazole	85	29

[a] VOC = volatile organic compound

[b] Tube Matrix Spikes (n=23), Spike = 4.8 to 27.8 nanograms (ng)/tube; all Lab Spikes were prepared on Carbopack X tubes at nominal concentrations of 2 parts per billion by volume (ppbv)

[c] Recoveries are calculated using the blank corrected tube results and the theoretical mass (ng) loaded

Table E-30. Recovery Quality Control Results for VOCs in FLM Run Calibration Check Samples [a,b,c]

Chemical	FLM Run Calibration Check Mean % Recovery	FLM Run Calibration Check % Recovery Standard Deviation
Freon 12	93	6
1,3-Butadiene	95	7
trans-2-Butene	88	6
cis-2-Butene	90	6
Freon 11	93	5
1,1-Dichloroethene	88	16
Freon 113	98	6
1,1-Dichloroethane	93	12
cis-1,2-Dichloroethene	89	12
1,2-Dichoroethane	89	11
1,1,1-Trichloroethane	105	16
Benzene	91	5
Carbon tetrachloride	108	31
1,2 -Dichloropropane	97	9
Trichloroethene	89	10
Methyl isobutyl ketone	107	57
Toluene	96	4
Tetrachloroethene	95	4
Chlorobenzene	92	4
Ethylbenzene	94	5
m,p-Xylene	92	8
Styrene	94	6
o-Xylene	93	5
4-Ethyltoluene	96	7
1,3,5-Trimethylbenzene	95	6
m-Dichlorobenzene	92	5
p-Dichlorobenzene	93	5
o-Dichlorobenzene	95	5
Benzothiazole	77	25

[a] VOC = volatile organic compound; FLM = fence line monitor

[b] FLM Run Calibration Check (n=50); Spike = 4.6 to 15.2 nanograms (ng)/tube. All Lab Spikes were prepared on Carbopack X tubes at nominal concentrations of 2 parts per billion by volume (ppbv).

[c] Recoveries are calculated using the blank corrected tube results and the theoretical mass (ng) loaded.

Precision – Analysis precision was assessed by the analysis of duplicate tire crumb rubber emission samples collected during an emissions test. Results are shown for select VOCs in Section 4.9.1, Tables 4-54 and 4-55 of the Volume 1 report (EPA/600/R-19/051a). Mean %RSDs of chamber emissions VOC measurements for 18 duplicate sample pairs analyzed at 25 °C ranged from 17% for benzothiazole (which was present at the highest concentrations among the target analytes) to 67% for benzene. Mean %RSDs of chamber emissions VOC measurements for 17 duplicate sample pairs analyzed at 60 °C ranged from 8.8% for benzothiazole (which was present at the highest concentrations among target analytes) to 100% for 1,3-butadiene. The average precision for benzothiazole, formaldehyde, methyl isobutyl ketone, styrene and m/p-xylene 60 °C emission samples were all ≤ 17%RSD. It is likely that the relatively poor precision for some analytes is due to measurements near or below the method detection limits. Based on tube matrix spike samples, the %RSDs were < 30% for most analytes, with methyl isobutyl ketone somewhat higher.

DQI – Most DQI objectives were met for VOC emission samples based on the quality control measurement results. Precision DQI values were not met for some analytes, likely as a result of measurements below or near the method detection limits.

E.4.8 Microbiological Analysis

Quality control (QC) procedures were employed for the microbiological component of the tire crumb rubber study as outlined in the QAPP "Characterization of the Microbiome and Occurrence of Antibiotic Resistance Genes in Tire Crumb Rubber Artificial Turf Athletic Fields."

A sample holding time of 24 hours was assigned to minimize growth and degradation of bacterial community members. This metric was met for 20% of sample collection events. The minimum exceedance time was 4 minutes and the maximum was 11.4 hours. The mean (± standard deviation) exceedance time was 2.4 hours (± 2.1). Also, to minimize growth and degradation processes of bacterial community members in collected samples, the holding temperature from sample collection to receipt was targeted to be between 2–8 °C. This criterion was met for 20% of collection events. The minimum holding temperature recorded was -40 °C and the maximum was 42 °C. Despite these derivations from ideal conditions, all samples were processed and analyzed. It is unclear how specific taxa in the sample may have been impacted by the exceeded holding time and temperatures, but it is likely that some taxa may not have survived and could be absent in resulting analyses.

Field and laboratory quality control samples were implemented to assess process proficiency and monitor potential contamination during sample processing and analysis. A description of the quality control samples implemented during sample collection and sample processing, as well as a summary of performance is shown in Table E-31. All processes performed within acceptance criteria except elution of microbes from tire crumb rubber. However, despite falling below acceptance criteria and indicating reduced recovery, those samples were still analyzed. Quality control samples were also implemented for each analytical procedure. Table E-32 lists the control samples utilized for each analytical procedure and resulting performance. All analytical procedure quality controls met acceptance criteria except the Universal Staphylococcus droplet digital polymerase chain reaction (ddPCR) assay and 1 of 13 positive controls for MiSeq sequencing. Because the Universal Staphylococcus ddPCR positive controls failed to meet acceptance criteria, results from tire crumb rubber samples were not reported. MiSeq sequencing included 6 replicates, so failure of a single replicate was accepted.

Table E-31. Description of Quality Control Samples for Sample Collection and Processing[a]

Sample/Laboratory Process	Control Type	Number of Control Samples	% Meet Acceptance Criteria	Qualifier
Sample Collection	Negative	40	100	N/A
Elution of microbes from TCR	Positive	23	87	Corresponding samples may have reduced recovery of microbes from tire crumb rubber, but samples were analyzed anyway
Elution of microbes from TCR	Negative	23	0	All samples were sequenced to identify potential contaminants
Extraction of genomic DNA of eluted microbes	Positive	17	100	N/A
Extraction of genomic DNA of eluted microbes	Negative	17	100	N/A

[a] N/A = Not applicable; TCR = Tire crumb rubber; DNA = deoxyribonucleic acid

Finally, some quality control metrics were implemented to evaluate sample quality. For targeted gene analysis, an internal amplification control was instituted with each sample to evaluate potential interference of the PCR reaction. Four samples failed to meet the acceptance criteria and were omitted from analysis (Table E-33). Analysis of the non-targeted data resulted in 1 sample falling outside of the quality metrics during sequence read processing (Table E-33). In addition, the negative controls for sample collection and elution of microbes from tire crumb showed one sample from each cohort contained potential bacterial contaminants. These two samples represented sample processing steps for four fields. As a result, 28 samples were omitted from analysis (Table E-33). Furthermore, the minimum sequence read count after quality filtering was set at 1000 per sample. A total of 8 samples fell below this threshold and were removed from analysis.

Table E-32. Description of Quality Control Samples for Analytical Procedures[a]

Microbial Analysis Type	Analytical Procedure	Control Type	Number of Control Samples	% Meet Acceptance Criteria	Action
Targeted	ddPCR - Internal Amplification Control	Positive	16	100	N/A
Targeted	ddPCR - Internal Amplification Control	Negative	16	100	N/A
Targeted	ddPCR - 16S rRNA gene	Positive	32	100	N/A
Targeted	ddPCR - 16S rRNA gene	Negative	32	100	N/A
Targeted	ddPCR - *S. aureus* SA104 protein gene	Positive	16	100	N/A
Targeted	ddPCR - *S. aureus* SA104 protein gene	Negative	32	100	N/A
Targeted	ddPCR - Universal *Staphylococcus*	Positive	16	0	Results are not reported for this gene target
Targeted	ddPCR - Universal *Staphylococcus*	Negative	32	100	N/A

Table E-32 Continued

Microbial Analysis Type	Analytical Procedure	Control Type	Number of Control Samples	% Meet Acceptance Criteria	Action
Targeted	ddPCR - *mecA* methicillin resistance gene	Positive	16	100	N/A
Targeted	ddPCR - *mecA* methicillin resistance gene	Negative	16	100	N/A
Non-targeted	PCR for non-targeted analysis	Positive	39	100	N/A
Non-targeted	PCR for non-targeted analysis	Negative	39	100	N/A
Non-targeted	MiSeq Sequencing	Positive	13	92	Accept failure of 1 replicate; Proceed with analysis

[a] ddPCR = droplet digital polymerase chain reaction; N/A = Not applicable; rRNA = ribosomal ribonucleic acid; PCR = polymerase chain reaction

Table E-33. Description of Quality Control Criteria Exceedances for Tire Crumb Rubber Samples

Microbial Analysis Type	Criteria	Number of Samples	Corrective Action
Targeted	Internal amplification Control	4	Samples were omitted from analysis
Non-targeted	Sequence Read Filter	1	Samples were omitted from analysis
Non-targeted	Potential Contamination	28	Samples were omitted from analysis
Non-targeted	Total Read Counts	8	Samples were omitted from analysis

Precision was examined within samples collected from artificial turf fields using duplicate ddPCR measurements (Table E-34). Only samples with quantifiable molecule counts for both duplicate ddPCR reactions were included in the analysis. The mean (± standard deviation) percent relative standard deviation was 12.7% (± 22.5), 37.3% (±29.3) and 22.3% (± 21.6) for the 16S rRNA gene, *S. aureus* SA0140 protein gene and *mecA* methicillin resistance gene, respectively. Precision was also examined between the 7 samples collected at each artificial turf field (Table E-35). To be included in analysis, all 7 replicate field samples had to have quantifiable results. Some variability was observed in replicate field samples as %RSD ranged from 58-63% for the targeted microbial genes. However, less variability was observed in 16S rRNA sequence read counts among replicated field samples as the %RSD was 28.7%.

Table E-34. Precision of ddPCR Measurements of Targeted Genes Within Samples[a]

Gene Target	Number of Samples	Mean % Relative Standard Deviation	Standard Deviation
16S rRNA gene	274	12.7	22.5
S. aureus SA0140 protein gene	70	37.3	29.3
mecA methicillin resistance gene	131	22.3	21.6

[a] ddPCR = droplet digital polymerase chain reaction; rRNA = ribosomal ribonucleic acid

Table E-35. Precision of Measurements Between Samples of a Field Where Microbes were Detected for All Seven Samples from the Field[a]

Microbial Analysis Type	Measurement	Number of Fields	Mean % Relative Standard Deviation	Standard Deviation
Targeted	16S rRNA gene	36	63.44	35.84
Targeted	*S. aureus* SA0140 protein gene	3	58.37	28.81
Targeted	*mecA* methicillin resistance gene	14	58.89	23.34
Non-targeted	16S rRNA Sequence Reads	36	28.7	22.6

[a] rRNA = ribosomal ribonucleic acid

E.4.9 Bioaccessibility Analysis for Metals

The QA/QC protocol for the bioaccessibility testing of metals in tire crumb rubber materials included QA/QC procedures for each individual step and an overall QA/QC assessment for the entire bioaccessibility analysis scheme. Bioaccessibility testing involves numerous steps and procedures, each following its own "base method," including formulation of the four artificial biofluids, dissolution of target analytes in tire crumb samples into biofluids, acid digestion of artificial biofluid extracts (EPA Method 3010), and analytical measurements by ICP/MS (EPA Method 6020), ICP/AES (EPA Method 6010), and mercury cold vapor technique (EPA Method 7470). Therefore, QA/QC procedures were employed for each step and documented following the guidelines specified in each of the base methods.

Maxxam Laboratories is a subsidiary of Buena Veritas North America and was contracted to perform analytical services for the National Institute for Occupational Safety and Health (NIOSH). The company participates in the American Industrial Hygiene Association Industrial Hygiene Proficiency Analytical Testing program and the Environmental Lead Proficiency Analytical Testing program and is documented to be fully proficient by these independent testing programs. Results from each 6-month testing period are available from Maxxam Laboratories. Maxxam Laboratories was subject to NIOSH QA/QC checks and required to comply with requirements outlined by NIOSH Division of Applied Research and Technology quality assurance and quality control protocol.

E.4.9.1 QA/QC for Dissolution in Artificial Biofluids

All fluids were produced using commercially-available reagents. All reagents were stored according to manufacturer recommendations. Artificial fluid pH was monitored using third party annually-calibrated pH meters (certificates are on file at the CDC/NIOSH in Morgantown, WV). Artificial biofluids were stored at -20 ºC until use. Once thawed, fluids were stored at 4 ºC for one month, then discarded. All freezers and refrigerators were monitored for temperature using traceable thermometers, but records were not maintained. Tire crumb rubber samples were weighed on an annually-calibrated balance. Balance accuracy was verified prior to each use using calibration weights within the range of individual sample masses. All tire crumb samples were 2.0 ± 0.005g. Balance calibration certificates are on file at NIOSH in Morgantown, WV. Pipetting was performed using annually-calibrated pipettes and pipette accuracy was verified weekly using 18 megΩ water. Pipette and balance precision was assumed to be ±2.0 %, as reported by the manufacturer.

E.4.9.2 QA/QC for Analytical Measurements at the Maxxam Laboratories

QA/QC for the metal analyses in this study was conducted according to guidelines set forth in EPA Methods 3010, 6010, 6020, and 7470, for acid digestion, ICP/AES analysis, ICP/MS analysis, and mercury cold vapor analysis, respectively. After the laboratory analyses were completed, the result reports underwent a QA/QC review at the Maxxam Laboratories before being uploaded to the NIOSH Laboratory Information Management System (LIMS).

E.4.9.3 QA/QC Review at NIOSH Laboratory Information Management System

Once the result reports were submitted to the NIOSH LIMS, they were reviewed by the NIOSH Comprehensive Analytical Support Contract quality assurance team. The report review process included reviews of data accuracy, errors of omission, and report formatting in accordance with the United States Department of Health and Human Services Section 508 compliance for digital communications. The review process was a multi-level process as outlined in Table E-36.

Table E-36. QA/QC Review Process at NIOSH for the Analytical Measurements of the Bioaccessibility Testing Sample Extracts[a]

Review levels	Actions
Level 1 – Data checker	Checker reviews QC sheets and narrative report to confirm data and determines whether report follows Branch policy.
Level 2 – Lab coordinator	Laboratory coordinator determines that the analyses have covered all aspects of the original laboratory request.
Level 3 – QA coordinator	QA coordinator assesses all QC data, reviews report for SOP conformance and creates and uploads a QA pdf file which includes the QC sheets.
Level 4 – Team leader	Team leader reviews comments of previous reviewers and provides final review to the author indicating anything that remains to be done.
Level 5 – Branch chief	Branch chief approves report. The LIMS automatically sends e-mail with URL to client, prints a hard copy of the report for the files and closes with date the report is approved.

[a] QA/QC = quality assurance/quality control; NIOSH = National Institute for Occupational Safety and Health; SOP= standard operating procedure; LIMS = laboratory information management system; URL = universal resource locator

E.4.9.4 QA/QC Scheme for the Entire Bioaccessibility Testing

This study used a series of systematic approaches to document the QA/QC process for the entire bioaccessibility analysis scheme, including method blanks, QC samples and repeated samples.

- Method blanks: artificial biofluids with no tire crumb rubber materials that was carried through the entire bioaccessibility testing process (extraction-digestion-analysis).
- QC samples: a native tire crumb material collected in bulk from a manufacturer facility that was carried through the entire bioaccessibility testing process
- Repeated samples: unknown field or facility tire crumb samples that had two or more repeated bioaccessibility tests. The repeated tests occurred either within the same batch or in different batches.

Tire crumb samples were processed in nine batches. For the first eight batches, each batch consisted of one method blank, two QC samples, 10 unknown field or facility tire crumb samples, and two repeated unknown tire crumb samples. The last batch consisted of one method blank, two QC samples, two unknown field or facility tire crumb samples, and 10 repeated unknown tire crumb samples. In addition, one batch was repeated for gastric fluid and another batch was repeated for sweat plus sebum. All results were blank-subtracted before further analysis.

QC results - QC samples were evaluated and monitored throughout this study. Before bioaccessibility testing on the tire crumb samples, 40 QC samples were tested over 5 different batches to assess the variability in the three artificial biofluids. In addition, 20, 18, and 20 QC samples were tested along with tire crumb samples for artificial gastric fluid, saliva, and sweat plus sebum, respectively. The preparation and analytical measurement of these QC samples spanned a period of six months. Therefore, the variability observed in the QC samples reflects the overall precision of all steps (dissolution, digestion, and analytical measurement), the temporal variability of the entire test scheme, and the heterogeneity of the tire crumb samples. Summary statistics of the QC samples for selected analytes and artificial biofluids are given in Table E-37. Only the analytes/artificial biofluids with mean concentrations 10 times above the analytical limit of detection (LOD) were monitored for variability and consistency. Overall, the coefficient of variance (CV) for the monitored analytes/artificial biofluid ranged from 22% to 40%.

Table E-37. Summary Statistics of the QC Samples for Selected Analytes and Artificial Biofluids[a]

Matrix	Analyte	Method	N	Mean (mg/kg TCR)	Standard Deviation (mg/kg TCR)	CV
Gastric Fluid	Barium	ICP/MS	60	0.32	0.09	30%
Gastric Fluid	Cobalt	ICP/MS	60	0.21	0.06	31%
Gastric Fluid	Copper	ICP/MS	60	2.32	0.71	31%
Gastric Fluid	Iron	ICP/AES	60	21	7.2	34%
Gastric Fluid	Lead	ICP/MS	60	0.22	0.06	29%
Gastric Fluid	Magnesium	ICP/AES	60	3.7	1.1	31%
Gastric Fluid	Strontium	ICP/MS	60	0.11	0.04	35%
Gastric Fluid	Zinc	ICP/AES	60	122	34	28%
Saliva	Magnesium	ICP/AES	58	0.7	0.3	39%
Sweat plus Sebum	Cobalt	ICP/MS	60	0.10	0.03	32%
Sweat plus Sebum	Magnesium	ICP/AES	60	1.0	0.2	22%
Sweat plus Sebum	Zinc	ICP/AES	60	12	4.9	40%

[a] QC = quality control; mg/kg TCR = milligram of analyte per kilogram of tire crumb rubber; CV = coefficient of variance; ICP/MS = inductively coupled plasma/mass spectrometry; ICP/AES = inductively coupled plasma/atomic emission spectrometry

Repeated bioaccessibility testing results - Twenty-four (24) tire crumb samples were repeated for the bioaccessibility test for each of the three artificial biofluids, either in the same batch or over different batches. In addition, one entire batch was repeated for artificial gastric fluid and another batch was repeated for artificial sweat plus sebum. A batch was not repeated for artificial saliva, because very few analytes were detected in artificial saliva extracts. In total, 34 (41%), 24 (29%), and 34 (41%) tire crumb samples were repeated for the bioaccessibility test for artificial gastric fluid, saliva and sweat plus sebum, respectively.

Correlation analyses were conducted on 10 metals with 50% or higher detection rates (i.e., 50% or more of results were above the LOD) in these repeated samples, combining results from all three artificial biofluids. The correlation parameters between the repeated results are given in Table E-38, stratified by analyte. Figures E-1 and E-2 present the scatter plots between the repeated bioaccessibility test results for the 10 metals with >50% detection rate, including 4 metals measured by ICP/AES and 6 metals measured by ICP/MS. As shown from the results of the correlation analyses, the repeated bioaccessibility results were, in general, consistent with each other; this demonstrates the reproducibility and consistency of the entire bioaccessibility test procedure, which included dissolution of tire crumb samples in artificial biofluids, acid digestion of the artificial biofluid extracts, and analytical measurements by ICP/MS and ICP/AES.

Table E-38. Correlation Parameters of Repeated Bioaccessibility Testing Results (mg/kg TCR) for Analytes with 50% or Higher Detection Rate[a]

Analyte	Method	N	Slope	Intercept	R^2
Aluminum	AES	92	0.96	0.03	0.938
Barium	MS	92	1.03	-0.03	0.908
Cobalt	MS	92	0.83	0.02	0.901
Copper	MS	92	0.90	0.07	0.972
Iron	AES	92	0.90	1.35	0.958
Lead	MS	92	0.91	0.01	0.911
Magnesium	AES	92	1.00	-0.17	0.974
Manganese	MS	92	1.02	-0.03	0.882
Strontium	MS	92	1.00	0.00	0.977
Zinc	AES	92	0.96	0.44	0.923

[a] mg/kg TCR = milligram of analyte per kilogram of tire crumb rubber; R^2 = statistical constant variability test; AES = atomic emission spectrometry; MS = mass spectrometry

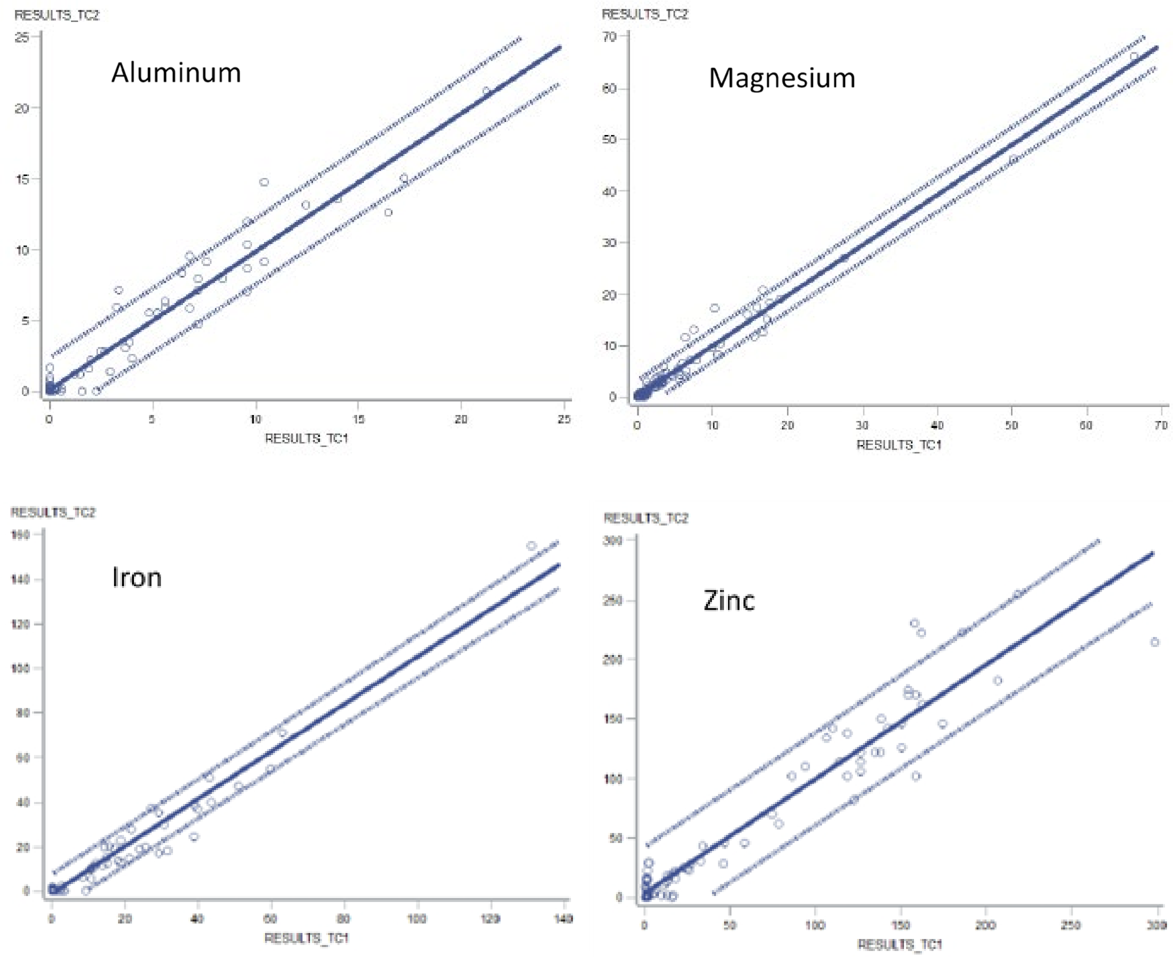

Figure E-1. Scatter plots between repeated bioaccessibility analyses results (mg/kg TCR) for four analytes with 50% or higher detection rate, as measured by ICP/AES (all three artificial biofluids combined).[mg/kg TCR = milligram of analyte per kilogram of tire crumb rubber; ICP/AES= inductively coupled plasma/atomic emission spectrometry]

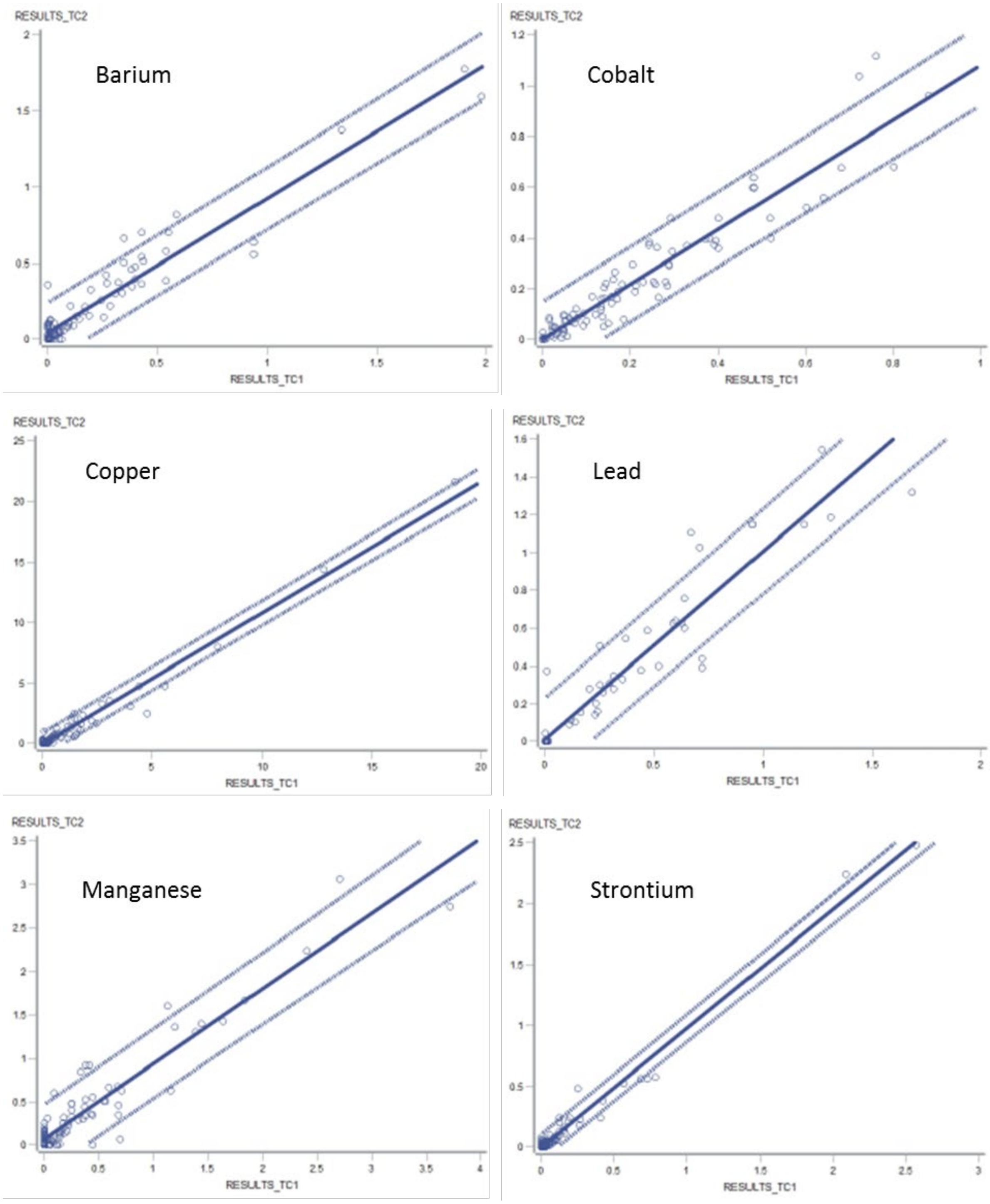

Figure E-2. Scatter plots between repeated bioaccessibility analyses results (mg/kg TCR) for six analytes with 50% or higher detection rate, as measured by ICP/MS (all three artificial biofluids combined). [mg/kg TCR = milligram of analyte per kilogram of tire crumb rubber; ICP/MS= inductively coupled plasma/mass spectrometry]

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Appendix F

Synthetic Turf Field Facility Owner/Manager Questionnaire

Form Approved
OMB No. 0923-0054
Exp. Date 01/31/2017

Owner/Manager Synthetic Turf Fields Questionnaire

Site ID number | Interview Date | Interviewer ID

Interviewer: In this interview, I would like to ask you some general questions about your role and responsibilities at this facility and about the operation, maintenance, and use of the synthetic turf fields with crumb rubber infill at your facility.

A1. Who owns the facility?

A1.a What type of organization owns the facility?

- Private
- School
- City
- County
- State
- Military/Federal
- (enter other if necessary)

A2. What is your profession and relationship to this facility?

(owner or manager)

A3. How long have you operated this facility?

yrs months

A4. May I have your phone number and E-mail address for future contact?

Phone

E-Mail

ATSDR estimates the average public reporting burden for this collection of information as 30 minutes per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. An agency may not conduct or sponsor, and a person is not required to respond to collection of information unless it displays a currently valid OMB control number. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden to CDC/ATSDR Reports Clearance Officer; 1600 Clifton Road, MS D-74, Atlanta, GA 30333, ATTN: PRA (0923-0054).

Facility User Information

A5. Are the synthetic fields at this facility open to the public?

- ○ Yes
- ○ No
- ○ Don't Know
- ○ Refused

A6. Is there an open or free-play schedule at this facility?

- ○ Yes
- ○ No
- ○ Don't Know
- ○ Refused

A7. Is field use at this facility limited to organization membership or school use only?

- ○ Yes
- ○ No
- ○ Don't Know
- ○ Refused

If yes, what organization(s) use the synthetic fields?

[ ]

A8. How many days per week are the synthetic fields open at this facility during each season?

Days per Week Spring	☐
Days per Week Summer	☐
Days per Week Fall	☐
Days per Week Winter	☐

A9. What is average number of hours per day that people use the synthetic fields at this facility during the four seasons?

Hours per Day Spring	☐
Hours per Day Summer	☐
Hours per Day Fall	☐
Hours per Day Winter	☐

A10a. On average, how many people per day use the synthetic fields at this facility during Spring? ☐

A10b. On average, how many people per day use the synthetic fields at this facility during Summer? ☐

A10c. On average, how many people per day use the synthetic fields at this facility during Fall? ☐

A10d. On average, how many people per day use the synthetic fields at this facility during Winter? ☐

A11. For each of the different age groups, what sports or other activities are played on the synthetic turf fields at this facility during which seasons (check all that apply)?

				Spring	Summer	Fall	Winter
☐	< 6	☐	Soccer	☐	☐	☐	☐
		☐	Football	☐	☐	☐	☐
		☐	Field Hockey	☐	☐	☐	☐
		☐	Baseball	☐	☐	☐	☐
		☐	Softball	☐	☐	☐	☐
		☐	Rugby	☐	☐	☐	☐
		☐	Ultimate Frisbee	☐	☐	☐	☐
		☐	Physical Training (PT)	☐	☐	☐	☐
		☐	Physical Education (PE)	☐	☐	☐	☐
		☐	Other: ☐	☐	☐	☐	☐
		☐	Other: ☐	☐	☐	☐	☐
☐	6 - 11	☐	Soccer	☐	☐	☐	☐
		☐	Football	☐	☐	☐	☐
		☐	Field Hockey	☐	☐	☐	☐
		☐	Baseball	☐	☐	☐	☐
		☐	Softball	☐	☐	☐	☐
		☐	Rugby	☐	☐	☐	☐
		☐	Ultimate Frisbee	☐	☐	☐	☐
		☐	Physical Training (PT)	☐	☐	☐	☐
		☐	Physical Education (PE)	☐	☐	☐	☐
		☐	Other: ☐	☐	☐	☐	☐
		☐	Other: ☐	☐	☐	☐	☐

A11. For each of the different age groups, what sports or other activities are played on the synthetic turf fields at this facility during which seasons (check all that apply)? (continued)

Age group		Activity	Spring	Summer	Fall	Winter
☐ 12 - 18	☐	Soccer	☐	☐	☐	☐
	☐	Football	☐	☐	☐	☐
	☐	Field Hockey	☐	☐	☐	☐
	☐	Baseball	☐	☐	☐	☐
	☐	Softball	☐	☐	☐	☐
	☐	Rugby	☐	☐	☐	☐
	☐	Ultimate Frisbee	☐	☐	☐	☐
	☐	Physical Training	☐	☐	☐	☐
	☐	Physical Education (PE)	☐	☐	☐	☐
	☐	Other: ____	☐	☐	☐	☐
	☐	Other: ____	☐	☐	☐	☐

Age group		Activity	Spring	Summer	Fall	Winter
☐ 18 +	☐	Soccer	☐	☐	☐	☐
	☐	Football	☐	☐	☐	☐
	☐	Field Hockey	☐	☐	☐	☐
	☐	Baseball	☐	☐	☐	☐
	☐	Softball	☐	☐	☐	☐
	☐	Rugby	☐	☐	☐	☐
	☐	Ultimate Frisbee	☐	☐	☐	☐
	☐	Physical Training	☐	☐	☐	☐
	☐	Physical Education (PE)	☐	☐	☐	☐
	☐	Other: ____	☐	☐	☐	☐
	☐	Other: ____	☐	☐	☐	☐

Facility Information

A12. Do you have any standard practices in place to reduce tire crumb exposure to people using the synthetic fields? ☐

If so (describe): ____

Outdoor Fields Only

A13. Are there outdoor fields at this facility? ☐

A14. When was each outdoor synthetic field installed at this facility?

Field	Month	Year

A15. Which company or companies installed these fields?

A16. Do you ever replace all of the tire crumb infill on the outdoor synthetic turf field(s) at your facility?

- ○ Yes
- ○ No
- ○ Don't Know
- ○ Refused

If yes, how often do you replace all of the tire crumb infill on the synthetic turf fields?

- ○ Never/rarely
- ○ Every 6 months
- ○ Yearly
- ○ Every 2-3 years
- ○ Every 3-5 years
- ○ Every 5-7 years
- ○ More than 7 years
- ○ Don't Know
- ○ Refused

A17. Do you ever refresh or add tire crumb infill to your outdoor synthetic turf field(s) at your facility?

- ◯ Yes
- ◯ No
- ◯ Don't Know
- ◯ Refused

If yes, how often do you refresh or add tire crumb infill to your synthetic turf fields?

- ◯ Rarely/Never
- ◯ Every 6 months
- ◯ Yearly
- ◯ Every 2-3 years
- ◯ Every 3-5 years
- ◯ Every 5-7 years
- ◯ More than 7 years
- ◯ Don't Know
- ◯ Refuse

A18. What was the date of the most recent replacement/refreshment? ______

A19. Which company or companies provides crumb rubber infill material for replacement/refreshment?

______

A20. Are the following routine field maintenance activities performed on the outdoor synthetic field(s) at this facility?

Activity	Times	per
☐ Sweeping		Day/week/month/year
☐ Brushing		Day/week/month/year
☐ Redistribution/leveling		Day/week/month/year
☐ Aerating		Day/week/month/year
☐ Magnet sweep		Day/week/month/year
☐ Rejuvenation		Day/week/month/year
☐ Deep Cleaning		Day/week/month/year

A21. Has the outdoor synthetic field(s) ever been treated with biocides, herbicides, insecticides, fungicides, or other agents?

- ◯ Yes
- ◯ No
- ◯ Don't Know
- ◯ Refused

A22. Have any of the following chemicals been used on the field? (check all that apply) and how often?

	Chemical	Times	per
☐	Algae Died B		Day/week/month/year
☐	Qualgex		Day/week/month/year
☐	Steri-maX		Day/week/month/year
☐	Other (specify)		Day/week/month/year
☐	Unknown Biocide		Daily/weekly/ monthly/annually

Indoor Fields Only

A23. Are there indoor fields at this facility? ☐

A24. When was each indoor synthetic field installed at this facility?

Field	Month	Year

A25. Which company or companies installed these fields?

A26. Do you ever replace all of the tire crumb infill on the indoor synthetic turf field(s) at your facility?

- ○ Yes
- ○ No
- ○ Don't Know
- ○ Refused

If yes, how often do you replace all of the tire crumb infill on the synthetic turf fields?

- ○ Rarely/Never
- ○ Every 6 months
- ○ Yearly
- ○ Every 2-3 years
- ○ Every 3-5 years
- ○ Every 5-7 years
- ○ More than 7 years
- ○ Don't Know
- ○ Refuse

A27. Do you ever refresh or add tire crumb infill to your indoor synthetic turf field(s) at your facility?

- ○ Yes
- ○ No
- ○ Don't Know
- ○ Refused

If yes, how often do you refresh or add tire crumb infill to your synthetic turf fields?

- ○ Rarely/Never
- ○ Every 6 months
- ○ Yearly
- ○ Every 2-3 years
- ○ Every 3-5 years
- ○ Every 5-7 years
- ○ More than 7 years
- ○ Don't Know
- ○ Refuse

A28. What was the date of the most recent replacement/refreshment? [ ]

A29. What company or companies provides crumb rubber infill material for replacement/refreshment?

[ ]

A30. Are the following routine field maintenance activities performed on the indoor synthetic field(s) at this facility?

Activity	Times	per
☐ Sweeping		Day/week/month/year
☐ Brushing		Day/week/month/year
☐ Redistribution/leveling		Day/week/month/year
☐ Aerating		Day/week/month/year
☐ Magnet sweep		Day/week/month/year
☐ Rejuvenation		Day/week/month/year
☐ Deep Cleaning		Day/week/month/year

A31. Has the outdoor synthetic field(s) ever been treated with biocides, herbicides, insecticides, fungicides, or other agents?

- ○ Yes
- ○ No
- ○ Don't Know
- ○ Refused

A32. Have any of the following chemicals been used on the field? (check all that apply) and how often?

☐	Algae Died B		Daily/weekly/ monthly/annually
☐	Qualgex		Daily/weekly/ monthly/annually
☐	Steri-maX		Daily/weekly/ monthly/annually
☐	Other (specify)		Daily/weekly/ monthly/annually
☐	Unknown Biocide		Daily/weekly/ monthly/annually

A33. Do you know the outdoor air fraction ventilation rates for this facility during each season? ☐

If yes (please specify):

Spring		(cfm)
Summer		(cfm)
Fall		(cfm)
Winter		(cfm)

If you do not know, can you identify a person, including their phone number, who can provide us with your facility ventilation rates?

__________ (full name) __________ (phone number)

Thank you so much for your time. I know that your time is valuable. If you have any questions or concerns, please, refer to the contact sheet for information on who to contact.

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Appendix G

Shapiro-Wilk Test Results for Selected Tire Crumb Rubber Characterization Measurement Distributions

G.1 Overview

Some data analyses for tire crumb rubber characterization included statistical tests of differences for measurement results between recycling plants and synthetic turf fields, or among synthetic turf fields with different characteristics (indoor vs. outdoor, installation age, and geographic region). For chemical concentration value, emission factor, and particle size tables, tests for equality of group means were performed in log-scale by 1-way analysis of variance (ANOVA) models fitted in the SAS MIXED procedure. The decision to use logarithmic transformations for these tests of group means was based on Shapiro-Wilk tests for normality that showed for a majority of the analytes the hypothesis of a normal distribution was not rejected following log transformation. Results for Shapiro-Wilk testing for untransformed and transformed data are shown below, first for recycling plant measurement and then for synthetic turf field measurements. The hypothesis of a normal distribution of untransformed or log-transformed data was considered not rejected when Shapiro–Wilk test values exceeded 0.05. For some particle groups or chemicals/analysis combinations, Shapiro-Wilk test results were below 0.05 for both untransformed and log-transformed measurement results. Caution is warranted in interpreting statistical testing results. Because the synthetic turf field sampling design was based on a stratified selection for specific field characteristics, it was not assumed that the field measurement results would necessarily follow a normal distribution. A conservative approach was taken to suppress reporting p-values when any chemical-specific or particle size data values represented in a table was not >0, since log-transformation could not be performed and the result was a less than complete data set.

G.2 Recycling Plant Shapiro-Wilk Test Results

Table G-1. P-values for Shapiro-Wilk Tests of Normality for Particle Size from Recycling Plants (Source Particle Size by Sieve with Gravimetric Analysis)

Particle Size Category	Linear Scale	Log Scale
<0.063 mm	<0.0001	0.0015
>0.063 - 0.125 mm	<0.0001	0.0001
>0.125 - 0.25 mm	<0.0001	0.0744
>0.25 - 1 mm	<0.0001	0.0001
>1 - 2 mm	0.0003	<0.0001
>2 - 4.75 mm	0.0462	<0.0001
>4.75 mm	<0.0001	0.9357

Table G-2. P-values for Shapiro-Wilk Tests of Normality for Metals from Recycling Plants (Source Tire Crumb Rubber Digests by ICP-MS)[a]

Analyte	Linear Scale	Log Scale
Aluminum	0.1087	0.4420
Antimony	0.1029	0.0610
Arsenic	0.0249	0.1854
Barium	<0.0001	0.0007
Beryllium	<0.0001	0.1286
Cadmium	0.0216	0.2732
Chromium	0.0095	0.4736
Cobalt	0.0638	0.9341
Copper	0.0220	0.5851
Iron	<0.0001	0.0291
Lead	<0.0001	0.0007
Magnesium	0.0003	0.068
Manganese	<0.0001	0.0058
Molybdenum	<0.0001	0.0226
Nickel	0.0285	0.2138
Rubidium	0.0202	0.0179
Selenium	0.2650	0.7832
Strontium	0.0741	0.3898
Tin	0.6180	0.8099
Vanadium	0.0023	0.7152
Zinc	0.0737	0.2543

[a] ICP/MS= inductively coupled plasma/mass spectrometry

Table G-3. P-values for Shapiro-Wilk Tests of Normality Metals from Recycling Plants (Source XRF)[a]

Analyte	Linear Scale	Log Scale
Barium	<0.0001	<0.0001
Chromium	0.3892	0.4017
Cobalt	0.0124	0.5930
Copper	0.1053	0.7091
Iron	<0.0001	0.0355
Lead	0.8025	0.2753
Manganese	N/A	N/A
Molybdenum	0.8564	0.1942
Rubidium	0.0464	0.1690
Strontium	0.0876	0.0169
Zinc	0.0218	0.0479

[a] XRF = X-ray fluorescence spectrometry; N/A = not applicable (no test performed)

Table G-4. P-values for Shapiro-Wilk Tests of Normality for SVOCs from Recycling Plants (Source Tire Crumb Rubber Extracts by GC/MS/MS)[a]

Analyte	Linear Scale	Log Scale
1-Methylnaphthalene	0.0142	0.0040
1-Methylphenanthrene	0.0111	0.7006
2-Bromomethylnaphthalene	N/A	N/A
2-Methylnaphthalene	0.0333	0.0085
2-Methylphenanthrene	<0.0001	0.0062
3-Methylphenanthrene	0.0103	0.1969
4-tert-octylphenol	0.0331	0.1862
Acenaphthylene	0.1227	0.4656
Aniline	<0.0001	0.0001
Anthracene	<0.0001	0.0192
Benz(a)anthracene	0.0009	0.3186
Benzo[a]pyrene	0.0029	0.8584
Benzo(b)fluoranthene	<0.0001	0.1612
Benzo(e)pyrene	0.0592	0.0114
Benzo[ghi]perylene	<0.0001	0.0546
Benzo(k)fluoranthene	0.2822	0.4439
Benzothiazole	0.2232	0.1869
Benzyl butyl phthalate	0.0086	0.1111
Bis(2,2,6,6-tetramethyl-4-piperidyl) sebacate	0.0209	0.0471
2,6-Di-tert-butyl-p-cresol	<0.0001	0.0217
Bis(2-ethylhexyl) phthalate	<0.0001	0.0259
Chrysene	0.0129	0.4231
Coronene	<0.0001	0.0368
Cyclohexylisothiocyanate	0.2151	0.2015
DBA + ICDP[b]	0.0100	0.3865
Di-n-octyl phthalate	0.0092	0.9637
Dibenzothiophene	0.0026	0.1214
Dibutyl phthalate	0.0013	0.0370
Diethyl phthalate	<0.0001	0.1621
Diisobutyl phthalate	<0.0001	0.0130
Dimethyl phthalate	0.0124	<0.0001
Fluoranthene	0.0690	0.7391
Fluorene	0.0217	0.8336
Naphthalene	0.0410	0.0364
Phenanthrene	0.1723	0.0958
Pyrene	0.0311	0.0921
Sum15PAH[c]	0.1095	0.3324
n-Butylbenzene	0.0185	0.0059
n-Hexadecane	0.0004	0.0033

[a] SVOC = semivolatile organic compound; GC/MS/MS = gas chromatography/tandem mass spectrometry; N/A = not applicable (no test performed)

[b] DBA = ICDP = Dibenz(a,h)anthracene + Indeno(1,2,3-cd)pyrene

[c] Sum15PAH = Sum of 15 of the 16 EPA 'priority' PAHs, including Acenaphthylene, Anthracene, Benz[a]anthracene, Benzo[a]pyrene, Benzo(b)fluoranthene, Benzo[ghi]perylene, Benzo(k)fluoranthene, Chrysene, Dibenz[a,h]anthracene, Fluoranthene, Fluorene, Indeno(1,2,3-cd)pyrene, Naphthalene, Phenanthrene, Pyrene

Table G-5. P-values for Shapiro-Wilk Tests of Normality for SVOCs from Recycling Plants (Source Tire Crumb Rubber Extracts by LC/TOFMS in Positive Mode)[a]

Analyte	Linear Scale	Log Scale
2-benzothiazolone	0.0972	<0.0001
2-mercaptobenzothiazole	<0.0001	0.0181
N-cyclohexyl-N-methylcyclohexanamine	0.0011	0.3153
cyclohexylamine	0.1591	0.0008
di-cyclohexylamine	<0.0001	0.0080
diisodecylphthalate	<0.0001	0.0919
diisononylphthalate	<0.0001	0.2940

[a] SVOC = semivolatile organic compound; LC/TOFMS = liquid chromatography/time-of-flight mass spectrometry

Table G-6. P-values for Shapiro-Wilk Tests of Normality for VOCs from Recycling Plants at 25 °C (Source Chamber Emissions by GC/TOFMS)[a]

Analyte	Linear Scale	Log Scale
1,1,1-Trichloroethane	N/A	N/A
1,1-Dichloroethane	<0.0001	<0.0001
1,1-Dichloroethene	0.3581	N/A
1,2-Dichloroethane	N/A	N/A
1,2-Dichloropropane	0.3581	N/A
1,3,5-Trimethylbenzene	0.7229	<0.0001
1,3-Butadiene	<0.0001	N/A
4-Ethyltoluene	0.0049	<0.0001
Benzene	0.003	0.7634
Benzothiazole	0.0001	<0.0001
Carbon Tetrachloride	<0.0001	N/A
Chlorobenzene	0.0002	0.0148
Dichlorodifluoromethane (Freon 12)	<0.0001	0.0495
Ethylbenzene	0.0029	0.0714
Formaldehyde	<0.0001	0.2755
Methyl isobutyl ketone	0.0148	<0.0001
Styrene	0.0045	0.5834
SumBTEX[b]	0.0513	0.0232
Tetrachloroethylene	<0.0001	0.0003
Toluene	0.0117	0.2127
Trichloroethylene	<0.0001	0.8823
Trichlorofluoromethane (Freon 11)	0.0752	0.0007
Trichlorotrifluoroethane (Freon 113)	<0.0001	0.2350
cis-1,2-Dichloroethene	0.3581	0.2860
cis-2-Butene	0.9183	0.5889
m-Dichlorobenzene	<0.0001	0.0793
m/p-Xylene	0.0002	0.3748
o-Dichlorobenzene	<0.0001	0.7381

Table G-6 Continued

Analyte	Linear Scale	Log Scale
o-Xylene	0.0016	0.0777
p-Dichlorobenzene	<0.0001	0.4276
trans-2-Butene	0.8181	0.1223

[a] VOC = volatile organic compound; °C = degrees Celsius; GC/TOFMS = gas chromatography/time-of-flight mass spectrometry; N/A = not applicable (no test performed)

[b] SumBTEX = Sum of benzene, toluene, ethylbenzene, m/p-xylene, and o-xylene

Table G-7. P-values for Shapiro-Wilk Tests of Normality for VOCs from Recycling Plants at 60 °C (Source Chamber Emissions by GC/TOFMS)

Analyte	Linear Scale	Log Scale
1,1,1-Trichloroethane	0.7347	0.8037
1,1-Dichloroethane	<0.0001	N/A
1,1-Dichloroethene	0.7347	N/A
1,2-Dichloroethane	<0.0001	N/A
1,2-Dichloropropane	0.7347	N/A
1,3,5-Trimethylbenzene	0.2217	0.0194
1,3-Butadiene	0.7347	N/A
4-Ethyltoluene	0.0097	0.3283
Benzene	0.0187	0.0295
Benzothiazole	0.8964	0.9574
Carbon Tetrachloride	0.0005	N/A
Chlorobenzene	0.0003	0.6211
Dichlorodifluoromethane (Freon 12)	<0.0001	0.0004
Ethylbenzene	0.0002	0.3206
Formaldehyde	0.2745	0.1932
Metyl isobutyl ketone	0.6141	0.3681
Styrene	0.1845	0.0293
SumBTEX[b]	0.1675	0.0157
Tetrachloroethylene	<0.0001	0.0282
Toluene	0.0016	0.1065
Trichloroethylene	0.0007	0.1213
Trichlorofluoromethane (Freon 11)	0.0235	0.0005
Trichlorotrifluoroethane (Freon 113)	<0.0001	0.3394
cis-1,2-Dichloroethene	<0.0001	<0.0001
cis-2-Butene	<0.0001	0.9493
m-Dichlorobenzene	0.0008	0.7655
m/p-Xylene	0.1398	0.2296
o-Dichlorobenzene	<0.0001	0.5595
o-Xylene	0.0052	0.7793

Table G-7 Continued

Analyte	Linear Scale	Log Scale
p-Dichlorobenzene	0.1290	0.0322
trans-2-Butene	<0.0001	0.9076

[a] VOC = volatile organic compound; °C = degrees Celsius; GC/TOFMS = gas chromatography/time-of-flight mass spectrometry; N/A = not applicable (no test performed)

[b] SumBTEX = Sum of benzene, toluene, ethylbenzene, m/p-xylene, and o-xylene

Table G-8. P-values for Shapiro-Wilk Tests of Normality for SVOCs from Recycling Plants at 25 °C (Source Chamber SVOC Emissions by GC/MS/MS)[a]

Analyte	Linear Scale	Log Scale
1-Methylnaphthalene	0.0151	0.0020
1-Methylphenanthrene	<0.0001	0.0612
2-Bromomethylnaphthalene	<.0001	0.9588
2-Methylnaphthalene	0.0194	0.0019
2-Methylphenanthrene	<0.0001	0.0189
3-Methylphenanthrene	0.0060	0.1741
4-tert-octylphenol	0.0065	0.6520
Acenaphthylene	0.5936	0.0016
Aniline	0.1129	0.0002
Anthracene	<0.0001	0.0867
Benz(a)anthracene	0.0001	0.0535
Benzo[a]pyrene	<0.0001	<0.0001
Benzo(b)fluoranthene	<0.0001	0.3549
Benzo(e)pyrene	N/A	N/A
Benzo[ghi]perylene	<0.0001	1
Benzo(k)fluoranthene	<0.0001	N/A
Benzothiazole	<0.0001	0.6140
Bis(2,2,6,6-tetramethyl-4-piperidyl) sebacate	<0.0001	N/A
Chrysene	<0.0001	0.0134
Coronene	<0.0001	N/A
DBA + ICDP[b]	0.0045	0.1378
Di-n-octyl phthalate	<0.0001	0.0045
Dibenzothiophene	0.0155	0.3881
Dibutyl phthalate	<0.0001	0.4369
Diisobutyl phthalate	0.0056	0.2616
Dimethyl phthalate	0.1597	0.0433
Fluoranthene	0.0003	0.1747
Fluorene	0.5162	0.7803
Naphthalene	0.1666	0.0075
Phenanthrene	0.0002	0.8634
Pyrene	0.0007	0.2149

Table G-8 Continued

Analyte	Linear Scale	Log Scale
Sum15PAH[c]	0.1514	0.0249
n-Butylbenzene	0.0003	0.3233

[a] SVOC = semivolatile organic compound; °C = degrees Celsius; GC/MS/MS = gas chromatography/tandem mass spectrometry; N/A = not applicable (no test performed)

[b] DBA + ICDP = Sum of Dibenz[a,h]anthracene and Indeno(1,2,3-cd)pyrene

[c] Sum15PAH = Sum of 15 of the 16 EPA 'priority' PAHs, including Acenaphthylene, Anthracene, Benz[a]anthracene, Benzo[a]pyrene, Benzo(b)fluoranthene, Benzo[ghi]perylene, Benzo(k)fluoranthene, Chrysene, Dibenz[a,h]anthracene, Fluoranthene, Fluorene, Indeno(1,2,3-cd)pyrene, Naphthalene, Phenanthrene, Pyrene

Table G-9. P-values for Shapiro-Wilk Tests of Normality for SVOCs from Recycling Plants at 60 °C (Source Chamber SVOC Emissions by GC/MS/MS)[a]

Analyte	Linear Scale	Log Scale
1-Methylnaphthalene	0.0097	0.0064
1-Methylphenanthrene	0.0011	0.3548
2-Bromomethylnaphthalene	<0.0001	0.0671
2-Methylnaphthalene	0.0002	0.0822
2-Methylphenanthrene	<0.0001	0.0029
3-Methylphenanthrene	<0.0001	0.0077
4-tert-octylphenol	0.0035	0.0148
Acenaphthylene	0.0181	0.5671
Aniline	0.0016	0.0610
Anthracene	0.1202	0.5441
Benz(a)anthracene	<0.0001	0.0096
Benzo[a]pyrene	<0.0001	1.000
Benzo(b)fluoranthene	<0.0001	0.4205
Benzo(e)pyrene	<0.0001	N/A
Benzo[ghi]perylene	<0.0001	0.0506
Benzo(k)fluoranthene	<0.0001	N/A
Benzothiazole	0.0019	0.9565
Bis(2,2,6,6-tetramethyl-4-piperidyl) sebacate	<0.0001	0.2920
Chrysene	0.0013	0.2476
Coronene	<0.0001	N/A
DBA + ICDP[b]	0.2196	0.1486
Di-n-octyl phthalate	<0.0001	0.6766
Dibenzothiophene	0.0007	0.2079
Dibutyl phthalate	<0.0001	0.9917
Diisobutyl phthalate	<0.0001	0.3226
Dimethyl phthalate	<0.0001	0.2597
Fluoranthene	0.0563	0.3667
Fluorene	0.0342	0.0248
Naphthalene	0.0004	0.2293
Phenanthrene	0.4948	0.0564

Table G-9 Continued

Analyte	Linear Scale	Log Scale
Pyrene	0.4833	0.2053
Sum15PAH[c]	0.0012	0.3191
n-Butylbenzene	0.0001	0.1759

[a] SVOC = semivolatile organic compound; °C = degrees Celsius; GC/MS/MS = gas chromatography/tandem mass spectrometry; N/A = not applicable (no test performed)

[b] DBA + ICDP = Sum of Dibenz[a,h]anthracene and Indeno(1,2,3-cd)pyrene

[c] Sum15PAH = Sum of 15 of the 16 EPA 'priority' PAHs, including Acenaphthylene, Anthracene, Benz[a]anthracene, Benzo[a]pyrene, Benzo(b)fluoranthene, Benzo[ghi]perylene, Benzo(k)fluoranthene, Chrysene, Dibenz[a,h]anthracene, Fluoranthene, Fluorene, Indeno(1,2,3-cd)pyrene, Naphthalene, Phenanthrene, Pyrene

Table G-10. P-values for Shapiro-Wilk Tests of Normality for SVOCs from Recycling Plants at 60 °C (Source Chamber SVOC Emissions by LC/TOFMS in Positive Mode)

Analyte	Linear Scale	Log Scale
2-benzothiazolone	<0.0001	0.0024
N-cyclohexyl-N-methylcyclohexanamine	<0.0001	0.2995
cyclohexylamine	0.0058	0.7152
di-cyclohexylamine	<0.0001	0.0651

[a] SVOC = semivolatile organic compound; °C = degrees Celsius; LC/TOFMS = liquid chromatography/time-of-flight mass spectrometry

G.3 Synthetic Turf Field Shapiro-Wilk Test Results

Table G-11. P-values for Shapiro-Wilk Tests of Normality for Particle Size from Synthetic Turf Fields (Source Particle Size Fractions Prepared by Sieve with Gravimetric Analysis)

Particle Size Category	Linear Scale	Log Scale
<0.063 mm	<0.0001	0.0002
>0.063 - 0.125 mm	<0.0001	0.0046
>0.125 - 0.25 mm	<0.0001	0.0353
>0.25 - 1 mm	<0.0001	0.0200
>1 - 2 mm	0.3397	0.0008
>2 - 4.75 mm	<0.0001	0.0078
>4.75 mm	<0.0001	0.9301

Table G-12. P-values for Shapiro-Wilk Tests of Normality for Metals from Synthetic Turf Fields (Source Tire Crumb Digests by ICP-MS)[a]

Analyte	Linear Scale	Log Scale
Aluminum	0.0015	0.4626
Antimony	0.0099	0.2053
Arsenic	0.0014	0.6626
Barium	<0.0001	0.1518
Beryllium	<0.0001	0.9401
Cadmium	<0.0001	0.0186
Chromium	0.0277	0.3043
Cobalt	0.0502	0.4517
Copper	0.0694	0.5052
Iron	<0.0001	0.0527
Lead	<0.0001	0.0002
Magnesium	<0.0001	<0.0001
Manganese	<0.0001	0.0047
Molybdenum	0.0442	<0.0001
Nickel	0.9208	0.2439
Rubidium	0.0005	0.2676
Selenium	<0.0001	0.0494
Strontium	<0.0001	0.0122
Tin	0.4436	0.0223
Vanadium	0.0020	0.0350
Zinc	0.1045	0.4915

[a] ICP/MS = inductively coupled plasma/mass spectrometry

Table G-13. P-values for Shapiro-Wilk Tests of Normality Metals from Synthetic Turf Fields (Source XRF)[a]

Analyte	Linear Scale	Log Scale
Arsenic	N/A	N/A
Barium	0.0016	0.0162
Cadmium	<0.0001	<0.0001
Chromium	0.8191	0.0463
Cobalt	0.0708	0.0025
Copper	0.0006	0.0243
Iron	<0.0001	0.6394
Lead	<0.0001	0.5391
Molybdenum	0.5513	0.0030
Rubidium	0.0005	0.7724
Strontium	<0.0001	<0.0001
Zinc	0.0219	0.0915

[a] XRF = X-ray fluorescence spectrometry; N/A = not applicable (no test performed)

Table G-14. P-values for Shapiro-Wilk Tests of Normality for SVOCs from Synthetic Turf Fields (Source Tire Crumb Extracts by GC/MS/MS)[a]

Analyte	Linear Scale	Log Scale
1-Methylnaphthalene	<0.0001	0.0050
1-Methylphenanthrene	0.0003	0.4355
2-Bromomethylnaphthalene	N/A	N/A
2-Methylnaphthalene	<0.0001	0.0157
2-Methylphenanthrene	<0.0001	0.2821
3-Methylphenanthrene	<0.0001	0.2677
4-tert-octylphenol	<0.0001	0.1739
Acenaphthylene	<0.0001	0.0596
Aniline	0.0001	0.5433
Anthracene	<0.0001	0.7132
Benz(a)anthracene	0.0145	0.2736
Benzo[a]pyrene	<0.0001	0.5280
Benzo(b)fluoranthene	0.0001	0.2868
Benzo(e)pyrene	0.0382	0.1703
Benzo[ghi]perylene	0.0942	0.0088
Benzo(k)fluoranthene	<0.0001	0.8732
Benzothiazole	<0.0001	0.4140
Benzyl butyl phthalate	<0.0001	0.0576
Bis(2,2,6,6-tetramethyl-4-piperidyl) sebacate	<0.0001	0.1197
2,6-Di-tert-butyl-p-cresol	<0.0001	0.8491
Bis(2-ethylhexyl) phthalate	<0.0001	0.1217
Chrysene	0.0007	0.1290
Coronene	0.0129	0.3921
Cyclohexylisothiocyanate	0.0028	0.0003
DBA + ICDP[b]	0.0038	0.1567
Di-n-octyl phthalate	0.0001	0.3877
Dibenzothiophene	<0.0001	0.1807
Dibutyl phthalate	0.0002	0.0051
Diethyl phthalate	<0.0001	0.0684
Diisobutyl phthalate	<0.0001	0.1401
Dimethyl phthalate	<0.0001	0.4050
Fluoranthene	0.0273	0.2158
Fluorene	<0.0001	0.1470
Naphthalene	<0.0001	0.1776
Phenanthrene	<0.0001	0.2971
Pyrene	0.2571	0.0234
Sum15PAH[c]	0.0898	0.5952

Table G-14 Continued

Analyte	Linear Scale	Log Scale
n-Butylbenzene	<0.0001	N/A
n-Hexadecane	<0.0001	0.0042

[a] SVOC = semivolatile organic compound; GC/MS/MS = gas chromatography/tandem mass spectrometry; N/A = not applicable (no test performed)

[b] DBA + ICDP = Sum of Dibenz[a,h]anthracene and Indeno(1,2,3-cd)pyrene

[c] Sum15PAH = Sum of 15 of the 16 EPA 'priority' PAHs, including Acenaphthylene, Anthracene, Benz[a]anthracene, Benzo[a]pyrene, Benzo(b)fluoranthene, Benzo[ghi]perylene, Benzo(k)fluoranthene, Chrysene, Dibenz[a,h]anthracene, Fluoranthene, Fluorene, Indeno(1,2,3-cd)pyrene, Naphthalene, Phenanthrene, Pyrene

Table G-15. P-values for Shapiro-Wilk Tests of Normality for SVOCs from Synthetic Turf Fields (Source Tire Crumb Extracts by LC/TOFMS in Positive Mode)[a]

Analyte	Linear Scale	Log Scale
2-benzothiazolone	<0.0001	0.0092
2-mercaptobenzothiazole	<0.0001	0.0022
N-cyclohexyl-N-methylcyclohexanamine	<0.0001	0.0016
cyclohexylamine	<0.0001	0.0843
di-cyclohexylamine	0.0006	0.0037
diisodecylphthalate	<0.0001	<0.0001
diisononylphthalate	<0.0001	0.2162

[a] SVOC = semivolatile organic compound; LC/TOFMS = liquid chromatography/time-of-flight mass spectrometry

Table G-16. P-values for Shapiro-Wilk Tests of Normality for VOCs from Synthetic Turf Fields at 25 °C (Source Chamber by GC/TOFMS)[a]

Analyte	Linear Scale	Log Scale
1,1,1-Trichloroethane	N/A	N/A
1,1-Dichloroethane	<0.0001	<0.0001
1,1-Dichloroethene	<0.0001	0.8222
1,2-Dichloroethane	<0.0001	N/A
1,2-Dichloropropane	<0.0001	<0.0001
1,3,5-Trimethylbenzene	<0.0001	0.2848
1,3-Butadiene	0.0002	0.1488
4-Ethyltoluene	<0.0001	0.1172
Benzene	<0.0001	0.8466
Benzothiazole	<0.0001	0.0049
Carbon Tetrachloride	<0.0001	0.2155
Chlorobenzene	<0.0001	0.5569
Dichlorodifluoromethane (Freon 12)	<0.0001	0.0003
Ethylbenzene	<0.0001	0.4328
Formaldehyde	<0.0001	0.3552
Metyl isobutyl ketone	<0.0001	0.0340
Styrene	<0.0001	0.6279

Table G-16 Continued

Analyte	Linear Scale	Log Scale
SumBTEX[b]	<0.0001	0.3509
Tetrachloroethylene	<0.0001	0.6958
Toluene	<0.0001	0.1165
Trichloroethylene	<0.0001	0.0003
Trichlorofluoromethane (Freon 11)	<0.0001	0.0003
Trichlorotrifluoroethane (Freon 113)	<0.0001	0.7372
cis-1,2-Dichloroethene	<0.0001	<0.0001
cis-2-Butene	<0.0001	0.9127
m-Dichlorobenzene	<0.0001	0.6828
m/p-Xylene	<0.0001	0.3651
o-Dichlorobenzene	<0.0001	0.5926
o-Xylene	0.0002	0.0051
p-Dichlorobenzene	<0.0001	0.4388
trans-2-Butene	<0.0001	0.8271

[a] VOC = volatile organic compound; °C = degrees Celsius, GC/TOFMS = gas chromatography/time-of-flight mass spectrometry; N/A = not applicable (no test performed)

[b] SumBTEX = Sum of benzene, toluene, ethylbenzene, m/p-xylene, and o-xylene

Table G-17. P-values for Shapiro-Wilk Tests of Normality for VOCs from Synthetic Turf Fields at 60 °C (Source Chamber by GC/TOFMS)[a]

Analyte	Linear Scale	Log Scale
1,1,1-Trichloroethane	<0.0001	<0.0001
1,1-Dichloroethane	<0.0001	N/A
1,1-Dichloroethene	<0.0001	0.6013
1,2-Dichloroethane	<0.0001	N/A
1,2-Dichloropropane	<0.0001	<0.0001
1,3,5-Trimethylbenzene	<0.0001	0.6718
1,3-Butadiene	<0.0001	0.7425
4-Ethyltoluene	0.0004	0.4653
Benzene	0.2162	0.0117
Benzothiazole	0.0003	0.0002
Carbon Tetrachloride	<0.0001	0.0010
Chlorobenzene	0.0007	0.3653
Dichlorodifluoromethane (Freon 12)	<0.0001	0.7770
Ethylbenzene	0.0029	0.0426
Formaldehyde	<0.0001	0.1826
Metyl isobutyl ketone	0.0055	0.2172
Styrene	0.0991	0.0030
SumBTEX[b]	0.0122	0.0297
Tetrachloroethylene	<0.0001	0.0098
Toluene	0.0020	0.1135

Table G-17 Continued

Analyte	Linear Scale	Log Scale
Trichloroethylene	<0.0001	0.2095
Trichlorofluoromethane (Freon 11)	0.0002	<0.0001
Trichlorotrifluoroethane (Freon 113)	<0.0001	0.5418
cis-1,2-Dichloroethene	<0.0001	<0.0001
cis-2-Butene	0.0516	0.0013
m-Dichlorobenzene	<0.0001	0.5732
m/p-Xylene	0.0266	0.2234
o-Dichlorobenzene	<0.0001	0.3476
o-Xylene	0.0010	0.8715
p-Dichlorobenzene	0.0117	0.0063
trans-2-Butene	0.0291	0.3927

[a] VOC = volatile organic compound; °C = degrees Celsius; GC/TOFMS = gas chromatography/time-of-flight mass spectrometry; N/A = not applicable (no test performed)

[b] SumBTEX = Sum of benzene, toluene, ethylbenzene, m/p-xylene, and o-xylene

Table G-18. P-values for Shapiro-Wilk Tests of Normality for SVOCs from Synthetic Turf Fields at 25 °C (Source Chamber SVOC by GC/MS/MS)[a]

Analyte	Linear Scale	Log Scale
1-Methylnaphthalene	<0.0001	0.0451
1-Methylphenanthrene	0.0349	0.2340
2-Bromomethylnaphthalene	<0.0001	0.3780
2-Methylnaphthalene	<0.0001	0.3015
2-Methylphenanthrene	0.0002	<0.0001
3-Methylphenanthrene	0.0015	0.0825
4-tert-octylphenol	<0.0001	0.0016
Acenaphthylene	<0.0001	<0.0001
Aniline	<0.0001	0.0162
Anthracene	<0.0001	0.2682
Benz(a)anthracene	<0.0001	0.0771
Benzo[a]pyrene	<0.0001	0.0097
Benzo(b)fluoranthene	<0.0001	0.5310
Benzo(e)pyrene	N/A	N/A
Benzo[ghi]perylene	<0.0001	0.0260
Benzo(k)fluoranthene	<0.0001	N/A
Benzothiazole	<0.0001	0.0758
Bis(2,2,6,6-tetramethyl-4-piperidyl) sebacate	<0.0001	N/A
Chrysene	<0.0001	<0.0001
Coronene	<0.0001	1.000
DBA + ICDP[b]	<0.0001	0.7175
Di-n-octyl phthalate	<0.0001	0.2274
Dibenzothiophene	0.7905	0.4084
Dibutyl phthalate	0.4677	0.0351
Diisobutyl phthalate	0.3137	0.2738

Table G-18 Continued

Analyte	Linear Scale	Log Scale
Dimethyl phthalate	<0.0001	0.1504
Fluoranthene	<0.0001	<0.0001
Fluorene	0.003	0.0413
Naphthalene	<0.0001	0.6471
Phenanthrene	0.0035	0.1351
Pyrene	<0.0001	0.0418
Sum15PAH[c]	<0.0001	0.0011
n-Butylbenzene	<0.0001	0.3008

[a] SVOC= semivolatile organic compound; °C = degrees Celsius; GC/MS/MS = gas chromatography/tandem mass spectrometry; N/A = not applicable (no test performed)

[b] DBA + ICDP = Sum of Dibenz[a,h]anthracene and Indeno(1,2,3-cd)pyrene

[c] Sum15PAH = Sum of 15 of the 16 EPA 'priority' PAHs, including Acenaphthylene, Anthracene, Benz[a]anthracene, Benzo[a]pyrene, Benzo(b)fluoranthene, Benzo[ghi]perylene, Benzo(k)fluoranthene, Chrysene, Dibenz[a,h]anthracene, Fluoranthene, Fluorene, Indeno(1,2,3-cd)pyrene, Naphthalene, Phenanthrene, Pyrene

Table G-19. P-values for Shapiro-Wilk Tests of Normality for SVOCs from Synthetic Turf Fields at 60 °C (Source Chamber SVOC by GC/MS/MS)[a]

Analyte	Linear Scale	Log Scale
1-Methylnaphthalene	<0.0001	0.0673
1-Methylphenanthrene	0.0002	0.2412
2-Bromomethylnaphthalene	<0.0001	0.3204
2-Methylnaphthalene	<0.0001	0.1229
2-Methylphenanthrene	<0.0001	0.1848
3-Methylphenanthrene	<0.0001	0.2753
4-tert-octylphenol	0.0006	0.0284
Acenaphthylene	<0.0001	0.3313
Aniline	<0.0001	0.0502
Anthracene	<0.0001	0.0824
Benz(a)anthracene	<0.0001	0.0021
Benzo[a]pyrene	<0.0001	0.3791
Benzo(b)fluoranthene	<0.0001	0.5785
Benzo(e)pyrene	<0.0001	N/A
Benzo[ghi]perylene	<0.0001	0.0297
Benzo(k)fluoranthene	<0.0001	1.000
Benzothiazole	<0.0001	0.0713
Bis(2,2,6,6-tetramethyl-4piperidyl) sebacate	<0.0001	1.000
Chrysene	<0.0001	0.0661
Coronene	<0.0001	0.0371
DBA + ICDP[b]	<0.0001	0.0114
Di-n-octyl phthalate	<0.0001	0.6675
Dibenzothiophene	<0.0001	0.1480
Dibutyl phthalate	0.1505	0.0173
Diisobutyl phthalate	0.2630	0.0075
Dimethyl phthalate	<0.0001	0.0005

Table G-19 Continued

Analyte	Linear Scale	Log Scale
Fluoranthene	0.0031	0.5544
Fluorene	<0.0001	0.4065
Naphthalene	<0.0001	0.5042
Phenanthrene	<0.0001	0.0626
Pyrene	0.0036	0.5481
Sum15PAH[c]	<0.0001	0.2764
n-Butylbenzene	0.0017	0.7679

[a] SVOC = semivolatile organic compound; °C = degrees Celsius; GC/MS/MS = gas chromatography/tandem mass spectrometry; N/A = not applicable (no test performed)

[b] DBA + ICDP = Sum of Dibenz[a,h]anthracene and Indeno(1,2,3-cd)pyrene

[c] Sum15PAH = Sum of 15 of the 16 EPA 'priority' PAHs, including Acenaphthylene, Anthracene, Benz[a]anthracene, Benzo[a]pyrene, Benzo(b)fluoranthene, Benzo[ghi]perylene, Benzo(k)fluoranthene, Chrysene, Dibenz[a,h]anthracene, Fluoranthene, Fluorene, Indeno(1,2,3-cd)pyrene, Naphthalene, Phenanthrene, Pyrene

Table G-20. P-values for Shapiro-Wilk Tests of Normality for SVOCs from Synthetic Turf Fields at 60 °C (Source Chamber SVOC by LC/TOFMS – Positive Mode)[a]

Analyte	Linear Scale	Log Scale
2-benzothiazolone	<0.0001	0.0190
N-cyclohexyl-N-methylcyclohexanamine	<0.0001	0.8144
cyclohexylamine	<0.0001	0.2814
di-cyclohexylamine	<0.0001	0.0318

[a] SVOC = semivolatile organic compound; °C = degrees Celsius; LC/TOFMS = liquid chromatography/time-of-flight mass spectrometry

Appendix H
Tire Crumb Rubber Particle Size Characterization Results and Sample Photos

Table H-1. Particle Size Fractions for Tire Crumb Rubber Collected at Tire Recycling Plants

Recycling Plant ID[a]	Particle Size Fractions >4.75 mm (g/kg)	Particle Size Fractions >2–4.75 mm (g/kg)	Particle Size Fractions >1–2 mm (g/kg)	Particle Size Fractions >0.25–1 mm (g/kg)	Particle Size Fractions >0.125–0.25 mm (g/kg)	Particle Size Fractions >0.063–0.125 mm (g/kg)	Particle Size Fractions ≤0.063 mm (g/kg)
A-1	0	21	850	130	5.9	1.3	0.1
A-2	0	5.4	830	160	5.1	1.3	0.1
A-3	0	12	870	110	5.5	1.3	0.2
B-1	0	67	830	100	0.5	0.1	0
B-2	0	60	810	130	0.5	0.1	0
B-3	0	93	810	96	0.7	0.1	0
C-1	0	150	830	18	0.5	0.1	0
C-2	0	130	810	59	0.6	0.1	0
C-3	0	100	840	60	0.9	0.1	0
D-1	0.4	62	930	1.9	0.6	0.1	0
D-2	0	110	890	2.2	0.5	0.1	0
D-3	0.1	270	730	0.5	0.1	0.1	0
E-1	0	66	790	140	1.5	0.5	0
E-2	0	95	780	130	1.6	0.6	0
E-3	0	77	790	130	1.4	0.7	0.1
F-1	0	93	850	61	0.3	0.1	0
F-2	0	80	840	79	0	0	0
F-3	0	100	840	63	0.7	0.1	0
G-1	0	8.1	750	240	0.7	0.1	0
G-2	0	16	870	110	0.5	0.1	0
G-3	0	14	830	160	0.5	0.1	0
H-1	0	0.1	380	620	1	0.8	0.2
H-2	0	230	760	15	0.1	0	0
H-3	0	0.2	580	420	0.2	0	0
I-1	0	160	610	230	1.5	0.8	0.2
I-2	0	150	620	230	0.6	0.3	0
I-3	1.9	170	630	190	1.1	0.5	0.1

[a] The 1, 2, or 3 refers to the samples collected from three different storage bags at each recycling plant.

Table H-2. Particle Size Fractions for Tire Crumb Rubber Infill Collected from Synthetic Turf Fields

Synthetic Turf Field ID	Particle Size Fractions >4.75 mm (g/kg)	Particle Size Fractions >2–4.75 mm (g/kg)	Particle Size Fractions >1–2 mm (g/kg)	Particle Size Fractions >0.25–1 mm (g/kg)	Particle Size Fractions >0.125–0.25 mm (g/kg)	Particle Size Fractions >0.063–0.125 mm (g/kg)	Particle Size Fractions ≤0.063 mm (g/kg)
1	0	930	73	0.5	0	0	0
2	0	640	350	7.7	0	0	0.1
3	0	0.4	390	610	0.8	0.3	0.2
4	0	20	650	330	0.3	0.1	0.2
5	0	4.3	770	230	0.2	0.1	0
6	0	49	900	44	2.3	0.9	0.5
7	0	1.7	990	4.7	0.4	0.5	0.2
8	0.6	40	950	6.5	0	0	0
9	0	4.3	420	580	0.8	0.2	0.2
10	0.2	11	480	510	0.3	0.1	0
11	0	17	890	92	0.5	1.2	3.2
12	0	17	790	170	3.2	5	13
13	0.9	3.1	680	310	1.5	1.1	0.9
14	0.9	11	690	290	1.8	1.2	1
15	2.8	250	740	12	0	0	0
16	0	480	510	10	0	0	0
17	0	19	910	69	0.2	0.1	0.1
18	0	100	530	360	4.5	0.7	0.4
19	1.5	760	240	5.1	0	0	0
20	0	20	920	40	5.7	4.8	3.9
21	0	27	970	0.6	0	0	0
22	0	140	700	160	0.3	0.1	0.1
23	0	5	420	570	1.3	0.2	0.1
24	0	680	310	16	0.3	0.2	0.2
25	0	780	220	4	0.1	0	0
26	0	350	650	3.6	0	0	0
27	0	8	560	440	0.1	0	0
28	0	460	500	39	0.5	0.4	0.3
29	0	31	940	28	0.2	0.2	0.1
30	0	27	540	430	1.3	0.3	0.1
31	0	160	670	170	0.3	0	0.1
32	0	1.4	350	640	0.3	0.1	0.1
33	0	370	580	51	0.3	0.2	0.1
34	0	320	530	150	0.1	0.1	0.1
35	0	430	520	54	0.1	0	0
36	0	390	520	89	0.1	0.1	0
37	0.3	770	230	0.9	0.1	0	0
38	0	630	340	24	0	0	0
39	0	250	670	82	2.1	0.6	0.3
40	0	820	180	3.1	0	0	0

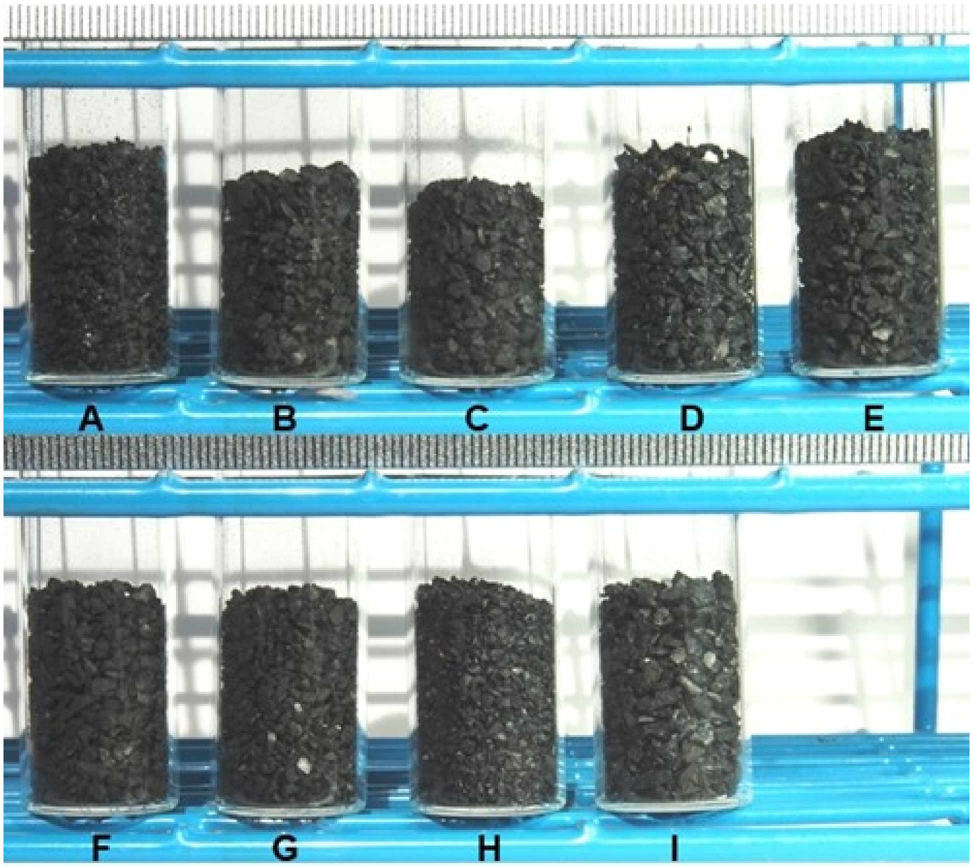

Figure H-1. Photos of tire crumb rubber infill collected from nine tire recycling plants (Plant ID letters are shown). Scale gradations are 1 mm.

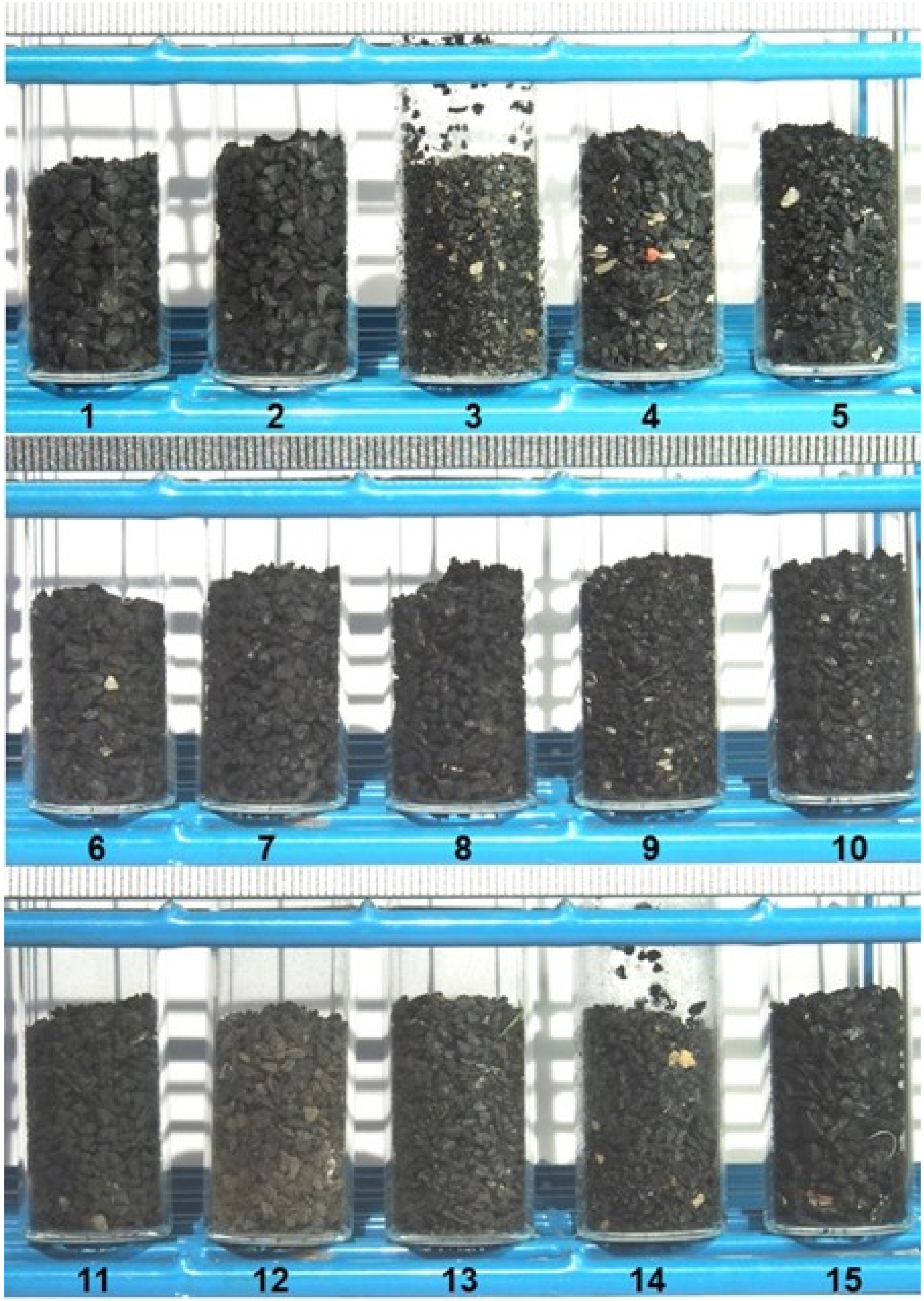

Figure H-2. Photos of tire crumb rubber infill collected from 15 synthetic turf fields (Field ID numbers are shown). Scale gradations are 1 mm.

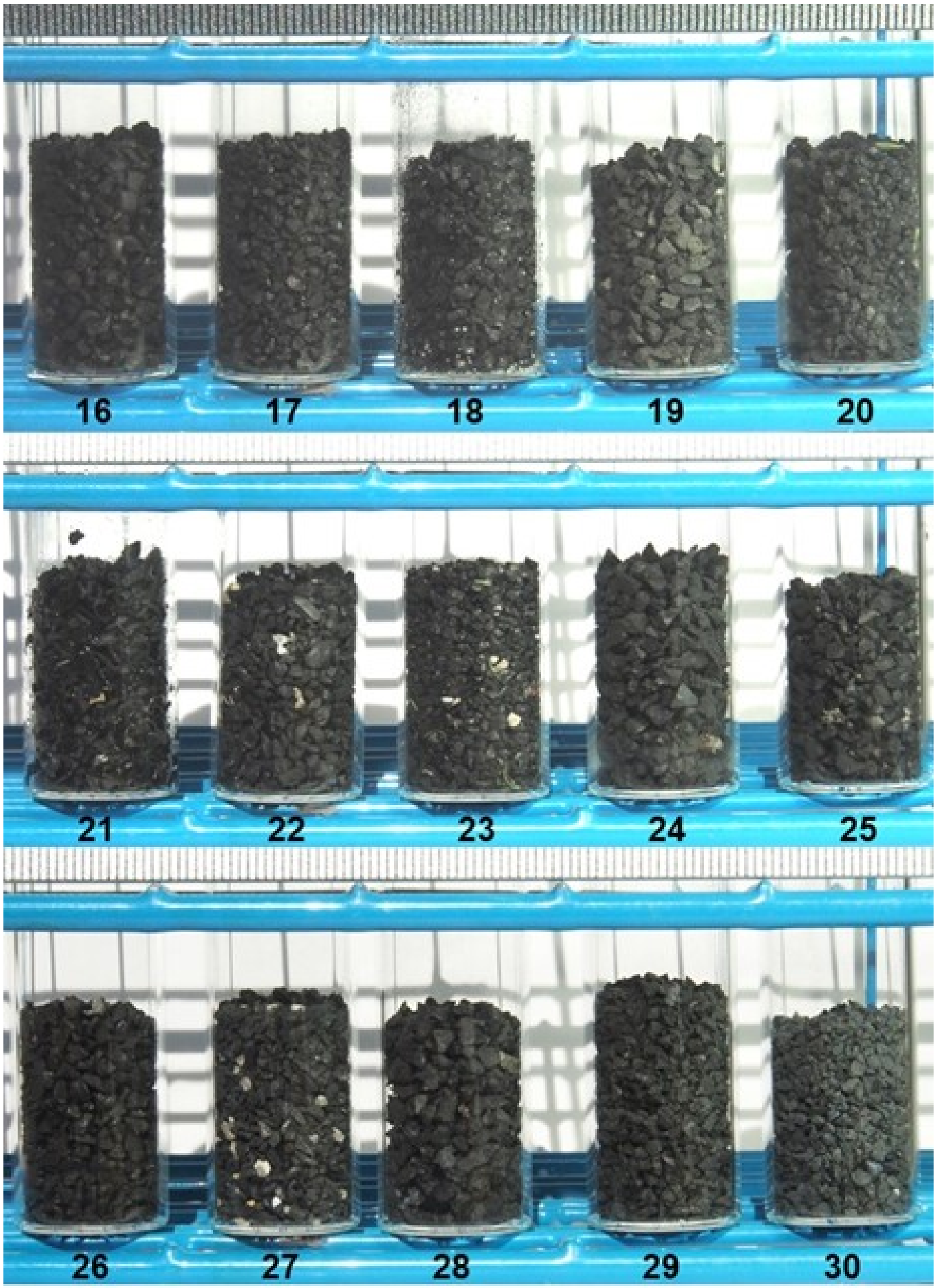

Figure H-3. Photos of tire crumb rubber infill collected from 15 synthetic turf fields (Field ID numbers are shown). Scale gradations are 1 mm.

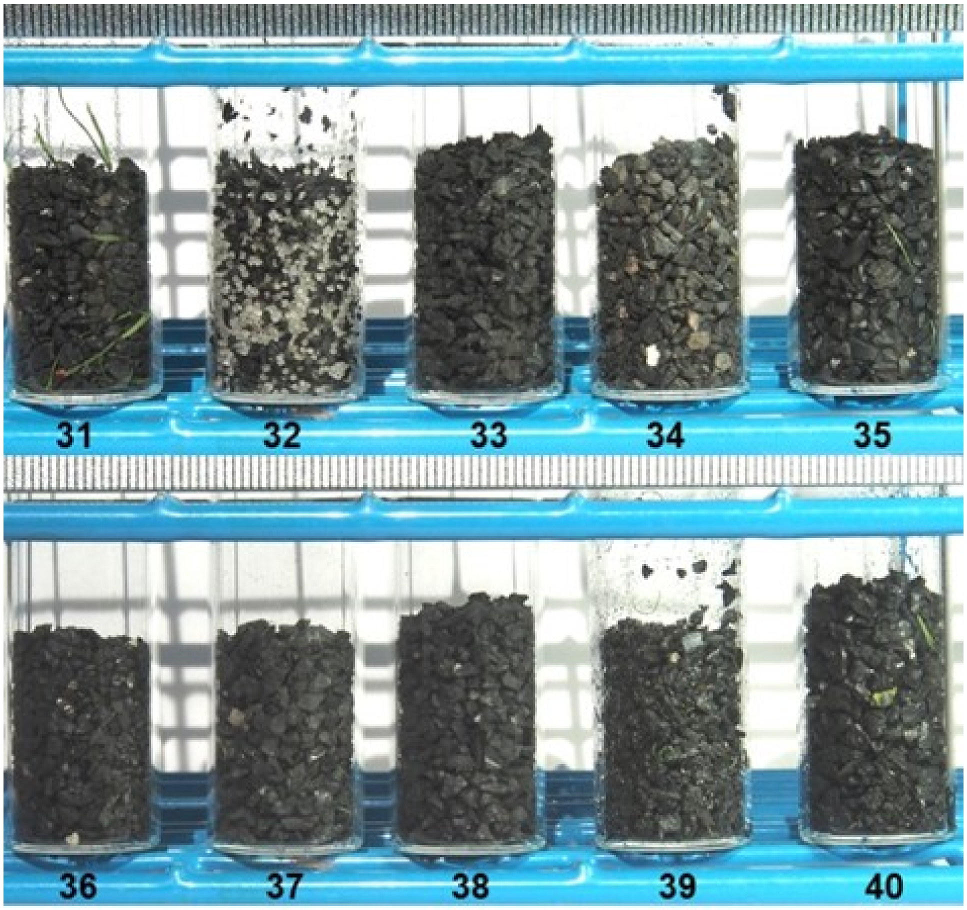

Figure H-4. Photos of tire crumb rubber infill collected from 10 synthetic turf fields (Field ID numbers are shown). Scale gradations are 1 mm.

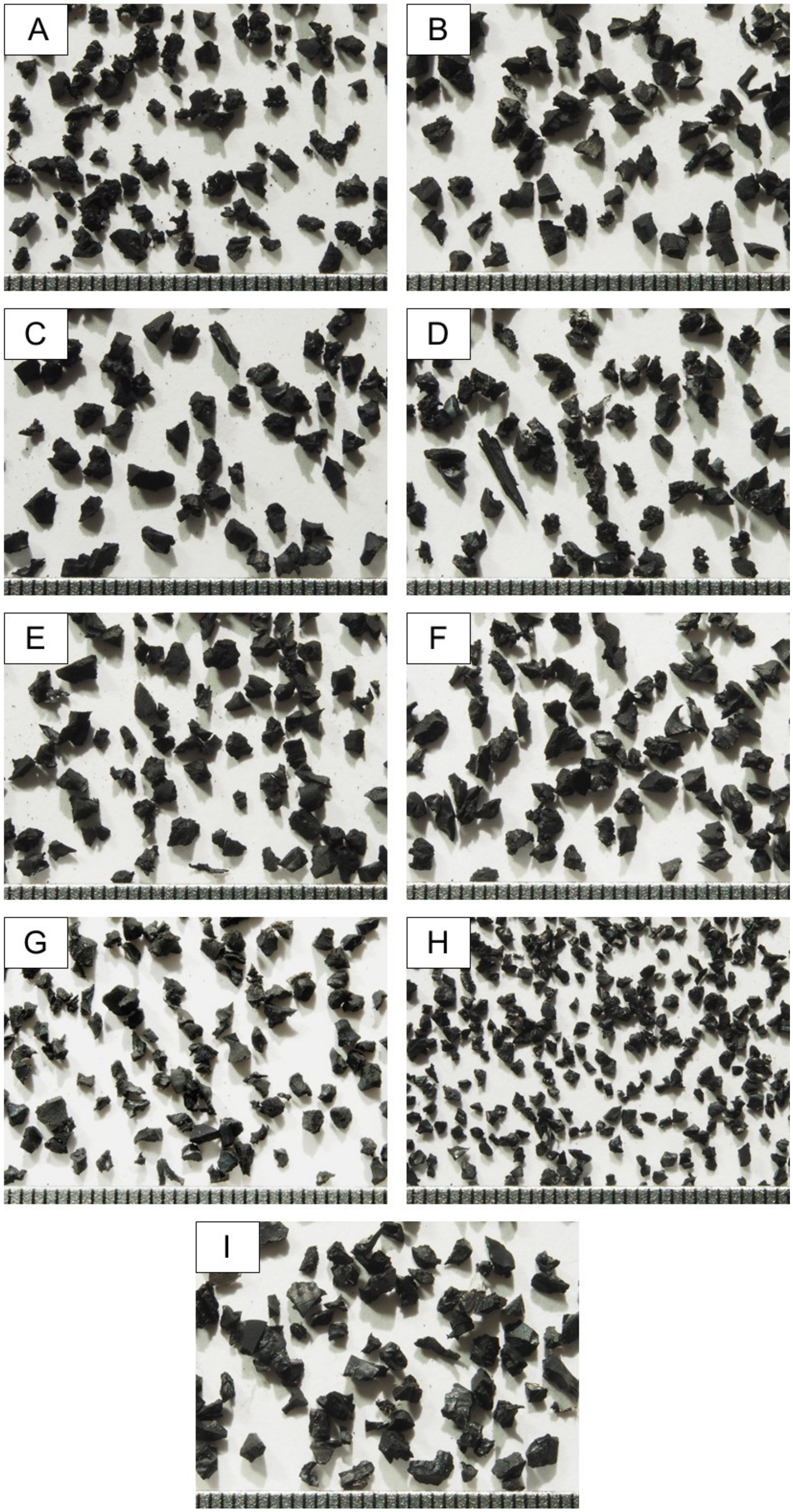

Figure H-5. Photos of tire crumb rubber infill collected from nine tire recycling plants (Plant ID letters are shown). Scale gradations are 1 mm.

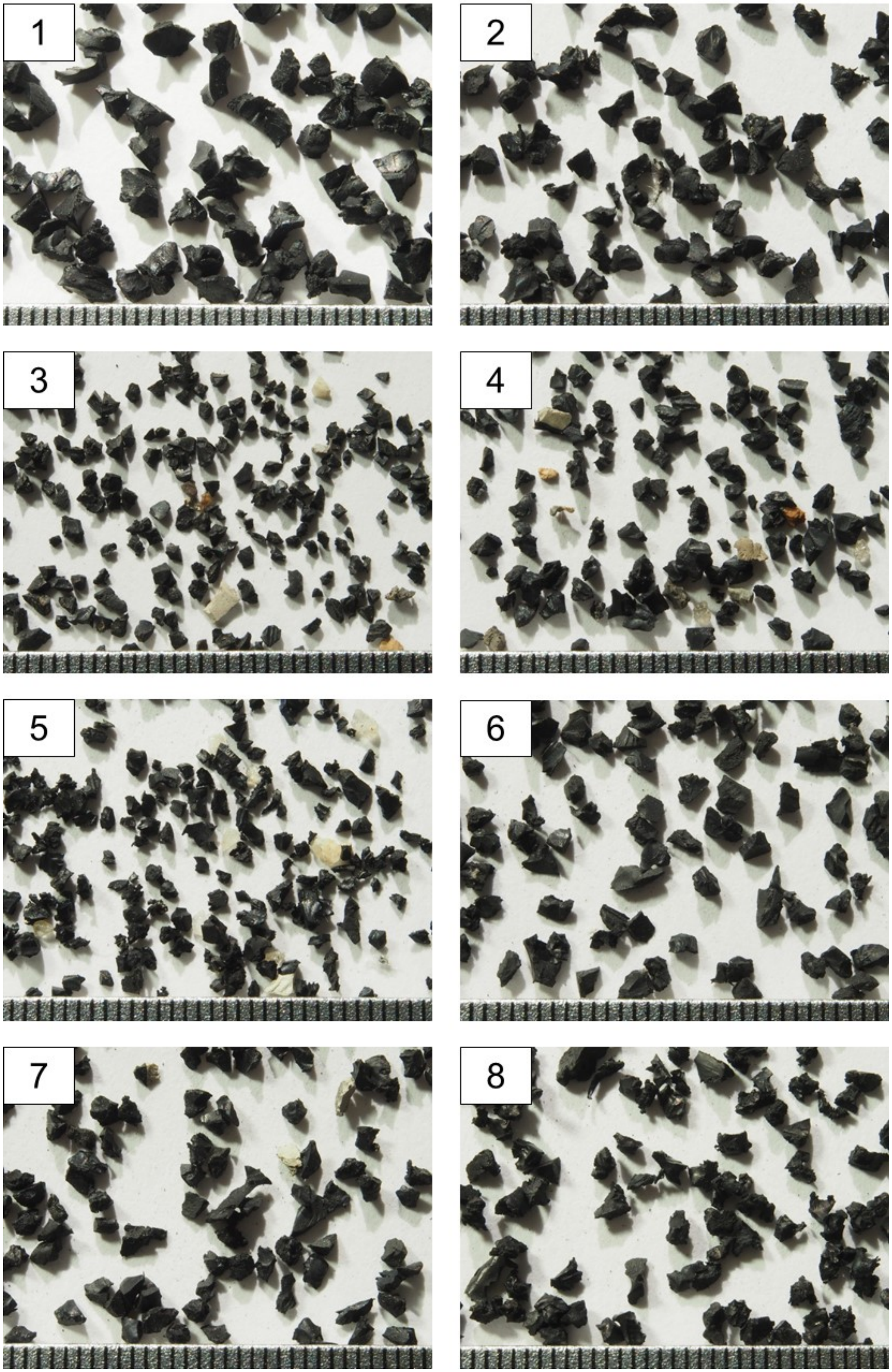

Figure H-6. Photos of tire crumb rubber infill collected from eight synthetic turf fields (Field ID numbers are shown). Scale gradations are 1 mm.

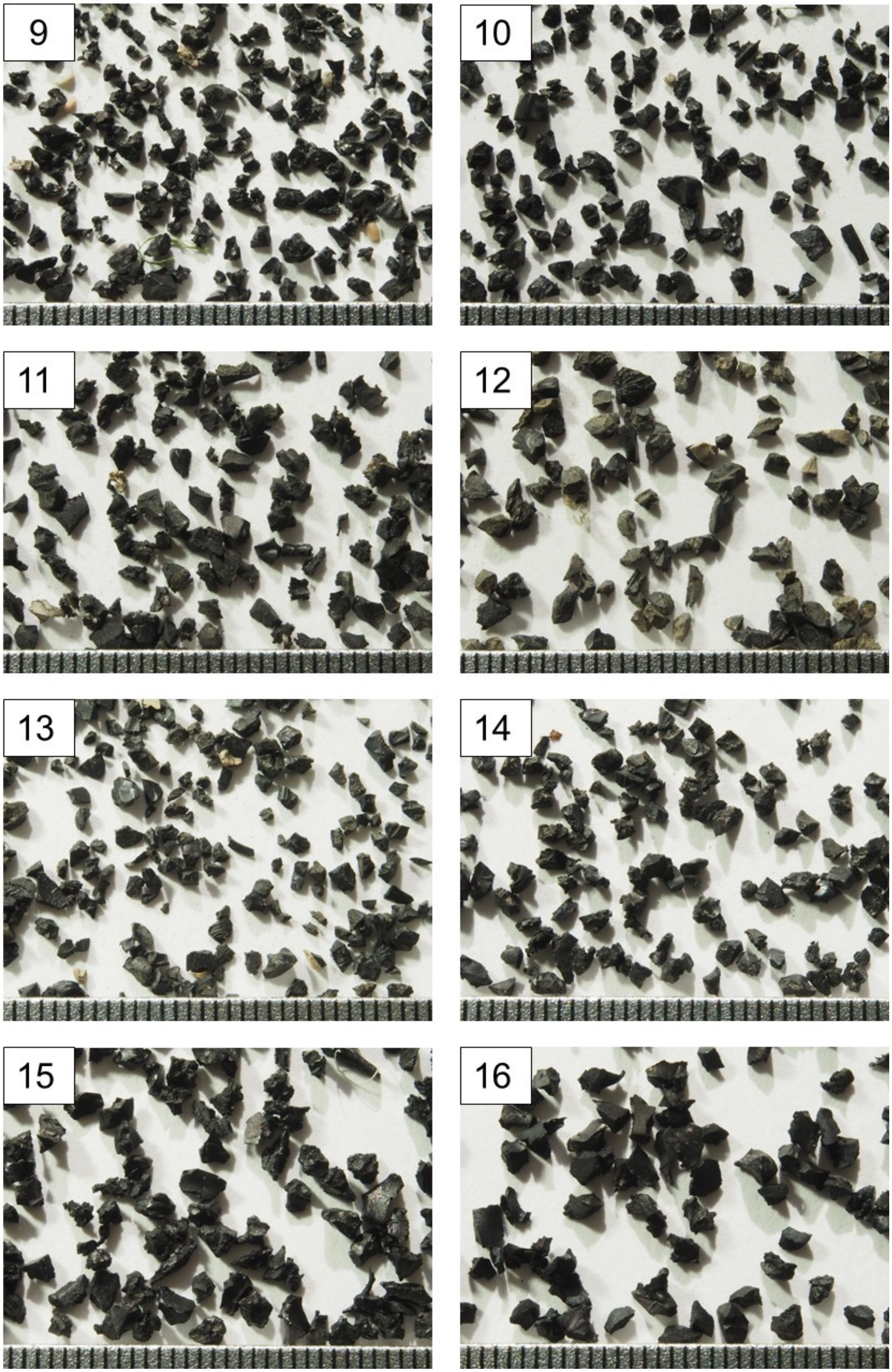

Figure H-7. Photos of tire crumb rubber infill collected from eight synthetic turf fields (Field ID numbers are shown). Scale gradations are 1 mm.

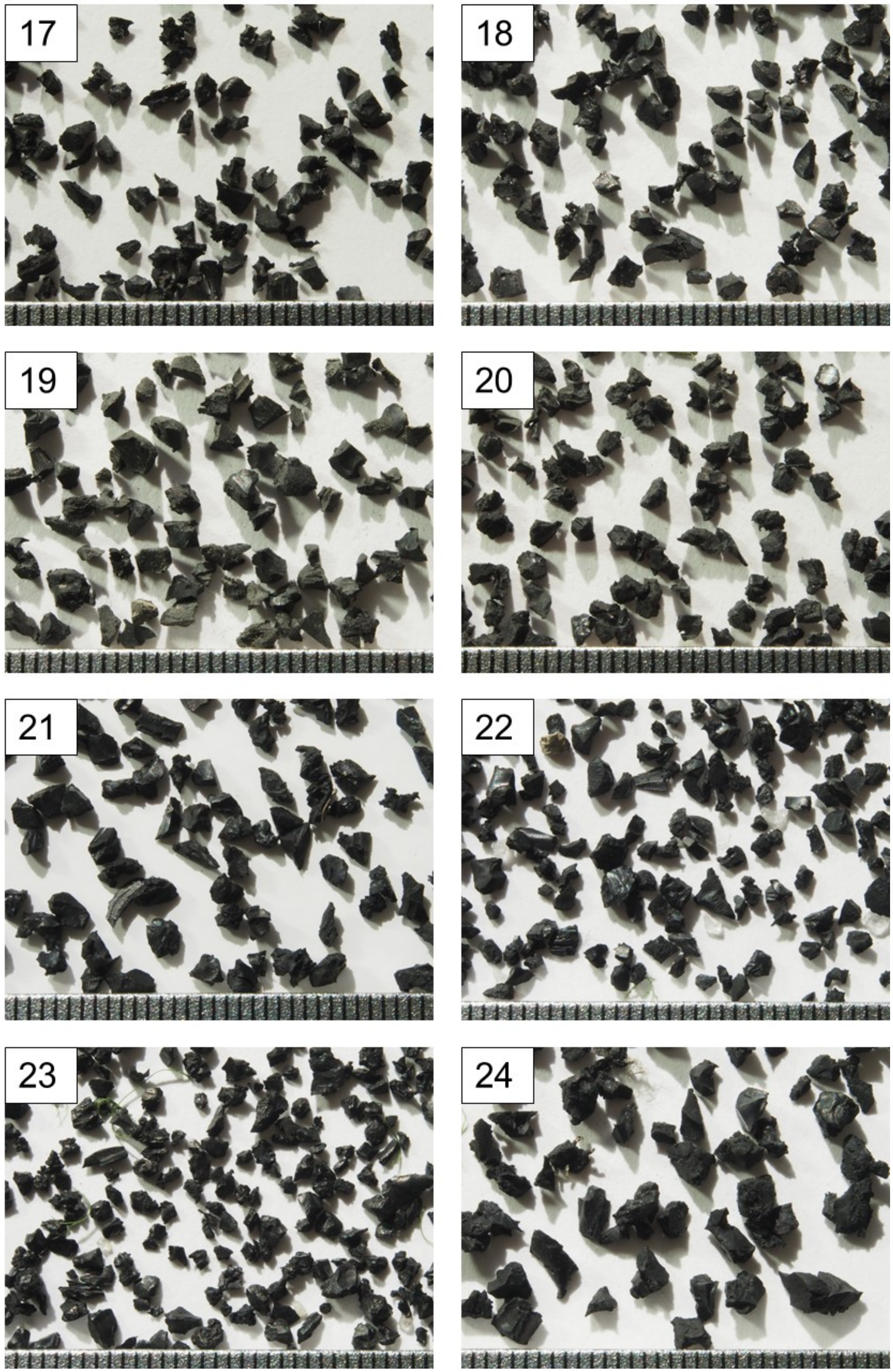

Figure H-8. Photos of tire crumb rubber infill collected from eight synthetic turf fields (Field ID numbers are shown). Scale gradations are 1 mm.

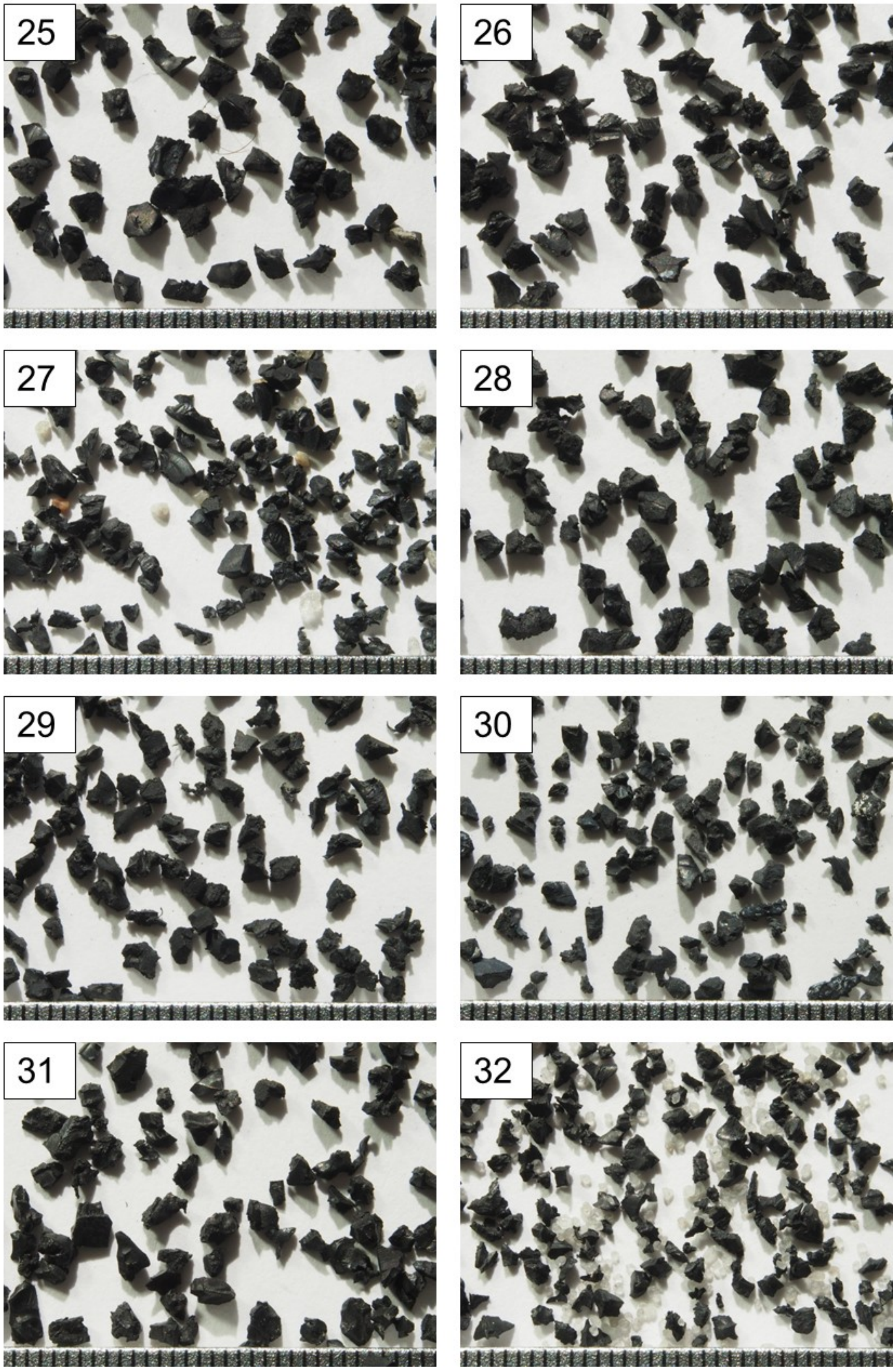

Figure H-9. Photos of tire crumb rubber infill collected from eight synthetic turf fields (Field ID numbers are shown). Scale gradations are 1 mm.

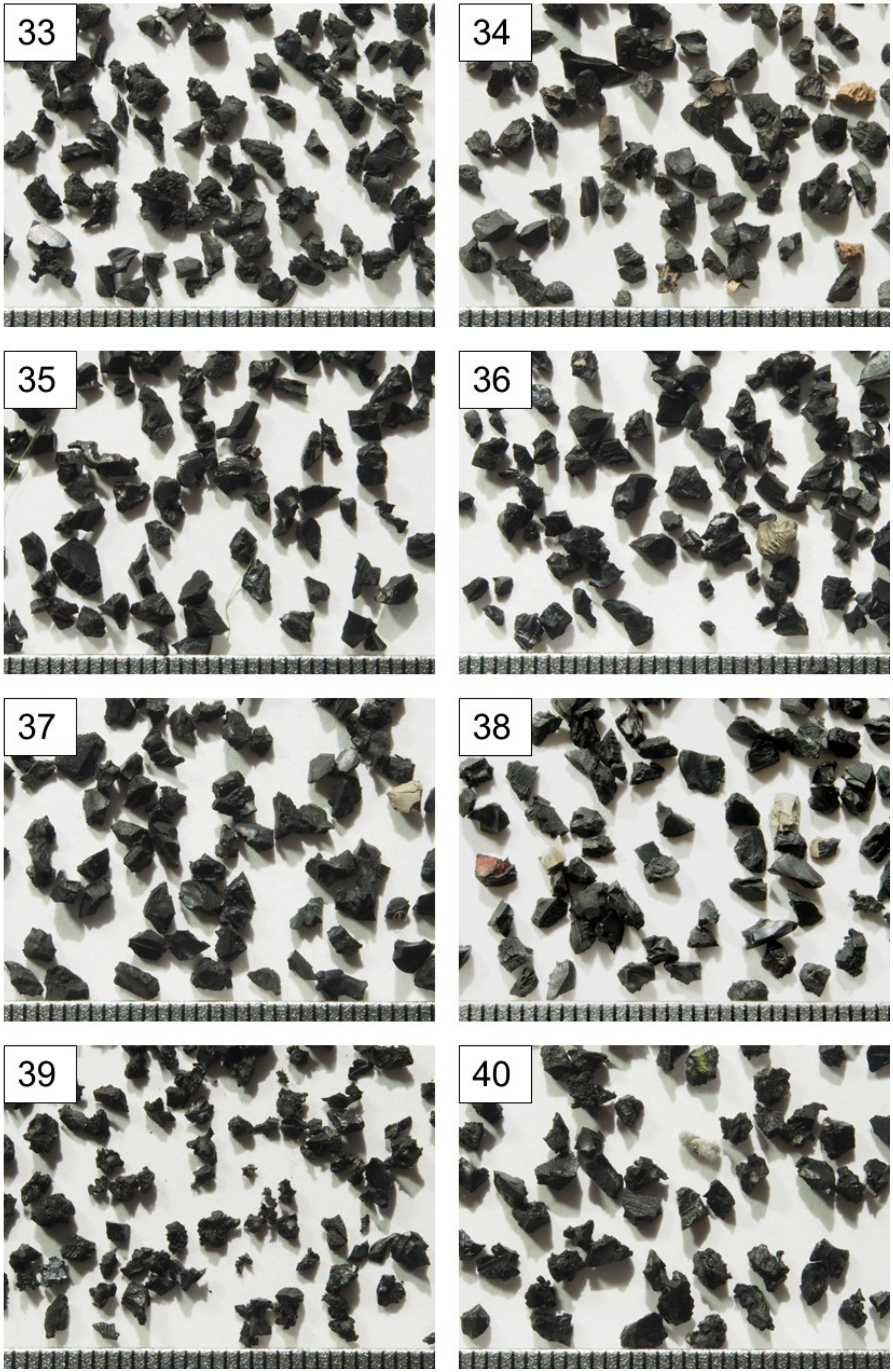

Figure H-10. Photos of tire crumb rubber infill collected from eight synthetic turf fields (Field ID numbers are shown). Scale gradations are 1 mm.

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Appendix I

Tire Crumb Rubber Measurement Results – Summary Statistics

Table I-1. Summary Statistics for Metals Analyzed by ICP/MS in Tire Crumb Rubber Samples Collected from Tire Recycling Plants[a]

Chemical	n	% >LOD	Mean (mg/kg)	Standard Deviation (mg/kg)	% Relative Standard Deviation	10th Percentile (mg/kg)	25th Percentile (mg/kg)	50th Percentile (mg/kg)	75th Percentile (mg/kg)	90th Percentile (mg/kg)	Max (mg/kg)
Arsenic	27	100	0.30	0.088	29	0.2	0.24	0.28	0.37	0.45	0.51
Cadmium	27	100	0.55	0.13	23	0.4	0.45	0.55	0.63	0.73	0.93
Chromium	27	100	1.8	0.70	39	1.0	1.2	1.7	2.0	2.4	3.6
Cobalt	27	100	190	87	46	96	120	180	250	280	440
Lead	27	100	13	10	78	7.7	9.4	10	14	22	61
Zinc	27	100	17000	3500	20	13000	14000	16000	20000	21000	25000
Aluminum	27	100	1000	510	49	430	580	980	1300	1900	2000
Antimony	27	100	1.2	0.41	34	0.66	0.81	1.3	1.5	1.7	2.0
Barium	27	100	7.4	7.9	110	3.3	3.8	5.1	7.0	11	39
Beryllium	27	100	0.015	0.0071	49	0.0083	0.011	0.012	0.017	0.022	0.042
Copper	27	100	42	22	53	20	23	35	56	73	100
Iron	27	100	490	290	59	260	320	440	520	640	1700
Magnesium	27	100	290	78	27	210	240	290	310	370	590
Manganese	27	100	5.7	2.1	37	3.9	4.5	5.1	6.1	9.3	13
Molybdenum	27	100	0.22	0.09	41	0.14	0.18	0.2	0.23	0.32	0.56
Nickel	27	100	3.2	1.0	32	2.1	2.3	2.8	4.1	4.3	5.8
Rubidium	27	100	1.8	0.46	26	1.2	1.3	1.8	2.2	2.4	2.5
Selenium	27	0	*	*	*	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Strontium	27	100	2.9	0.68	23	2.2	2.4	2.8	3.5	4.0	4.8
Tin	27	100	1.8	0.64	36	1.1	1.3	1.6	2.3	2.6	3.2
Vanadium	27	100	1.7	0.64	37	1.0	1.4	1.6	2.0	2.4	4.0

[a] ICP/MS = inductively coupled plasma/mass spectrometry; LOD = limit of detection; Max = maximum

*Values reported only when % >LOD is ≥ 60%.

Table I-2. Summary Statistics for Metals Analyzed by ICP/MS in Tire Crumb Rubber Infill Samples Collected from Synthetic Turf Fields[a]

Chemical	n	% >LOD	Mean (mg/kg)	Standard Deviation (mg/kg)	% Relative Standard Deviation	10th Percentile (mg/kg)	25th Percentile (mg/kg)	50th Percentile (mg/kg)	75th Percentile (mg/kg)	90th Percentile (mg/kg)	Max (mg/kg)
Arsenic	40	100	0.38	0.20	52	0.19	0.26	0.34	0.45	0.6	1.1
Cadmium	40	100	0.95	0.68	72	0.49	0.57	0.70	1.1	1.7	4.2
Chromium	40	100	1.6	0.84	51	0.97	1.2	1.6	1.9	2.7	3.7
Cobalt	40	100	140	60	44	68	85	120	180	220	290
Lead	40	100	24	26	110	9.3	11	14	25	55	160
Zinc	40	100	15000	3000	20	11000	13000	14000	16000	19000	22000
Aluminum	40	100	1300	740	58	540	670	1100	1600	2500	3400
Antimony	40	100	0.95	0.43	45	0.48	0.66	0.91	1.1	1.6	2.2
Barium	40	100	8.3	5.3	63	3.6	4.8	7.3	10	12	29
Beryllium	40	85	0.008	0.03	380	<LOD	0.0059	0.0098	0.018	0.03	0.068
Copper	40	100	26	12	47	13	16	23	35	42	55
Iron	40	100	610	400	66	280	350	510	620	1200	1800
Magnesium	40	100	330	230	71	210	230	260	330	400	1400
Manganese	40	100	7.7	5.2	67	4.2	4.9	6.2	8.1	12	31
Molybdenum	40	100	0.16	0.064	41	0.076	0.13	0.15	0.18	0.24	0.35
Nickel	40	100	2.7	0.89	33	1.6	2.0	2.7	3.3	3.8	4.6
Rubidium	40	100	1.9	0.58	31	1.3	1.4	1.8	2.1	2.5	3.9
Selenium	40	0	*	*	*	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Strontium	40	100	3.4	1.4	42	2.1	2.5	2.9	4.1	5.1	8.3
Tin	40	100	1.6	1.1	70	0.45	0.75	1.5	2.3	3.0	4.3
Vanadium	40	100	1.9	0.87	47	1.2	1.4	1.7	2.3	3.0	4.8

[a] ICP/MS= inductively coupled plasma/mass spectrometry; LOD= limit of detection; Max = maximum

*Values reported only when % >LOD is ≥ 60%

Table I-3. Summary Statistics for Metals Analyzed by XRF in Tire Crumb Rubber Samples Collected from Tire Recycling Plants[a]

Chemical	n	% >LOD	Mean (mg/kg)	Standard Deviation (mg/kg)	% Relative Standard Deviation	10th Percentile (mg/kg)	25th Percentile (mg/kg)	50th Percentile (mg/kg)	75th Percentile (mg/kg)	90th Percentile (mg/kg)	Max (mg/kg)
Arsenic	27	0	*	*	*	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Cadmium	27	0	*	*	*	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Chromium	27	100	15	4	26	10	12	15	18	21	25
Cobalt	27	100	58	35	61	24	31	52	72	130	150
Lead	27	100	35	8.6	25	23	29	37	41	47	54
Zinc	27	100	39000	8800	22	30000	32000	36000	48000	54000	58000
Antimony	27	0	*	*	*	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Barium	27	100	60	20	34	45	50	56	63	68	150
Copper	27	100	200	80	40	110	130	190	250	310	410
Iron	27	100	1500	1100	78	660	810	1100	1700	2000	6200
Manganese	27	4	*	*	*	<LOD	<LOD	<LOD	<LOD	<LOD	21
Molybdenum	27	100	54	7.0	13	46	50	55	59	63	68
Nickel	27	0	*	*	*	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Rubidium	27	100	86	34	39	50	59	76	110	140	140
Selenium	27	0	*	*	*	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Strontium	27	100	8.6	2.1	25	5.5	6.5	9.5	10	11	12
Tin	27	0	*	*	*	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD

[a] XRF = X-ray fluorescence spectrometry; LOD = limit of detection; Max = maximum

*Values reported only when % >LOD is ≥ 60%

Table I-4. Summary Statistics for Metals Analyzed by XRF in Tire Crumb Rubber Infill Collected from Synthetic Turf Fields[a]

Chemical	n	% >LOD	Mean (mg/kg)	Standard Deviation (mg/kg)	% Relative Standard Deviation	10th Percentile (mg/kg)	25th Percentile (mg/kg)	50th Percentile (mg/kg)	75th Percentile (mg/kg)	90th Percentile (mg/kg)	Max (mg/kg)
Arsenic	40	3	*	*	*	<LOD	<LOD	<LOD	<LOD	<LOD	12
Cadmium	40	8	*	*	*	<LOD	<LOD	<LOD	<LOD	<LOD	27
Chromium	40	100	14	2.9	21	10	12	13	16	17	20
Cobalt	40	100	39	17	44	15	22	43	52	61	69
Lead	40	100	36	22	61	15	22	33	44	54	110
Zinc	40	100	33000	7100	22	26000	29000	31000	37000	45000	47000
Antimony	40	0	*	*	*	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Barium	40	100	60	16	26	45	48	55	76	81	92
Copper	40	100	120	44	36	79	88	100	160	190	220
Iron	40	100	1300	550	44	750	930	1100	1500	1800	3600
Manganese	40	0	*	*	*	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Molybdenum	40	100	47	13	29	30	41	49	54	63	84
Nickel	40	0	*	*	*	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Rubidium	40	100	56	29	53	27	34	54	66	95	140
Selenium	40	0	*	*	*	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Strontium	40	100	14	13	94	6.3	8.0	10	12	30	62
Tin	40	0	*	*	*	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD

[a] XRF = X-ray fluorescence spectrometry; LOD = limit of detection; Max = maximum

*Values reported only when % >LOD is ≥ 60%

Table I-5. Summary Statistics for SVOCs Analyzed by GC/MS/MS in Solvent Extracts for Tire Crumb Rubber Samples Collected from Tire Recycling Plants[a]

Chemical	n	% >LOD	Mean (mg/kg)	Standard Deviation (mg/kg)	% Relative Standard Deviation	10th Percentile (mg/kg)	25th Percentile (mg/kg)	50th Percentile (mg/kg)	75th Percentile (mg/kg)	90th Percentile (mg/kg)	Max (mg/kg)
Phenanthrene	27	100	3.6	1.3	35	1.8	2.6	3.6	4.5	5.8	5.9
Fluoranthene	27	100	6.1	1.7	27	4.3	4.8	5.8	6.7	8.6	10
Pyrene	27	100	18	2.4	13	16	17	18	20	22	23
Benzo[a]pyrene	27	100	0.74	0.39	52	0.39	0.47	0.64	0.95	1.4	1.9
Benzo[ghi]perylene	27	100	1.3	0.59	45	0.82	0.97	1.1	1.3	2.0	3.4
Sum15PAH[b]	27	100	41	8.9	22	31	34	39	49	53	62
Benzothiazole	27	100	79	19	24	54	61	79	96	100	110
Dibutyl phthalate	27	100	0.68	0.44	65	0.27	0.31	0.44	0.85	1.5	1.7
Bis(2-ethylhexyl) phthalate	27	100	12	14	120	2.9	3.5	6.1	15	34	58
Aniline	27	100	3.8	1.8	47	2.3	2.3	2.6	5.5	6.3	7.2
4-tert-octylphenol	27	100	30	6.2	21	23	25	30	34	40	46
n-Hexadecane	27	100	3.6	1.8	51	1.8	2.1	2.7	5.5	6.5	6.6
Naphthalene	27	100	1.4	0.75	55	0.45	0.54	1.3	1.6	2.6	3.3
1-Methylnaphthalene	27	100	1.6	1.3	76	0.26	0.35	1.7	2.3	3.7	4.3
2-Methylnaphthalene	27	100	1.8	1.3	72	0.31	0.44	1.9	2.7	3.8	4.7
Acenaphthylene	27	100	0.37	0.085	23	0.28	0.29	0.37	0.43	0.49	0.56
Fluorene	27	100	0.37	0.14	37	0.24	0.27	0.35	0.42	0.58	0.79
Anthracene	27	100	0.59	0.4	68	0.26	0.35	0.47	0.55	1.3	1.6
1-Methylphenanthrene	27	100	1.4	0.53	38	0.74	1.0	1.3	1.5	2.3	2.8
2-Methylphenanthrene	27	100	1.4	0.8	57	0.79	0.87	1.1	1.6	3.4	3.5
3-Methylphenanthrene	27	100	2.1	1.1	52	0.95	1.2	1.7	2.7	3.9	4.9
Benz(a)anthracene	27	100	1.1	0.57	53	0.52	0.66	0.98	1.3	1.8	2.9
Chrysene	27	100	4.3	1.7	39	2.6	2.9	4.1	5.1	6.3	8.8
Benzo(b)fluoranthene	27	100	1.6	1.0	64	0.84	1.0	1.2	1.8	2.9	5.3
Benzo(k)fluoranthene	27	100	0.44	0.19	44	0.18	0.26	0.4	0.59	0.73	0.82
Benzo(e)pyrene	27	100	1.7	1.1	63	0.59	0.74	1.4	2.4	3.3	3.9
DBA + ICDP[c]	27	100	0.35	0.21	59	0.13	0.18	0.31	0.48	0.65	0.97

Table I-5 Continued

Chemical	n	% >LOD	Mean (mg/kg)	Standard Deviation (mg/kg)	% Relative Standard Deviation	10th Percentile (mg/kg)	25th Percentile (mg/kg)	50th Percentile (mg/kg)	75th Percentile (mg/kg)	90th Percentile (mg/kg)	Max (mg/kg)
Coronene	27	100	0.82	0.48	58	0.38	0.55	0.69	0.81	1.9	2.0
Dibenzothiophene	27	100	0.42	0.13	31	0.29	0.34	0.4	0.45	0.59	0.78
2-Bromomethylnaphthalene	27	0	*	*	*	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
n-Butylbenzene	27	78	0.14	0.12	87	<LOD	0.012	0.11	0.2	0.32	0.39
Dimethyl phthalate	27	93	0.04	0.022	54	0.0061	0.038	0.045	0.051	0.074	0.077
Diethyl phthalate	27	100	0.091	0.17	180	0.013	0.024	0.059	0.11	0.12	0.9
Diisobutyl phthalate	27	100	0.5	0.39	79	0.21	0.25	0.40	0.47	1.2	1.6
Benzyl butyl phthalate	27	100	0.64	0.37	57	0.23	0.36	0.5	1.0	1.2	1.3
Di-n-octyl phthalate	27	100	0.32	0.19	61	0.11	0.19	0.26	0.41	0.57	0.9
2,6-Di-tert-butyl-p-cresol	27	100	13	10	80	4.8	5.4	9.3	18	34	40
Bis(2,2,6,6-tetramethyl-4-piperidyl) sebacate	21	100	0.44	0.30	66	0.12	0.17	0.45	0.72	0.84	0.93
Cyclohexylisothiocyanate	27	100	0.98	0.33	34	0.55	0.74	0.97	1.2	1.5	1.7

[a] SVOC = semivolatile organic compound; GC/MS/MS = gas chromatography/tandem mass spectrometry; LOD = limit of detection; Max = maximum

[b] Sum15PAH = Sum of 15 of the 16 EPA 'priority' PAHs, including Acenaphthylene, Anthracene, Benz[a]anthracene, Benzo[a]pyrene, Benzo(b)fluoranthene, Benzo[ghi]perylene, Benzo(k)fluoranthene, Chrysene, Dibenz[a,h]anthracene, Fluoranthene, Fluorene, Indeno(1,2,3-cd)pyrene, Naphthalene, Phenanthrene, Pyrene

[c] DBA + ICDP = Sum of Dibenz[a,h]anthracene and Indeno(1,2,3-cd)pyrene

*Values reported only when % >LOD is ≥ 60%.

Table I-6. Summary Statistics for SVOCs Analyzed by GC/MS/MS in Solvent Extracts for Tire Crumb Rubber Infill Collected from Synthetic Turf Fields[a]

Chemical	n	% >LOD	Mean (mg/kg)	Standard Deviation (mg/kg)	% Relative Standard Deviation	10th Percentile (mg/kg)	25th Percentile (mg/kg)	50th Percentile (mg/kg)	75th Percentile (mg/kg)	90th Percentile (mg/kg)	Max (mg/kg)
Phenanthrene	40	100	2.3	2.6	110	0.26	0.44	1.1	3.3	6.1	10
Fluoranthene	40	100	4.5	2.6	57	2.0	2.4	3.9	6.5	8.1	10
Pyrene	40	100	12	6.2	49	4.2	7.0	13	17	21	25
Benzo[a]pyrene	40	100	0.78	0.52	66	0.38	0.43	0.62	0.91	1.4	3.0
Benzo[ghi]perylene	40	100	1.3	0.64	49	0.47	0.64	1.4	1.8	2.0	2.8
Sum15PAH[b]	40	100	29	15	51	13	17	27	38	49	68
Benzothiazole	40	100	11	13	120	1.1	1.8	7.0	14	31	54
Dibutyl phthalate	40	100	1.5	1.5	100	0.054	0.26	0.97	2.3	3.5	6.6
Bis(2-ethylhexyl) phthalate	40	100	43	42	100	4.9	7.8	28	58	100	170
Aniline	40	100	0.67	0.53	79	0.16	0.27	0.57	0.96	1.2	2.4
4-tert-octylphenol	40	100	9.8	9.7	99	0.90	2.5	5.6	16	27	33
n-Hexadecane	40	100	0.94	1.3	130	0.079	0.1	0.26	1.3	2.6	5.4
Naphthalene	40	100	0.034	0.041	120	0.0058	0.01	0.017	0.039	0.082	0.22
1-Methylnaphthalene	40	100	0.050	0.10	200	0.0024	0.0044	0.0081	0.052	0.13	0.52
2-Methylnaphthalene	40	100	0.083	0.17	200	0.0059	0.010	0.018	0.082	0.19	0.85
Acenaphthylene	40	100	0.046	0.057	120	0.0086	0.011	0.024	0.055	0.11	0.25
Fluorene	40	100	0.18	0.28	150	0.0055	0.012	0.051	0.26	0.47	1.3
Anthracene	40	100	0.52	0.75	140	0.038	0.087	0.17	0.54	1.5	3.1
1-Methylphenanthrene	40	100	1.6	1.3	82	0.33	0.54	1.3	2.1	3.4	5.2
2-Methylphenanthrene	40	100	3.0	4.6	150	0.43	0.58	1.5	3.1	6.3	23
3-Methylphenanthrene	40	100	2.3	2.1	91	0.48	0.69	1.6	3.7	4.8	9.2
Benz(a)anthracene	40	100	2.2	1.4	63	0.71	1.2	1.9	3.1	4.3	6
Chrysene	40	100	2.5	1.8	70	0.73	1.0	2	3.9	5.4	6.2
Benzo(b)fluoranthene	40	100	1.3	0.80	59	0.58	0.72	1.1	1.8	2.2	3.9
Benzo(k)fluoranthene	40	100	0.45	0.31	68	0.18	0.24	0.40	0.58	0.77	1.5
Benzo(e)pyrene	40	100	1.9	0.98	51	0.72	1.1	1.9	2.4	3.5	4.1

Table I-6 Continued

Chemical	n	% >LOD	Mean (mg/kg)	Standard Deviation (mg/kg)	% Relative Standard Deviation	10th Percentile (mg/kg)	25th Percentile (mg/kg)	50th Percentile (mg/kg)	75th Percentile (mg/kg)	90th Percentile (mg/kg)	Max (mg/kg)
DBA + ICDP[c]	40	100	0.54	0.31	58	0.19	0.34	0.44	0.78	1.0	1.3
Coronene	40	100	0.54	0.31	58	0.19	0.28	0.49	0.74	1.0	1.4
Dibenzothiophene	40	100	0.31	0.35	110	0.026	0.049	0.16	0.50	0.78	1.4
2-Bromomethylnaphthalene	40	0	*	*	*	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
n-Butylbenzene	40	0	*	*	*	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Dimethyl phthalate	40	65	0.027	0.061	230	<LOD	<LOD	0.0065	0.019	0.08	0.32
Diethyl phthalate	34	68	0.52	2.4	460	<LOD	<LOD	0.0029	0.19	0.55	14
Diisobutyl phthalate	40	100	1.2	1.8	150	0.04	0.22	0.59	1.4	3.2	9.1
Benzyl butyl phthalate	40	100	1.2	2.0	170	0.049	0.16	0.7	1.4	2.2	12
Di-n-octyl phthalate	40	98	0.25	0.24	96	0.027	0.067	0.19	0.36	0.62	0.99
2,6-Di-tert-butyl-p-cresol	40	20	*	*	*	<LOD	<LOD	<LOD	<LOD	0.56	5.3
Bis(2,2,6,6-tetramethyl-4-piperidyl) sebacate	39	82	0.78	0.89	110	<LOD	0.20	0.37	1.1	2.5	3.0
Cyclohexylisothiocyanate	40	100	0.25	0.18	74	0.016	0.13	0.23	0.32	0.43	0.78

[a] SVOC = semivolatile organic compound; GC/MS/MS = gas chromatography/tandem mass spectrometry; LOD = limit of detection; Max = maximum

[b] Sum15PAH = Sum of 15 of the 16 EPA 'priority' PAHs, including Acenaphthylene, Anthracene, Benz[a]anthracene, Benzo[a]pyrene, Benzo(b)fluoranthene, Benzo[ghi]perylene, Benzo(k)fluoranthene, Chrysene, Dibenz[a,h]anthracene, Fluoranthene, Fluorene, Indeno(1,2,3-cd)pyrene, Naphthalene, Phenanthrene, Pyrene

[c] DBA + ICDP = Sum of Dibenz[a,h]anthracene and Indeno(1,2,3-cd)pyrene

*Values reported only when % >LOD is ≥ 60%.

Table I-7. Summary Statistics for VOC 25 °C Emission Factors for Tire Crumb Rubber Samples Collected from Tire Recycling Plants[a]

Chemical	n	% >LOD	Mean (mg/kg)	Standard Deviation (mg/kg)	% Relative Standard Deviation	10th Percentile (mg/kg)	25th Percentile (mg/kg)	50th Percentile (mg/kg)	75th Percentile (mg/kg)	90th Percentile (mg/kg)	Max (mg/kg)
Formaldehyde	26	11	*	*	*	<LOD	<LOD	<LOD	<LOD	8.8	25
Metyl isobutyl ketone	27	96	24	16	65	5.7	14	21	31	48	72
Benzothiazole	27	96	150	41	28	93	130	150	180	180	180
1,3-Butadiene	27	0	*	*	*	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Styrene	27	85	0.31	0.21	69	<LOD	0.16	0.23	0.41	0.70	0.87
Benzene	27	44	*	*	*	<LOD	<LOD	<LOD	0.33	0.76	1.4
Toluene	27	93	0.39	0.35	91	0.027	0.095	0.24	0.61	0.99	1.3
Ethylbenzene	27	41	*	*	*	<LOD	<LOD	<LOD	0.086	0.17	0.27
m/p-Xylene	27	96	0.86	0.81	95	0.13	0.32	0.63	1.2	1.6	3.7
o-Xylene	27	93	0.21	0.20	93	0.0077	0.095	0.16	0.32	0.45	0.89
SumBTEX[b]	27	100	1.7	1.3	77	0.10	0.86	1.5	2.7	3.4	5.4
trans-2-Butene	27	100	0.055	0.024	43	0.024	0.039	0.059	0.071	0.086	0.10
cis-2-Butene	27	100	0.05	0.025	50	0.02	0.033	0.047	0.071	0.079	0.10
4-Ethyltoluene	27	74	0.26	0.18	68	<LOD	<LOD	0.24	0.36	0.41	0.90
1,3,5-Trimethylbenzene	27	96	0.68	0.34	50	0.26	0.41	0.66	0.93	1.0	1.6
1,1-Dichloroethene	27	0	*	*	*	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
1,1-Dichloroethane	27	0	*	*	*	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
cis-1,2-Dichloroethene	27	0	*	*	*	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
1,2-Dichloroethane	27	0	*	*	*	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
1,1,1-Trichloroethane	27	0	*	*	*	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Carbon Tetrachloride	27	0	*	*	*	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
1,2-Dichloropropane	27	0	*	*	*	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Trichloroethylene	27	4	*	*	*	<LOD	<LOD	<LOD	<LOD	<LOD	0.43
Tetrachloroethylene	27	67	0.36	0.67	190	<LOD	<LOD	0.059	0.47	1.3	2.8
Chlorobenzene	27	11	*	*	*	<LOD	<LOD	<LOD	<LOD	0.042	0.049
m-Dichlorobenzene	27	0	*	*	*	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD

Table I-7. Continued

Chemical	n	% >LOD	Mean (mg/kg)	Standard Deviation (mg/kg)	% Relative Standard Deviation	10th Percentile (mg/kg)	25th Percentile (mg/kg)	50th Percentile (mg/kg)	75th Percentile (mg/kg)	90th Percentile (mg/kg)	Max (mg/kg)
p-Dichlorobenzene	27	11	*	*	*	<LOD	<LOD	<LOD	<LOD	0.11	0.26
o-Dichlorobenzene	27	4	*	*	*	<LOD	<LOD	<LOD	<LOD	<LOD	0.09
Trichlorofluoromethane (Freon 11)	27	89	0.16	0.55	340	<LOD	-0.46	0.32	0.53	0.95	1.1
Dichlorodifluoromethane (Freon 12)	27	100	0.029	0.053	190	-0.077	0.020	0.044	0.059	0.067	0.080
Trichlorotrifluoroethane (Freon 113)	27	0	*	*	*	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD

[a] VOC = volatile organic compound; °C = degrees Celsius; LOD = limit of detection; Max = maximum

[b] SumBTEX = Sum of benzene, toluene, ethylbenzene, m/p-xylene, and o-xylene

*Values reported only when % >LOD is ≥ 60%.

Table I-8. Summary Statistics for VOC 60 °C Emission Factors for Tire Crumb Rubber Samples Collected from Tire Recycling Plants[a]

Chemical	n	% >LOD	Mean (mg/kg)	Standard Deviation (mg/kg)	% Relative Standard Deviation	10th Percentile (mg/kg)	25th Percentile (mg/kg)	50th Percentile (mg/kg)	75th Percentile (mg/kg)	90th Percentile (mg/kg)	Max (mg/kg)
Formaldehyde	27	96	40	16	40	20	24	40	49	62	73
Metyl isobutyl ketone	27	100	140	15	11	110	130	130	150	160	160
Benzothiazole	27	100	220	8.3	3.7	210	220	220	230	230	240
1,3-Butadiene	27	0	*	*	*	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Styrene	27	100	1.1	0.58	53	0.33	0.55	1.0	1.6	1.9	2.1
Benzene	27	89	0.21	0.45	220	<LOD	-0.098	0.027	0.64	0.92	1.2
Toluene	27	100	1.1	0.95	85	0.20	0.3	0.64	1.7	2.6	3.2
Ethylbenzene	27	100	-0.0055	0.26	-4800	-0.22	-0.18	-0.13	0.092	0.52	0.68
m/p-Xylene	27	100	1.2	0.71	57	0.36	0.60	1.1	1.6	2.1	2.9
o-Xylene	27	100	-0.4	0.43	-110	-0.80	-0.73	-0.49	-0.28	0.23	0.79
SumBTEX[b]	27	100	2.1	2.2	100	-0.57	0.36	1.9	3.4	5.7	7.7
trans-2-Butene	27	100	-0.22	0.25	-120	-0.42	-0.36	-0.27	-0.19	0.26	0.59

Table I-8 Continued

Chemical	n	% >LOD	Mean (mg/kg)	Standard Deviation (mg/kg)	% Relative Standard Deviation	10th Percentile (mg/kg)	25th Percentile (mg/kg)	50th Percentile (mg/kg)	75th Percentile (mg/kg)	90th Percentile (mg/kg)	Max (mg/kg)
cis-2-Butene	27	100	-0.2	0.21	-110	-0.38	-0.34	-0.24	-0.16	0.18	0.5
4-Ethyltoluene	27	22	*	*	*	<LOD	<LOD	<LOD	<LOD	0.15	0.21
1,3,5-Trimethylbenzene	27	63	0.10	0.058	57	<LOD	<LOD	0.10	0.14	0.17	0.27
1,1-Dichloroethene	27	0	*	*	*	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
1,1-Dichloroethane	27	0	*	*	*	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
cis-1,2-Dichloroethene	27	0	*	*	*	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
1,2-Dichloroethane	27	0	*	*	*	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
1,1,1-Trichloroethane	27	0	*	*	*	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Carbon Tetrachloride	27	0	*	*	*	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
1,2-Dichloropropane	27	0	*	*	*	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Trichloroethylene	27	26	*	*	*	<LOD	<LOD	<LOD	0.36	0.58	1.0
Tetrachloroethylene	27	63	0.14	0.23	160	<LOD	<LOD	0.042	0.15	0.66	0.89
Chlorobenzene	27	41	*	*	*	<LOD	<LOD	<LOD	0.035	0.13	0.24
m-Dichlorobenzene	27	22	*	*	*	<LOD	<LOD	<LOD	<LOD	0.16	0.34
p-Dichlorobenzene	27	85	0.019	0.12	650	<LOD	-0.027	0.0067	0.065	0.21	0.30
o-Dichlorobenzene	27	22	*	*	*	<LOD	<LOD	<LOD	<LOD	0.19	0.38
Trichlorofluoromethane (Freon 11)	27	93	0.23	0.58	250	-0.66	-0.47	0.42	0.58	1.1	1.2
Dichlorodifluoromethane (Freon 12)	27	100	0.041	0.047	110	0.0041	0.028	0.045	0.067	0.08	0.098
Trichlorotrifluoroethane (Freon 113)	27	0	*	*	*	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD

[a] VOC = volatile organic compound; °C = degrees Celsius; LOD = limit of detection; Max = maximum

[b] SumBTEX = Sum of benzene, toluene, ethylbenzene, m/p-xylene, and o-xylene

*Values reported only when % >LOD is ≥ 60%.

Table I-9. Summary Statistics for VOC 25 °C Emission Factors for Tire Crumb Rubber Infill Samples Collected from Synthetic Turf Fields[a]

Chemical	n	% >LOD	Mean (mg/kg)	Standard Deviation (mg/kg)	% Relative Standard Deviation	10th Percentile (mg/kg)	25th Percentile (mg/kg)	50th Percentile (mg/kg)	75th Percentile (mg/kg)	90th Percentile (mg/kg)	Max (mg/kg)
Formaldehyde	38	0	*	*	*	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Metyl isobutyl ketone	38	58	*	*	*	<LOD	<LOD	0.87	1.4	4.5	20
Benzothiazole	38	63	25	28	110	<LOD	<LOD	15	40	72	110
1,3-Butadiene	38	13	*	*	*	<LOD	<LOD	<LOD	<LOD	0.094	0.23
Styrene	38	21	*	*	*	<LOD	<LOD	<LOD	<LOD	0.3	1.0
Benzene	38	18	*	*	*	<LOD	<LOD	<LOD	<LOD	0.74	2.2
Toluene	38	26	*	*	*	<LOD	<LOD	<LOD	0.081	0.27	0.77
Ethylbenzene	38	26	*	*	*	<LOD	<LOD	<LOD	0.032	0.089	0.48
m/p-Xylene	38	50	*	*	*	<LOD	<LOD	0.0082	0.13	0.21	0.70
o-Xylene	38	76	0.032	0.090	290	<LOD	-0.028	0.0088	0.077	0.14	0.34
SumBTEX[b]	38	89	0.31	0.84	270	<LOD	-0.23	0.044	0.54	1.3	2.9
trans-2-Butene	38	16	*	*	*	<LOD	<LOD	<LOD	<LOD	0.016	0.51
cis-2-Butene	38	8	*	*	*	<LOD	<LOD	<LOD	<LOD	<LOD	0.6
4-Ethyltoluene	38	0	*	*	*	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
1,3,5-Trimethylbenzene	38	3	*	*	*	<LOD	<LOD	<LOD	<LOD	<LOD	0.26
1,1-Dichloroethene	38	11	*	*	*	<LOD	<LOD	<LOD	<LOD	0.16	0.17
1,1-Dichloroethane	38	0	*	*	*	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
cis-1,2-Dichloroethene	38	0	*	*	*	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
1,2-Dichloroethane	38	0	*	*	*	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
1,1,1-Trichloroethane	38	0	*	*	*	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Carbon Tetrachloride	38	0	*	*	*	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
1,2-Dichloropropane	38	0	*	*	*	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Trichloroethylene	38	0	*	*	*	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Tetrachloroethylene	38	16	*	*	*	<LOD	<LOD	<LOD	<LOD	0.038	0.075
Chlorobenzene	38	21	*	*	*	<LOD	<LOD	<LOD	<LOD	0.10	0.25
m-Dichlorobenzene	38	24	*	*	*	<LOD	<LOD	<LOD	<LOD	0.19	0.47

Table I-9 Continued

Chemical	n	% >LOD	Mean (mg/kg)	Standard Deviation (mg/kg)	% Relative Standard Deviation	10th Percentile (mg/kg)	25th Percentile (mg/kg)	50th Percentile (mg/kg)	75th Percentile (mg/kg)	90th Percentile (mg/kg)	Max (mg/kg)
p-Dichlorobenzene	38	21	*	*	*	<LOD	<LOD	<LOD	<LOD	0.33	0.84
o-Dichlorobenzene	38	34	*	*	*	<LOD	<LOD	<LOD	0.089	0.35	0.69
Trichlorofluoromethane (Freon 11)	38	79	0.034	0.66	1900	<LOD	-0.62	-0.12	0.66	0.76	1.1
Dichlorodifluoromethane (Freon 12)	38	100	-0.022	0.049	-220	-0.048	-0.034	-0.016	-0.0023	0.022	0.056
Trichlorotrifluoroethane (Freon 113)	38	21	*	*	*	<LOD	<LOD	<LOD	<LOD	0.017	0.043

[a] VOC = volatile organic compound; °C = degrees Celsius; LOD = limit of detection; Max = maximum

[b] SumBTEX = Sum of benzene, toluene, ethylbenzene, m/p-xylene, and o-xylene

*Values reported only when % >LOD is ≥ 60%.

Table I-10. Summary Statistics for VOC 60 °C Emission Factors for Tire Crumb Rubber Infill Samples Collected from Synthetic Turf Fields[a]

Chemical	n	% >LOD	Mean (mg/kg)	Standard Deviation (mg/kg)	% Relative Standard Deviation	10th Percentile (mg/kg)	25th Percentile (mg/kg)	50th Percentile (mg/kg)	75th Percentile (mg/kg)	90th Percentile (mg/kg)	Max (mg/kg)
Formaldehyde	40	75	16	9.5	58	<LOD	11	15	19	24	48
Metyl isobutyl ketone	37	100	42	26	61	15	22	34	61	87	96
Benzothiazole	37	95	56	39	70	8	14	68	93	100	110
1,3-Butadiene	37	11	*	*	*	<LOD	<LOD	<LOD	<LOD	0.12	0.81
Styrene	37	100	0.45	0.41	91	-0.016	0.092	0.40	0.73	0.96	1.3
Benzene	37	49	*	*	*	<LOD	<LOD	<LOD	0.21	0.55	0.73
Toluene	37	100	0.15	0.31	200	-0.15	-0.048	0.07	0.22	0.72	0.91
Ethylbenzene	37	100	-0.082	0.22	-270	-0.33	-0.27	-0.16	0.14	0.28	0.40
m/p-Xylene	37	100	0.24	1.0	410	-0.96	-0.58	0.16	0.73	1.7	2.5
o-Xylene	37	100	-0.35	0.66	-190	-0.99	-0.88	-0.44	-0.024	0.61	1.5
SumBTEX[b]	37	100	-0.085	2.2	-2600	-2.5	-2.3	-0.4	0.94	3.3	4.6
trans-2-Butene	37	89	-0.25	0.24	-95	<LOD	-0.42	-0.29	-0.12	-0.022	0.33

Table I-10 Continued

Chemical	n	% >LOD	Mean (mg/kg)	Standard Deviation (mg/kg)	% Relative Standard Deviation	10th Percentile (mg/kg)	25th Percentile (mg/kg)	50th Percentile (mg/kg)	75th Percentile (mg/kg)	90th Percentile (mg/kg)	Max (mg/kg)
cis-2-Butene	37	89	-0.23	0.21	-92	<LOD	-0.38	-0.27	-0.1	0.014	0.25
4-Ethyltoluene	37	3	*	*	*	<LOD	<LOD	<LOD	<LOD	<LOD	0.22
1,3,5-Trimethylbenzene	37	3	*	*	*	<LOD	<LOD	<LOD	<LOD	<LOD	0.78
1,1-Dichloroethene	37	11	*	*	*	<LOD	<LOD	<LOD	<LOD	0.15	0.19
1,1-Dichloroethane	37	0	*	*	*	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
cis-1,2-Dichloroethene	37	0	*	*	*	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
1,2-Dichloroethane	37	0	*	*	*	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
1,1,1-Trichloroethane	37	0	*	*	*	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Carbon Tetrachloride	37	0	*	*	*	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
1,2-Dichloropropane	37	0	*	*	*	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Trichloroethylene	37	0	*	*	*	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Tetrachloroethylene	37	65	0.0035	0.032	900	<LOD	<LOD	-0.0031	0.011	0.040	0.13
Chlorobenzene	37	68	-0.0028	0.06	-2100	<LOD	<LOD	-0.0057	0.014	0.073	0.19
m-Dichlorobenzene	37	30	*	*	*	<LOD	<LOD	<LOD	0.042	0.14	0.32
p-Dichlorobenzene	37	76	0.079	0.23	290	<LOD	-0.10	0.073	0.22	0.34	0.83
o-Dichlorobenzene	37	38	*	*	*	<LOD	<LOD	<LOD	0.093	0.27	0.52
Trichlorofluoromethane (Freon 11)	37	86	0.079	0.64	810	<LOD	-0.52	0.030	0.66	0.89	1.1
Dichlorodifluoromethane (Freon 12)	37	100	-0.005	0.038	-760	-0.038	-0.018	-0.0077	0.0064	0.027	0.12
Trichlorotrifluoroethane (Freon 113)	37	35	*	*	*	<LOD	<LOD	<LOD	0.0092	0.018	0.12

[a] VOC = volatile organic compound; °C = degrees Celsius; LOD = limit of detection; Max = maximum

[b] SumBTEX = Sum of benzene, toluene, ethylbenzene, m/p-xylene, and o-xylene

*Values reported only when % >LOD is ≥ 60%.

Table I-11. Summary Statistics for SVOC 25 °C Emission Factors for Tire Crumb Rubber Samples Collected from Tire Recycling Plants[a]

Chemical	n	% >LOD	Mean (mg/kg)	Standard Deviation (mg/kg)	% Relative Standard Deviation	10th Percentile (mg/kg)	25th Percentile (mg/kg)	50th Percentile (mg/kg)	75th Percentile (mg/kg)	90th Percentile (mg/kg)	Max (mg/kg)
Phenanthrene	27	100	-0.0071	0.07	-980	-0.12	-0.02	0.014	0.037	0.051	0.087
Fluoranthene	27	22	*	*	*	<LOD	<LOD	<LOD	<LOD	0.0074	0.024
Pyrene	27	22	*	*	*	<LOD	<LOD	<LOD	<LOD	0.010	0.034
Benzo[a]pyrene	27	0	*	*	*	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Benzo[ghi]perylene	27	0	*	*	*	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Sum15PAH[b]	27	100	2.3	1.1	46	0.84	1.2	2.3	3.2	3.7	4.2
Benzothiazole	27	100	41	26	65	16	20	38	52	65	140
Dibutyl phthalate	27	100	-0.021	0.67	-3200	-0.50	-0.36	-0.067	0.14	0.44	2.9
Aniline	27	100	3.5	2.0	58	0.42	2.0	4.1	4.7	6.4	6.9
4-tert-octylphenol	27	100	0.47	0.25	52	0.21	0.31	0.42	0.63	0.8	1.3
Naphthalene	27	100	1.9	1.1	56	0.49	0.79	1.9	2.8	3.3	3.7
1-Methylnaphthalene	27	100	0.97	0.73	75	0.16	0.19	0.84	1.6	2.1	2.5
2-Methylnaphthalene	27	100	1.6	1.2	74	0.25	0.29	1.4	2.6	3.4	3.8
Acenaphthylene	27	100	0.059	0.019	32	0.032	0.049	0.056	0.074	0.083	0.094
Fluorene	27	100	0.016	0.0099	63	0.0064	0.0097	0.013	0.020	0.03	0.042
Anthracene	27	0	*	*	*	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
1-Methylphenanthrene	27	26	*	*	*	<LOD	<LOD	<LOD	0.0048	0.005	0.014
2-Methylphenanthrene	27	19	*	*	*	<LOD	<LOD	<LOD	<LOD	0.02	0.021
3-Methylphenanthrene	27	30	*	*	*	<LOD	<LOD	<LOD	0.0048	0.0097	0.029
Benz(a)anthracene	27	0	*	*	*	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Chrysene	27	0	*	*	*	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Benzo(b)fluoranthene	27	7	*	*	*	<LOD	<LOD	<LOD	<LOD	<LOD	0.038
Benzo(k)fluoranthene	27	0	*	*	*	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Benzo(e)pyrene	27	0	*	*	*	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
DBA + ICDP[c]	27	0	*	*	*	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD

Table I-11 Continued

Chemical	n	% >LOD	Mean (mg/kg)	Standard Deviation (mg/kg)	% Relative Standard Deviation	10th Percentile (mg/kg)	25th Percentile (mg/kg)	50th Percentile (mg/kg)	75th Percentile (mg/kg)	90th Percentile (mg/kg)	Max (mg/kg)
Coronene	27	0	*	*	*	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Dibenzothiophene	27	30	*	*	*	<LOD	<LOD	<LOD	0.0056	0.011	0.012
2-Bromomethylnaphthalene	27	15	*	*	*	<LOD	<LOD	<LOD	<LOD	0.052	0.10
n-Butylbenzene	27	100	0.56	0.50	89	0.13	0.21	0.34	0.72	1.3	1.9
Dimethyl phthalate	27	52	*	*	*	<LOD	<LOD	-0.00068	0.003	0.0077	0.011
Diisobutyl phthalate	27	100	-0.044	0.26	-590	-0.34	-0.17	-0.094	0.034	0.29	0.80
Di-n-octyl phthalate	27	48	*	*	*	<LOD	<LOD	<LOD	0.042	0.83	1.0
Bis(2,2,6,6-tetramethyl-4-piperidyl) sebacate	27	0	*	*	*	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD

[a] SVOC = semivolatile organic compound; °C = degrees Celsius; LOD = limit of detection; Max = maximum

[b] Sum15PAH = Sum of 15 of the 16 EPA 'priority' PAHs, including Acenaphthylene, Anthracene, Benz[a]anthracene, Benzo[a]pyrene, Benzo(b)fluoranthene, Benzo[ghi]perylene, Benzo(k)fluoranthene, Chrysene, Dibenz[a,h]anthracene, Fluoranthene, Fluorene, Indeno(1,2,3-cd)pyrene, Naphthalene, Phenanthrene, Pyrene

[c] DBA + ICDP = Sum of Dibenz[a,h]anthracene and Indeno(1,2,3-cd)pyrene

*Values reported only when % >LOD is ≥ 60%.

Table I-12. Summary Statistics for SVOC 60 °C Emission Factors for Tire Crumb Rubber Samples Collected from Tire Recycling Plants [a]

Chemical	n	% >LOD	Mean (mg/kg)	Standard Deviation (mg/kg)	% Relative Standard Deviation	10th Percentile (mg/kg)	25th Percentile (mg/kg)	50th Percentile (mg/kg)	75th Percentile (mg/kg)	90th Percentile (mg/kg)	Max (mg/kg)
Phenanthrene	26	100	0.83	0.34	41	0.4	0.63	0.76	1.0	1.3	1.6
Fluoranthene	26	100	0.16	0.054	33	0.11	0.12	0.15	0.20	0.25	0.27
Pyrene	26	100	0.34	0.072	22	0.23	0.28	0.34	0.40	0.44	0.45
Benzo[a]pyrene	26	0	*	*	*	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Benzo[ghi]perylene	26	4	*	*	*	<LOD	<LOD	<LOD	<LOD	<LOD	0.013
Sum15PAH[b]	26	100	13	7.0	56	4.8	7.6	13	16	18	38
Benzothiazole	26	100	520	340	66	220	290	400	690	950	1500
Dibutyl phthalate	26	100	0.21	0.72	350	-0.49	0.014	0.085	0.34	0.95	3.0
Aniline	26	100	23	7.2	31	18	19	21	25	34	46
4-tert-octylphenol	26	100	20	8.8	43	14	15	18	23	35	47
Naphthalene	26	100	9.5	6.9	73	2.4	4.7	9.3	13	14	35
1-Methylnaphthalene	26	100	7.5	5.9	78	1.3	1.8	6.9	11	16	20
2-Methylnaphthalene	26	100	11	11	94	2.1	2.6	9.3	16	21	48
Acenaphthylene	26	100	0.93	0.34	37	0.59	0.64	0.96	1.1	1.3	2.0
Fluorene	26	100	0.33	0.14	44	0.17	0.23	0.28	0.42	0.53	0.67
Anthracene	26	100	0.12	0.063	55	0.044	0.06	0.10	0.17	0.21	0.26
1-Methylphenanthrene	26	100	0.12	0.052	42	0.074	0.092	0.11	0.15	0.19	0.29
2-Methylphenanthrene	26	92	0.18	0.1	57	0.11	0.11	0.15	0.19	0.31	0.58
3-Methylphenanthrene	26	100	0.28	0.17	61	0.16	0.17	0.24	0.29	0.40	0.96
Benz(a)anthracene	26	4	*	*	*	<LOD	<LOD	<LOD	<LOD	<LOD	0.02
Chrysene	26	27	*	*	*	<LOD	<LOD	<LOD	0.0068	0.012	0.017
Benzo(b)fluoranthene	26	0	*	*	*	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Benzo(k)fluoranthene	26	0	*	*	*	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Benzo(e)pyrene	26	0	*	*	*	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
DBA + ICDP[c]	26	0	*	*	*	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD

Table I-12 Continued

Chemical	n	% >LOD	Mean (mg/kg)	Standard Deviation (mg/kg)	% Relative Standard Deviation	10th Percentile (mg/kg)	25th Percentile (mg/kg)	50th Percentile (mg/kg)	75th Percentile (mg/kg)	90th Percentile (mg/kg)	Max (mg/kg)
Coronene	26	4	*	*	*	<LOD	<LOD	<LOD	<LOD	<LOD	0.010
Dibenzothiophene	26	100	0.11	0.043	38	0.073	0.090	0.095	0.13	0.17	0.25
2-Bromomethylnaphthalene	26	23	*	*	*	<LOD	<LOD	<LOD	<LOD	0.39	0.93
n-Butylbenzene	26	100	1.1	1.0	94	0.11	0.34	0.79	1.3	2.7	4.4
Dimethyl phthalate	26	85	0.037	0.058	160	<LOD	0.0078	0.02	0.032	0.15	0.24
Diisobutyl phthalate	26	100	0.15	0.4	270	-0.2	-0.034	0.11	0.28	0.33	1.8
Di-n-octyl phthalate	26	69	0.019	0.19	1000	<LOD	<LOD	-0.016	0.018	0.044	0.86
Bis(2,2,6,6-tetramethyl-4-piperidyl) sebacate	25	4	*	*	*	<LOD	<LOD	<LOD	<LOD	<LOD	0.56

[a] SVOC = semivolatile organic compound; °C = degrees Celsius; LOD = limit of detection; Max = maximum

[b] Sum15PAH = Sum of 15 of the 16 EPA 'priority' PAHs, including Acenaphthylene, Anthracene, Benz[a]anthracene, Benzo[a]pyrene, Benzo(b)fluoranthene, Benzo[ghi]perylene, Benzo(k)fluoranthene, Chrysene, Dibenz[a,h]anthracene, Fluoranthene, Fluorene, Indeno(1,2,3-cd)pyrene, Naphthalene, Phenanthrene, Pyrene

[c] DBA + ICDP = Sum of Dibenz[a,h]anthracene and Indeno(1,2,3-cd)pyrene

*Values reported only when % >LOD is ≥ 60%.

Table I-13. Summary Statistics for SVOC 25 °C Emission Factors for Tire Crumb Rubber Infill Collected at Synthetic Turf Fields[a]

Chemical	n	% >LOD	Mean (mg/kg)	Standard Deviation (mg/kg)	% Relative Standard Deviation	10th Percentile (mg/kg)	25th Percentile (mg/kg)	50th Percentile (mg/kg)	75th Percentile (mg/kg)	90th Percentile (mg/kg)	Max (mg/kg)
Phenanthrene	40	100	0.025	0.049	200	-0.015	-0.0003	0.018	0.043	0.093	0.15
Fluoranthene	40	28	*	*	*	<LOD	<LOD	<LOD	0.0034	0.0085	0.016
Pyrene	40	20	*	*	*	<LOD	<LOD	<LOD	<LOD	0.011	0.040
Benzo[a]pyrene	40	0	*	*	*	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Benzo[ghi]perylene	40	3	*	*	*	<LOD	<LOD	<LOD	<LOD	<LOD	0.020
Sum15PAH[b]	40	100	0.62	0.63	100	0.23	0.27	0.34	0.72	1.2	3.1
Benzothiazole	40	100	4.2	5.2	120	0.043	0.49	1.8	5.3	12	19
Dibutyl phthalate	40	100	-0.011	0.38	-3500	-0.50	-0.20	-0.044	0.20	0.54	0.83
Aniline	40	88	0.34	0.45	130	<LOD	-0.0026	0.16	0.53	1.1	1.5
4-tert-octylphenol	40	85	0.85	3.3	390	<LOD	-0.0007	0.082	0.23	0.43	16
Naphthalene	40	80	0.14	0.37	270	<LOD	-0.0082	0.018	0.19	0.46	2.0
1-Methylnaphthalene	40	100	0.034	0.090	260	-0.033	-0.0055	0.019	0.034	0.098	0.49
2-Methylnaphthalene	40	100	0.064	0.17	270	-0.056	-0.0099	0.018	0.065	0.22	0.75
Acenaphthylene	40	15	*	*	*	<LOD	<LOD	<LOD	<LOD	0.022	0.088
Fluorene	40	98	0.011	0.019	180	-0.01	-0.0013	0.008	0.021	0.032	0.084
Anthracene	40	13	*	*	*	<LOD	<LOD	<LOD	<LOD	0.0071	0.014
1-Methylphenanthrene	40	18	*	*	*	<LOD	<LOD	<LOD	<LOD	0.0067	0.012
2-Methylphenanthrene	40	38	*	*	*	<LOD	<LOD	<LOD	0.0093	0.016	0.035
3-Methylphenanthrene	40	38	*	*	*	<LOD	<LOD	<LOD	0.013	0.020	0.033
Benz(a)anthracene	40	5	*	*	*	<LOD	<LOD	<LOD	<LOD	<LOD	0.084
Chrysene	40	0	*	*	*	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Benzo(b)fluoranthene	40	3	*	*	*	<LOD	<LOD	<LOD	<LOD	<LOD	0.028
Benzo(k)fluoranthene	40	0	*	*	*	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Benzo(e)pyrene	40	0	*	*	*	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD

Table I-13 Continued

Chemical	n	% >LOD	Mean (mg/kg)	Standard Deviation (mg/kg)	% Relative Standard Deviation	10th Percentile (mg/kg)	25th Percentile (mg/kg)	50th Percentile (mg/kg)	75th Percentile (mg/kg)	90th Percentile (mg/kg)	Max (mg/kg)
DBA + ICDP[c]	40	0	*	*	*	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Coronene	40	0	*	*	*	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Dibenzothiophene	40	28	*	*	*	<LOD	<LOD	<LOD	0.0055	0.0093	0.014
2-Bromomethylnaphthalene	40	10	*	*	*	<LOD	<LOD	<LOD	<LOD	0.014	0.049
n-Butylbenzene	40	95	0.019	0.12	630	-0.025	-0.0083	-0.0025	0.014	0.035	0.74
Dimethyl phthalate	40	45	*	*	*	<LOD	<LOD	<LOD	0.0027	0.011	0.088
Diisobutyl phthalate	40	100	0.014	0.24	1700	-0.22	-0.15	-0.025	0.15	0.35	0.65
Di-n-octyl phthalate	40	45	*	*	*	<LOD	<LOD	<LOD	0.019	0.040	0.36
Bis(2,2,6,6-tetramethyl-4-piperidyl) sebacate	39	3	*	*	*	<LOD	<LOD	<LOD	<LOD	<LOD	0.41

[a] SVOC = semivolatile organic compound; °C = degrees Celsius; LOD = limit of detection; Max = maximum

[b] Sum15PAH = Sum of 15 of the 16 EPA 'priority' PAHs, including Acenaphthylene, Anthracene, Benz[a]anthracene, Benzo[a]pyrene, Benzo(b)fluoranthene, Benzo[ghi]perylene, Benzo(k)fluoranthene, Chrysene, Dibenz[a,h]anthracene, Fluoranthene, Fluorene, Indeno(1,2,3-cd)pyrene, Naphthalene, Phenanthrene, Pyrene

[c] DBA + ICDP = Sum of Dibenz[a,h]anthracene and Indeno(1,2,3-cd)pyrene

*Values reported only when % >LOD is ≥ 60%.

Table I-14. Summary Statistics for SVOC 60 °C Emission Factors for Tire Crumb Rubber Infill Collected at Synthetic Turf Fields[a]

Chemical	n	% >LOD	Mean (mg/kg)	Standard Deviation (mg/kg)	% Relative Standard Deviation	10th Percentile (mg/kg)	25th Percentile (mg/kg)	50th Percentile (mg/kg)	75th Percentile (mg/kg)	90th Percentile (mg/kg)	Max (mg/kg)
Phenanthrene	40	100	0.58	0.71	120	0.035	0.069	0.29	0.89	1.4	3.1
Fluoranthene	40	98	0.16	0.11	73	0.046	0.068	0.12	0.23	0.33	0.46
Pyrene	40	98	0.29	0.21	73	0.083	0.15	0.22	0.40	0.62	0.89
Benzo[a]pyrene	40	0	*	*	*	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Benzo[ghi]perylene	40	0	*	*	*	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Sum15PAH[b]	40	100	2.0	1.9	93	0.55	0.70	1.5	2.7	3.7	9.4
Benzothiazole	40	100	34	50	150	1.9	3.1	18	34	120	220
Dibutyl phthalate	40	100	0.14	0.41	290	-0.30	-0.15	0.073	0.38	0.63	1.5
Aniline	40	100	3.5	5.1	150	0.12	0.26	0.81	3.8	11	22
4-tert-octylphenol	40	98	5.8	5.5	94	0.50	1.2	5.1	9.1	14	21
Naphthalene	40	98	-0.14	0.56	-410	-1.1	-0.086	0.021	0.087	0.21	1.6
1-Methylnaphthalene	40	100	0.24	0.63	260	-0.027	0.0068	0.022	0.21	0.63	3.6
2-Methylnaphthalene	40	100	0.46	1.3	280	-0.055	0.013	0.043	0.30	1.0	6.4
Acenaphthylene	40	68	0.10	0.18	180	<LOD	<LOD	0.037	0.10	0.24	0.97
Fluorene	40	100	0.19	0.35	190	-0.0005	0.0085	0.056	0.25	0.42	1.9
Anthracene	40	53	*	*	*	<LOD	<LOD	0.053	0.13	0.22	1.2
1-Methylphenanthrene	40	98	0.14	0.13	91	0.029	0.038	0.10	0.23	0.31	0.57
2-Methylphenanthrene	40	90	0.23	0.28	120	0.025	0.045	0.11	0.34	0.59	1.2
3-Methylphenanthrene	40	90	0.37	0.44	120	0.041	0.075	0.20	0.53	0.92	1.8
Benz(a)anthracene	40	3	*	*	*	<LOD	<LOD	<LOD	<LOD	<LOD	0.057
Chrysene	40	30	*	*	*	<LOD	<LOD	<LOD	0.011	0.017	0.082
Benzo(b)fluoranthene	40	0	*	*	*	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Benzo(k)fluoranthene	40	3	*	*	*	<LOD	<LOD	<LOD	<LOD	<LOD	0.023
Benzo(e)pyrene	40	0	*	*	*	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
DBA + ICDP[c]	40	0	*	*	*	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD

Table I-14 Continued

Chemical	n	% >LOD	Mean (mg/kg)	Standard Deviation (mg/kg)	% Relative Standard Deviation	10th Percentile (mg/kg)	25th Percentile (mg/kg)	50th Percentile (mg/kg)	75th Percentile (mg/kg)	90th Percentile (mg/kg)	Max (mg/kg)
Coronene	40	0	*	*	*	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Dibenzothiophene	40	88	0.087	0.12	130	<LOD	0.0082	0.039	0.15	0.19	0.52
2-Bromomethylnaphthalene	40	23	*	*	*	<LOD	<LOD	<LOD	<LOD	0.14	0.41
n-Butylbenzene	40	95	-0.0037	0.027	-740	-0.030	-0.014	-0.0031	0.0058	0.018	0.074
Dimethyl phthalate	40	65	0.016	0.027	170	<LOD	<LOD	0.0053	0.028	0.056	0.11
Diisobutyl phthalate	40	100	0.11	0.31	280	-0.26	-0.095	0.082	0.31	0.49	1.0
Di-n-octyl phthalate	40	55	*	*	*	<LOD	<LOD	-0.0026	0.015	0.064	0.50
Bis(2,2,6,6-tetramethyl-4-piperidyl) sebacate	40	0	*	*	*	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD

[a] SVOC = semivolatile organic compound; °C = degrees Celsius; LOD = limit of detection; Max = maximum

[b] Sum15 PAH = Sum of 15 of the 16 EPA 'priority' PAHs, including Acenaphthylene, Anthracene, Benz[a]anthracene, Benzo[a]pyrene, Benzo(b)fluoranthene, Benzo[ghi]perylene, Benzo(k)fluoranthene, Chrysene, Dibenz[a,h]anthracene, Fluoranthene, Fluorene, Indeno(1,2,3-cd)pyrene, Naphthalene, Phenanthrene, Pyrene

[c] DBA + ICDP = Sum of Dibenz[a,h]anthracene and Indeno(1,2,3-cd)pyrene

*Values reported only when % >LOD is ≥ 60%.

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Appendix J

Dynamic Chamber Emissions Measurements

Time Series Test Results

J.1 Chamber Emission Time Series Tests

J.1.1 Purpose

Determine VOC, formaldehyde, and SVOC emission factor profiles over a 48-hour period in tire crumb rubber dynamic emissions tests performed at 25 ° and 60 °C.

J.1.2 Materials and Experiments

Number of Tire Crumb Rubber Samples = 2

- 1 recycling plant tire crumb rubber sample
- 1 relatively new synthetic turf field tire crumb rubber infill sample
- 15 g of tire crumb rubber used in the small chamber tests for VOCs and formaldehyde
- 10 g tire crumb rubber used for each micro chamber test for SVOCs

Chamber Emission Experiments

- VOC/Formaldehyde recycling plant 25 °C - Small chamber
- VOC/Formaldehyde recycling plant 60 °C - Small chamber
- VOC/Formaldehyde synthetic turf field 25 °C - Small chamber
- VOC/Formaldehyde synthetic turf field 60 °C - Small chamber
- SVOC recycling plant 25 °C - Micro chamber
- SVOC recycling plant 60 °C - Micro chamber
- SVOC synthetic turf field 25 °C - Micro chamber
- SVOC synthetic turf field 60 °C - Micro chamber

Chamber setup and sampling followed the same procedures as those used for all dynamic chamber emission experiments. The only differences included addition of sampling time points prior to the usual 24-hour collection time and extending the chamber experiment time for collection of samples at a 48-hour time point.

J.1.3 Sampling Schedule

Sampling schedules are described in Table J-1 for the small chamber tests for VOCs and formaldehyde, and in Table J-2 for the micro chamber tests for SVOCs.

J.1.4 Chamber Time Series Test Measurement Results

The chamber emission time series test results are shown in Tables J-3 through J-6 for VOCs and formaldehyde. Time series test results are shown graphically for selected chemicals in Figures J-1 through J-8.

The chamber emission time series test results are shown in Tables J-7 through J-10 for SVOCs. Time series test results are shown graphically for selected chemicals in Figures J-9 through J-16.

Table J-1. Sampling Schedule for One Small Chamber Test for VOCs and Formaldehyde[a]

Sample Type	Elapsed Time (hours)
Background for VOCs	-71.50
Background for formaldehyde	-71.25
Tire crumb rubber sample placed into chamber	0
VOC Sample	1.0
Formaldehyde Sample	1.0
VOC Sample	2.5
Formaldehyde Sample	2.5
VOC Sample	5.0
Formaldehyde Sample	5.0
VOC Sample	8.0
Formaldehyde Sample	8.0
VOC Sample	24.0
Formaldehyde Sample	24.0
VOC Sample	48.0
Formaldehyde Sample	48.0

[a] VOC = volatile organic compound

Table J-2. Sampling Schedule for One Micro-Chamber Test for SVOCs[a]

Sample Type	Elapsed Time (hours)
Background for SVOCs	-70.5
Tire crumb rubber sample placed into chamber	0
SVOC Sample	1.5
SVOC Sample	5.5
SVOC Sample	9.0
SVOC Sample	24.0
SVOC Sample	48.0

[a] SVOC = semivolatile organic compound

Table J-3. VOC 25 °C Chamber Emission Factor Time Series Test Results for Tire Crumb Rubber from a Tire Recycling Plant[a]

Chemical	Emission Factor – 1 Hr in Test Chamber (ng/g/h)	Emission Factor – 2.5 Hr in Test Chamber (ng/g/h)	Emission Factor – 5 Hr in Test Chamber (ng/g/h)	Emission Factor – 8 Hr in Test Chamber (ng/g/h)	Emission Factor – 24 Hr in Test Chamber (ng/g/h)	Emission Factor – 48 Hr in Test Chamber (ng/g/h)
Formaldehyde	12	12	8.8	5.5	6.9	3.8
Metyl isobutyl ketone	NR	199	153	78	22	14
Benzothiazole	NR	150	150	154	146	136
1,3-Butadiene	NR	-0.077	-0.076	-0.076	-0.076	-0.075
Styrene	NR	5.7	3.0	1.5	0.14	0.062
Benzene	NR	0.59	0.065	0.045	-0.027	0.085
Toluene	NR	6.2	1.8	0.72	0.13	0.27
Ethylbenzene	NR	1.5	0.62	0.26	0.022	0.033
m/p-Xylene	NR	22	10	4.7	0.31	0.16
o-Xylene	NR	2.6	1.3	0.68	0.058	0.029
SumBTEX[b]	NR	33	14	6.4	0.49	0.58
trans-2-Butene	NR	0.038	0.038	0.038	0.021	0.029
cis-2-Butene	NR	0.040	0.029	0.032	0.019	0.019
4-Ethyltoluene	NR	2.2	1.4	0.90	0.093	0.025
1,3,5-Trimethylbenzene	NR	3.7	2.6	1.8	0.299	0.054
1,1-Dichloroethene	NR	-0.0018	-0.0018	-0.0018	-0.0018	-0.0018
1,1-Dichloroethane	NR	0.00055	0.00055	0.00055	0.00054	0.00054
cis-1,2-Dichloroethene	NR	0.013	0.013	0.013	0.012	0.012
1,2-Dichloroethane	NR	0	0	0	0	0
Carbon Tetrachloride	NR	0.099	-0.017	-0.00569	-0.00566	-0.011
1,2-Dichloropropane	NR	-0.00026	-0.00026	-0.00026	-0.00026	-0.00025
Trichloroethylene	NR	1.9	0.70	0.20	0.086	0.039
Tetrachloroethylene	NR	5.0	1.9	0.70	0.089	0.045
Chlorobenzene	NR	-0.077	-0.077	0.0060	-0.0059	-0.0042
m-Dichlorobenzene	NR	0.014	0.037	0.015	0.026	-0.067
p-Dichlorobenzene	NR	1.8	1.4	1.0	0.27	0.067
o-Dichlorobenzene	NR	0.0037	0.029	0.0060	0.014	-0.070
Trichlorofluoromethane (Freon 11)	NR	0.18	-0.091	-0.13	-0.11	-0.11
Dichlorodifluoromethane (Freon 12)	NR	0.089	0.060	0.071	0.057	0.046
Trichlorotrifluoroethane (Freon 113)	NR	0.21	-0.051	-0.051	-0.051	-0.051

[a] VOC = volatile organic compound; °C = degrees Celsius; NR = not reported

[b] SumBTEX = Sum of benzene, toluene, ethylbenzene, m/p-xylene, and o-xylene

Table J-4. VOC 60 °C Chamber Emission Factor Time Series Test Results for Tire Crumb Rubber from a Tire Recycling Plant[a]

Chemical	Emission Factor – 1 Hr in Test Chamber (ng/g/h)	Emission Factor – 2.5 Hr in Test Chamber (ng/g/h)	Emission Factor – 5 Hr in Test Chamber (ng/g/h)	Emission Factor – 8 Hr in Test Chamber (ng/g/h)	Emission Factor – 24 Hr in Test Chamber (ng/g/h)	Emission Factor – 48 Hr in Test Chamber (ng/g/h)
Formaldehyde	48	126	84	73	44	31
Metyl isobutyl ketone	229	188	164	149	135	129
Benzothiazole	221	242	246	245	220	196
1,3-Butadiene	-0.086	-0.084	-0.083	-0.084	-0.083	-0.087
Styrene	12	13	3.6	2.0	0.96	0.56
Benzene	1.4	1.6	1.0	0.28	0.15	-0.0015
Toluene	16	5.0	2.3	0.98	0.33	0.36
Ethylbenzene	3.4	1.5	0.39	-0.080	-0.15	-0.22
m/p-Xylene	35	22	5.4	2.2	0.97	0.36
o-Xylene	4.1	1.9	-0.033	-0.47	-0.61	-0.74
SumBTEX[b]	60	32	9.1	2.9	0.70	-0.23
trans-2-Butene	-0.099	-0.23	0.077	-0.19	-0.24	-0.34
cis-2-Butene	-0.099	-0.22	0.013	-0.19	-0.20	-0.31
4-Ethyltoluene	5.2	3.7	1.0	0.12	-0.027	-0.050
1,3,5-Trimethylbenzene	7.8	6.8	2.1	0.42	0.054	0.016
1,1-Dichloroethene	-0.0015	-0.0015	-0.0015	-0.0015	-0.0015	-0.0015
1,1-Dichloroethane	-0.00038	-0.00037	-0.00037	-0.00037	-0.00037	-0.00039
cis-1,2-Dichloroethene	0.0069	0.0067	0.0066	0.0067	0.0066	0.0070
1,2-Dichloroethane	0	0	0	0	0	0
1,1,1-Trichloroethane	-0.084	0.0012	0.0012	0.0012	0.0012	0.0013
Carbon Tetrachloride	0.50	0.15	-0.035	-0.031	-0.035	-0.035
1,2-Dichloropropane	-0.00027	-0.00026	-0.00026	-0.00026	-0.00026	-0.00027
Trichloroethylene	6.1	4.1	2.0	0.85	0.28	0.15
Tetrachloroethylene	9.3	3.2	0.59	0.22	0.098	0.070
Chlorobenzene	-0.11	-0.11	-0.10	-0.10	-0.10	-0.11
m-Dichlorobenzene	0.018	0.014	0.019	0.010	0.013	0.0033
p-Dichlorobenzene	4.6	4.1	1.7	0.47	0.057	0.0049
o-Dichlorobenzene	0.047	0.037	0.025	0.0095	0.014	0.0054
Trichlorofluoromethane (Freon 11)	1.1	0.18	-0.0086	-0.014	-0.1585	-0.085
Dichlorodifluoromethane (Freon 12)	0.071	0.053	0.071	0.066	0.047	0.039
Trichlorotrifluoroethane (Freon 113)	1.3	0.14	0.033	0.052	0.022	-0.053

[a] VOC = volatile organic compound; °C = degrees Celsius

[b] SumBTEX = Sum of benzene, toluene, ethylbenzene, m/p-xylene, and o-xylene

Table J-5. VOC 25 °C Chamber Emission Factor Time Series Test Results for Tire Crumb Rubber Infill from a Synthetic Turf Field[a]

Chemical	Emission Factor – 1 Hr in Test Chamber (ng/g/h)	Emission Factor – 2.5 Hr in Test Chamber (ng/g/h)	Emission Factor – 5 Hr in Test Chamber (ng/g/h)	Emission Factor – 8 Hr in Test Chamber (ng/g/h)	Emission Factor – 24 Hr in Test Chamber (ng/g/h)	Emission Factor – 48 Hr in Test Chamber (ng/g/h)
Formaldehyde	9.4	0	0	0	2.5	0.80
Metyl isobutyl ketone	57	39	18	12	3.9	1.8
Benzothiazole	37	48	53	51	41	41
1,3-Butadiene	-0.033	-0.10	-0.049	-0.050	-0.100	-0.094
Styrene	0.34	0.21	0.12	0.080	-0.015	-0.028
Benzene	0.56	-0.066	0.17	0.16	0.27	-0.079
Toluene	1.9	0.54	0.14	0.16	0.036	0.059
Ethylbenzene	0.23	0.080	0.040	0.037	0.0081	0.0097
m/p-Xylene	0.98	0.46	0.26	0.14	0.051	0.052
o-Xylene	0.26	0.095	0.038	0.025	-0.00083	0.0060
SumBTEX[b]	3.9	1.1	0.65	0.52	0.36	0.048
trans-2-Butene	0.012	-0.019	-0.00581	-0.021	-0.020	-0.022
cis-2-Butene	0.011	-0.025	-0.010	-0.026	-0.025	-0.027
4-Ethyltoluene	0.10	0.034	0.0071	-0.0029	-0.0046	-0.017
1,3,5-Trimethylbenzene	0.089	0.021	-0.0077	-0.015	-0.01069	-0.031
1,1-Dichloroethene	-0.0018	-0.0018	-0.0018	-0.0018	-0.0018	-0.0018
1,1-Dichloroethane	0.00055	0.00055	0.00055	0.00055	0.00055	0.00055
cis-1,2-Dichloroethene	0.013	0.013	0.013	0.013	0.013	0.013
1,2-Dichloroethane	0	0	0	0	0	0
1,1,1-Trichloroethane	-0.11	0	0	0	0	0
Carbon Tetrachloride	0.33	0.15	0.13	-0.03296	0.12	0.16
1,2-Dichloropropane	0.00014	0.00014	0.00014	0.00014	0.00014	0.00014
Trichloroethylene	-0.024	-0.028	-0.03	-0.031	-0.028	-0.032
Tetrachloroethylene	0.092	0.021	-0.0031	-0.0073	-0.0074	-0.0095
Chlorobenzene	0.00079	-0.0066	0.0025	0.0097	0.013	-0.0027
m-Dichlorobenzene	-0.016	-0.027	-0.022	-0.024	-0.00030	-0.016
p-Dichlorobenzene	0.065	0.018	0.011	0.0027	0.0073	-0.00075
o-Dichlorobenzene	-0.027	-0.050	-0.056	-0.055	-0.0087	-0.053
Trichlorofluoromethane (Freon 11)	1.0	0.094	-0.12	-0.063	-0.15	0.039
Dichlorodifluoromethane (Freon 12)	-0.0072	-0.010	0.0091	0.0065	0.0033	0.0047
Trichlorotrifluoroethane (Freon 113)	0.63	0.13	0.015	0.0096	0.011	0.054

[a] VOC = volatile organic compound; °C = degrees Celsius

[b] SumBTEX = Sum of benzene, toluene, ethylbenzene, m/p-xylene, and o-xylene

Table J-6. VOC 60 °C Chamber Emission Factor Time Series Test Results for Tire Crumb Rubber Infill from a Synthetic Turf Field[a]

Chemical	Emission Factor – 1 Hr in Test Chamber (ng/g/h)	Emission Factor – 2.5 Hr in Test Chamber (ng/g/h)	Emission Factor – 5 Hr in Test Chamber (ng/g/h)	Emission Factor – 8 Hr in Test Chamber (ng/g/h)	Emission Factor – 24 Hr in Test Chamber (ng/g/h)	Emission Factor – 48 Hr in Test Chamber (ng/g/h)
Formaldehyde	8.2	14	16	40	11	13
Metyl isobutyl ketone	67	68	66	66	77	56
Benzothiazole	94	103	99	97	90	82
1,3-Butadiene	-0.057	-0.057	-0.057	-0.057	-0.057	-0.057
Styrene	0.48	0.64	0.40	0.40	0.18	0.076
Benzene	0.27	0.075	0.39	0.077	-0.10912	0.092
Toluene	2.3	0.60	0.11	0.055	-0.044	0.0096
Ethylbenzene	0.096	0.13	0.089	0.082	-0.14	-0.18
m/p-Xylene	0.58	1.5	1.7	1.4	0.53	0.10
o-Xylene	-0.16	1.1	1.3	0.97	-0.16	-0.61
SumBTEX[b]	3.1	3.4	3.6	2.6	0.076	-0.58
trans-2-Butene	-0.29	-0.23	-0.63	-0.28	-0.46	-0.31
cis-2-Butene	-0.27	-0.22	-0.12	-0.25	-0.41	-0.29
4-Ethyltoluene	0.17	0.059	-0.023	-0.051	-0.057	-0.066
1,3,5-Trimethylbenzene	0.20	0.096	0.039	-0.0033	-0.010	-0.015
1,1-Dichloroethene	-0.0015	-0.0015	-0.0015	-0.0015	-0.0015	-
1,1-Dichloroethane	-0.60	-0.00037	-0.00037	-0.00037	-0.00037	-0.00037
cis-1,2-Dichloroethene	0.0066	0.0066	0.0067	0.0067	0.0067	0.0067
1,2-Dichloroethane	-0.60	0	0	0	0	0
1,1,1-Trichloroethane	-0.098	0.0012	0.0012	0.0012	0.0012	0.0012
Carbon Tetrachloride	0.35	0.17	0.093	0.11	0.10	0.10
1,2-Dichloropropane	0.00013	0.00013	0.00013	0.00013	0.00013	0.00013
Trichloroethylene	0.0011	-0.014	-0.0055	-0.014	-0.016	-0.015
Tetrachloroethylene	0.12	0.015	-0.0040	-0.018	-0.023	-0.023
Chlorobenzene	0.0025	0.013	0.039	-0.076	0.0078	-0.076
m-Dichlorobenzene	0.0014	-0.026	0.027	-0.030	-0.030	-0.034
p-Dichlorobenzene	0.25	0.21	0.19	0.11	0.10	0.095
o-Dichlorobenzene	0.041	-0.033	0.058	-0.051	-0.036	-0.041
Trichlorofluoromethane (Freon 11)	1.1	0.20	-0.043	-0.025	0.0063	-0.10
Dichlorodifluoromethane (Freon 12)	0.016	0.0043	0.0095	0.012	0.0055	-0.0063
Trichlorotrifluoroethane (Freon 113)	0.69	0.14	0.011	0.024	0.011	0.023

[a] VOC = volatile organic compound; °C = degrees Celsius

[b] SumBTEX = Sum of benzene, toluene, ethylbenzene, m/p-xylene, and o-xylene

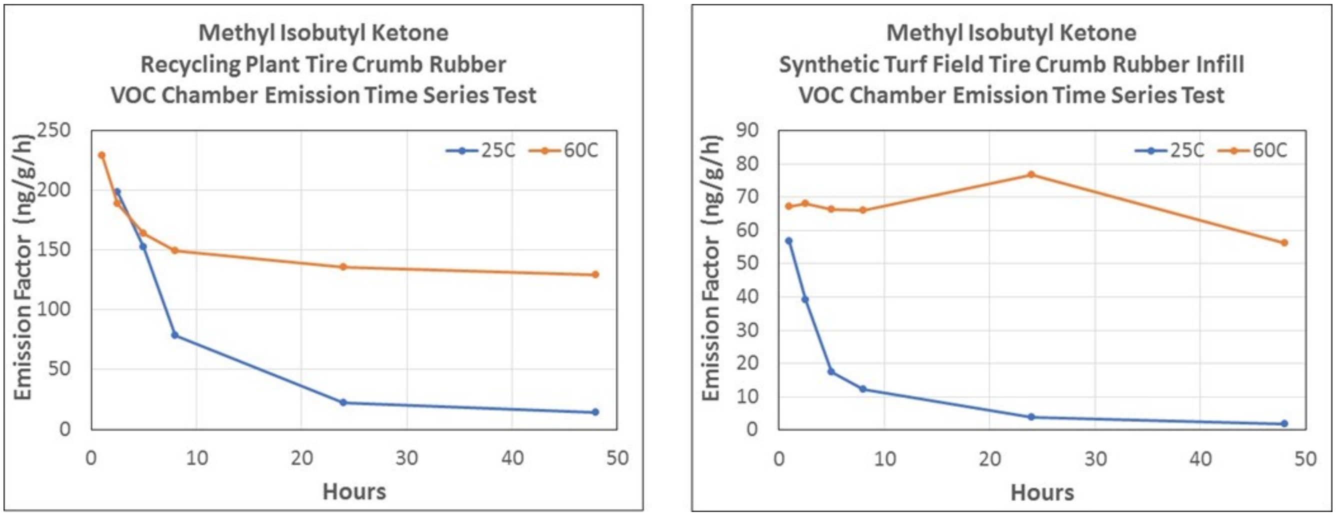


Figure J-1. Chamber emission factor time series test results for methyl isobutyl ketone from recycling plant tire crumb rubber (left) and synthetic turf field tire crumb rubber infill (right).[VOC = volatile organic compound; 25C = 25 degrees Celsius; 60C = 60 degrees Celsius]

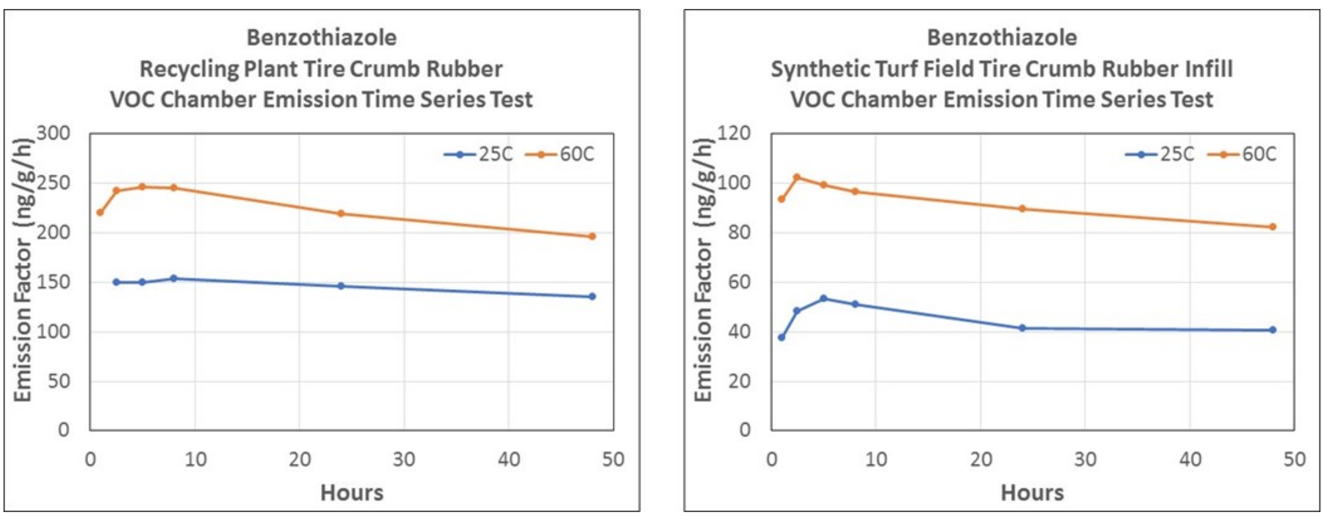


Figure J-2. Chamber emission factor time series test results for benzothiazole from recycling plant tire crumb rubber (left) and synthetic turf field tire crumb rubber infill (right). [VOC = volatile organic compound; 25C = 25 degrees Celsius; 60C = 60 degrees Celsius]

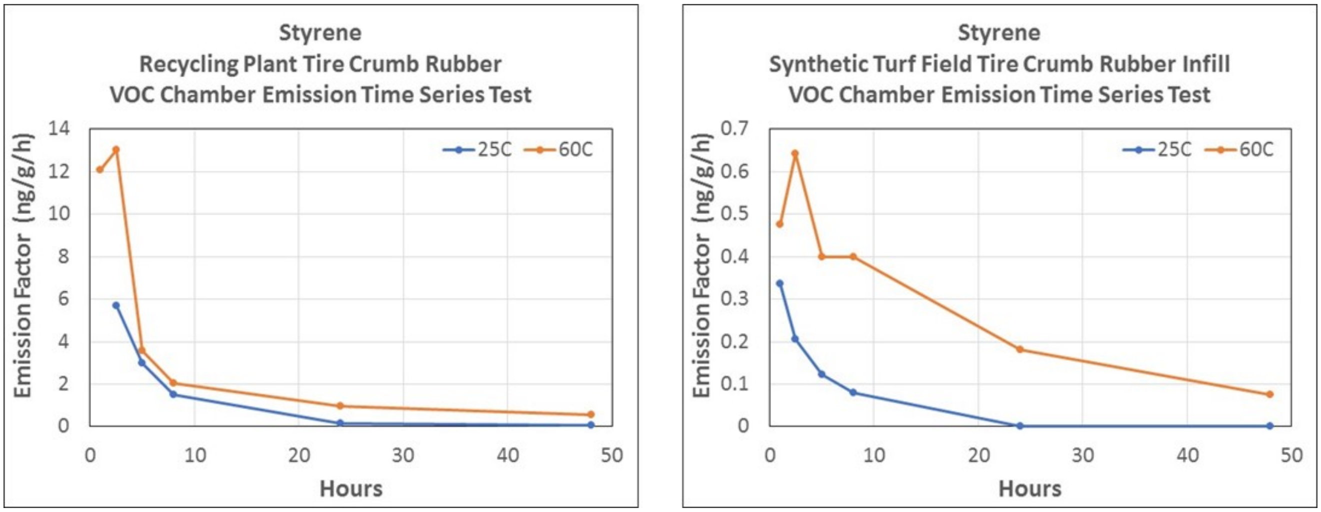


Figure J-3. Chamber emission factor time series test results for styrene from recycling plant tire crumb rubber (left) and synthetic turf field tire crumb rubber infill (right). [VOC = volatile organic compound; 25C = 25 degrees Celsius; 60C = 60 degrees Celsius]

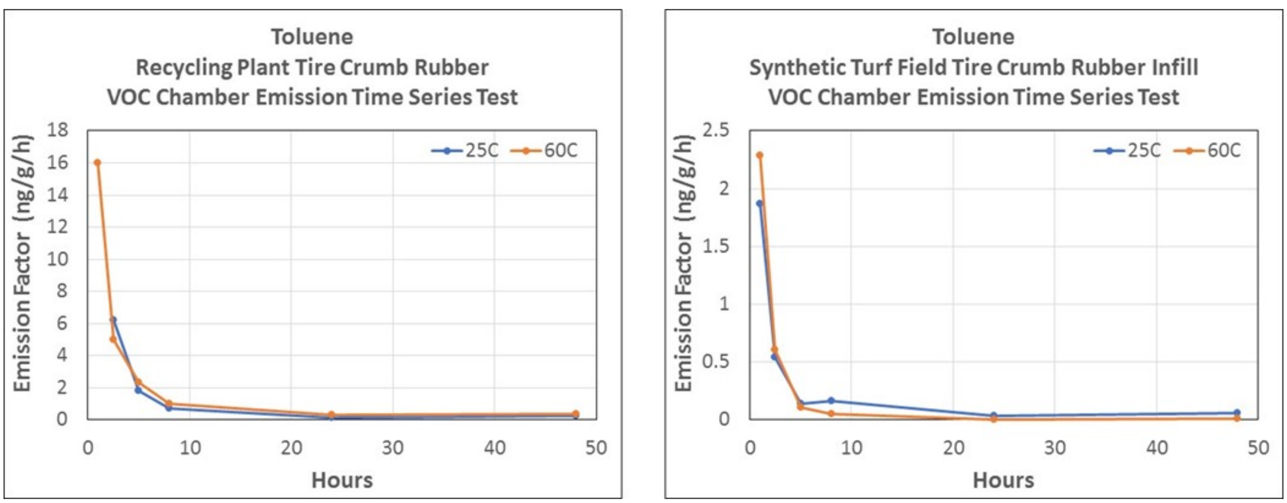


Figure J-4. Chamber emission factor time series test results for toluene from recycling plant tire crumb rubber (left) and synthetic turf field tire crumb rubber infill (right). [VOC = volatile organic compound; 25C = 25 degrees Celsius; 60C = 60 degrees Celsius]

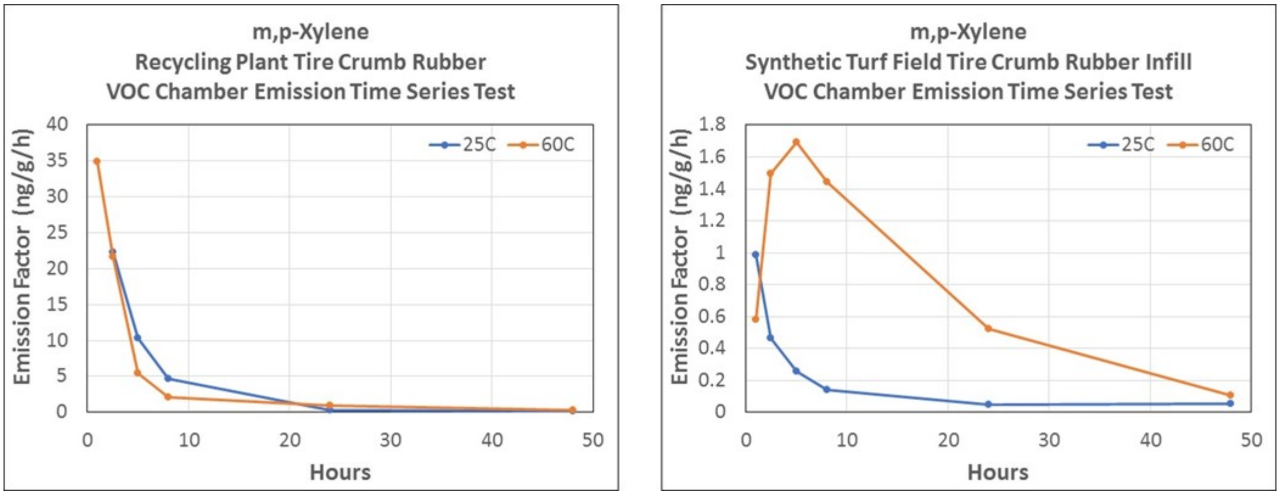


Figure J-5. Chamber emission factor time series test results for m/p-xylene from recycling plant tire crumb rubber (left) and synthetic turf field tire crumb rubber infill (right).[VOC = volatile organic compound; 25C = 25 degrees Celsius; 60C = 60 degrees Celsius]

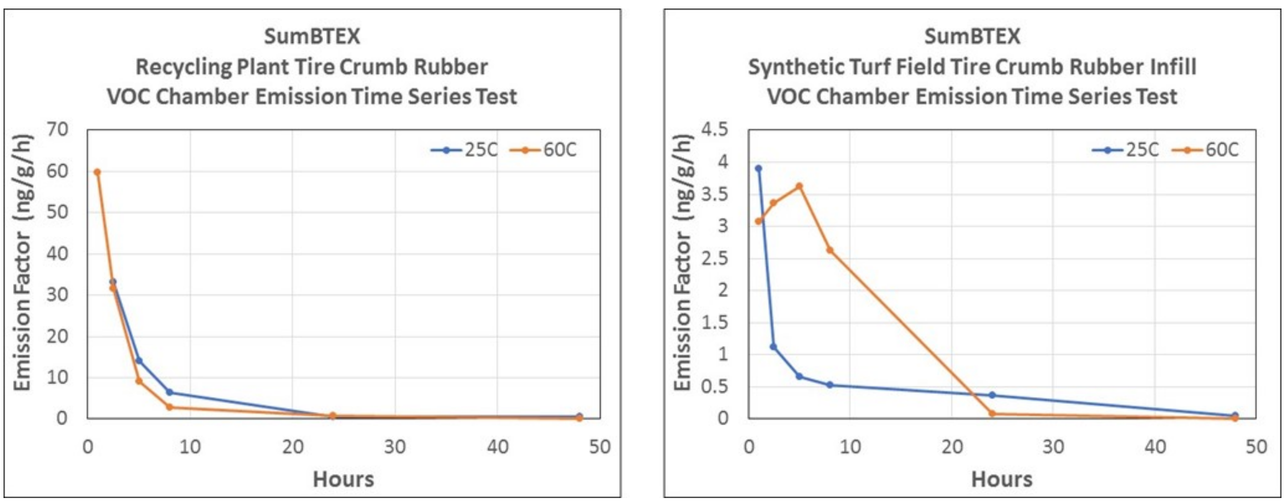
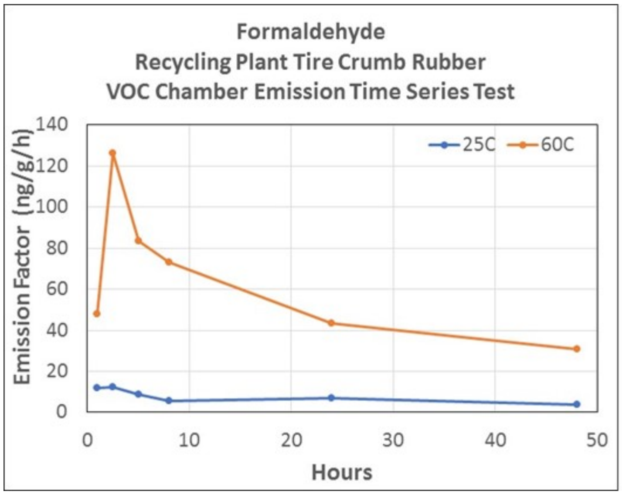


Figure J-6. Chamber emission factor time series test results for the sum of benzene, toluene, ethylbenzene, m/p-xyene, and o-xylene (SumBTEX) from recycling plant tire crumb rubber (left) and synthetic turf field tire crumb rubber infill (right). [VOC = volatile organic compound; 25C = 25 degrees Celsius; 60C = 60 degrees Celsius; SumBTEX = Sum of benzene, toluene, ethylbenzene, m/p-xylene, and o-xylene]



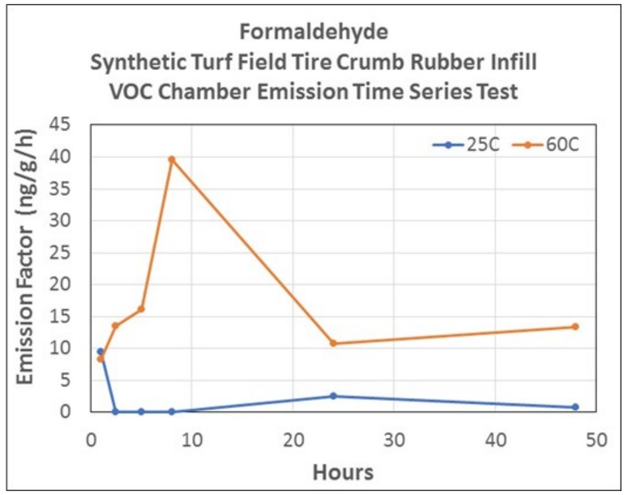


Figure J-7. Chamber emission factor time series test results for formaldehyde from recycling plant tire crumb rubber (left) and synthetic turf field tire crumb rubber infill (right). [VOC = volatile organic compound; 25C = 25 degrees Celsius; 60C = 60 degrees Celsius]

Table J-7. SVOC 25 °C Chamber Emission Factor Time Series Test Results for Tire Crumb Rubber Collected from a Tire Recycling Plant[a]

Chemical	Emission Factor – 2 Hr in Test Chamber (ng/g/h)	Emission Factor – 5.5 Hr in Test Chamber (ng/g/h)	Emission Factor – 9 Hr in Test Chamber (ng/g/h)	Emission Factor – 24 Hr in Test Chamber (ng/g/h)	Emission Factor – 48 Hr in Test Chamber (ng/g/h)
Phenanthrene	0.020	0.094	0.047	0.060	0.030
Fluoranthene	0.0051	0.0050	0.0017	0.0017	-0.0017
Pyrene	0.0067	0.0067	0.0067	0.0066	0.0033
Benzo[a]pyrene	0	0	0	0	0
Benzo[ghi]perylene	0	0	0.0034	0	0
Sum15PAH[b]	2.5	2.1	2.3	1.8	1.3
Benzothiazole	81	55	48	38	30
Dibutyl phthalate	0.71	0.36	0.29	0.30	0.21
Aniline	3.3	3.2	2.7	2.7	2.5
4-tert-octylphenol	0.018	0.14	0.055	0.26	0.31
Naphthalene	2.2	1.7	1.9	1.4	0.99
1-Methylnaphthalene	1.2	1.2	1.1	1.1	0.93
2-Methylnaphthalene	2.0	2.1	1.8	1.8	1.5
Acenaphthylene	0.067	0.070	0.063	0.069	0.063
Fluorene	0.025	0.035	0.039	0.028	0.022
Anthracene	-0.00084	0.0092	0.0059	0.0058	0.0025
1-Methylphenanthrene	0.0034	0.0034	0.0034	0.0033	0.0033
2-Methylphenanthrene	0.0034	0.0067	0.0034	0.0033	0.0033

Table J-7 Continued

Chemical	Emission Factor – 2 Hr in Test Chamber (ng/g/h)	Emission Factor – 5.5 Hr in Test Chamber (ng/g/h)	Emission Factor – 9 Hr in Test Chamber (ng/g/h)	Emission Factor – 24 Hr in Test Chamber (ng/g/h)	Emission Factor – 48 Hr in Test Chamber (ng/g/h)
3-Methylphenanthrene	0.0042	0.011	0.0042	0.0075	0.0042
Benz(a)anthracene	0	0	0	0	0
Chrysene	0	0	0	0	0
Benzo(b)fluoranthene	0	0	0	0	0
Benzo(k)fluoranthene	0	0	0	0	0
Benzo(e)pyrene	0	0	0	0	0
DBA + ICDP[c]	0	0	0	0	0
Coronene	0	0	0.0034	0	0
Dibenzothiophene	0.0025	0.0059	0.0059	0.0058	0.0025
n-Butylbenzene	-0.078	-0.20	-0.22	-0.37	-0.46
Dimethyl phthalate	0.0042	0.00084	0.0076	0.0042	0.00083
Diisobutyl phthalate	0.23	0.59	0.18	0.26	0.14
Di-n-octyl phthalate	0.15	-0.013	0.014	-0.012	0.011

[a] SVOC = semivolatile organic compound; °C = degrees Celsius

[b] Sum15PAH = Sum of 15 of the 16 EPA 'priority' PAHs, including Acenaphthylene, Anthracene, Benz[a]anthracene, Benzo[a]pyrene, Benzo(b)fluoranthene, Benzo[ghi]perylene, Benzo(k)fluoranthene, Chrysene, Dibenz[a,h]anthracene, Fluoranthene, Fluorene, Indeno(1,2,3-cd)pyrene, Naphthalene, Phenanthrene, Pyrene

[c] DBA + ICDP = Sum of Dibenz[a,h]anthracene and Indeno(1,2,3-cd)pyrene

Table J-8. SVOC 60 °C Chamber Emission Factor Time Series Test Results for Tire Crumb Rubber Collected from a Tire Recycling Plant[a]

Chemical	Emission Factor – 2 Hr in Test Chamber (ng/g/h)	Emission Factor – 5.5 Hr in Test Chamber (ng/g/h)	Emission Factor – 9 Hr in Test Chamber (ng/g/h)	Emission Factor – 24 Hr in Test Chamber (ng/g/h)	Emission Factor – 48 Hr in Test Chamber (ng/g/h)
Phenanthrene	1.2	1.1	1.1	1.1	1.1
Fluoranthene	0.18	0.19	0.18	0.17	0.17
Pyrene	0.44	0.44	0.43	0.42	0.40
Benzo[a]pyrene	0	0	0	0	0
Benzo[ghi]perylene	0	0	0	0	0
Sum15PAH[b]	26	22	21	14	9.4
Benzothiazole	1987	2128	1019	NR	622
Dibutyl phthalate	0.33	0.40	0.56	0.16	0.81
Aniline	51	55	38	42	25
4-tert-octylphenol	20	20	19	19	13
Naphthalene	22	18	17	10	5.6
1-Methylnaphthalene	18	18	18	15	11
2-Methylnaphthalene	56	67	39	21	15
Acenaphthylene	1.3	1.2	1.2	1.1	1.0
Fluorene	0.69	0.67	0.65	0.63	0.60
Anthracene	0.24	0.22	0.14	0.20	0.19
1-Methylphenanthrene	0.16	0.15	0.15	0.15	0.14
2-Methylphenanthrene	0.22	0.21	0.20	0.19	0.19
3-Methylphenanthrene	0.36	0.34	0.33	0.31	0.32
Benz(a)anthracene	0	0	0	0	0
Chrysene	0.010	0.010	0.010	0.0100	0.0099
Benzo(b)fluoranthene	0	0	0	0	0
Benzo(k)fluoranthene	0	0	0	0	0
Benzo(e)pyrene	0	0	0	0	0
DBA + ICDP[c]	0	0	0	0	0
Coronene	0	0	0	0	0
Dibenzothiophene	0.13	0.13	0.13	0.13	0.13
n-Butylbenzene	6.1	4.1	2.1	-0.18	-0.71
Dimethyl phthalate	0.021	0.021	0.018	0.017	0.017
Diisobutyl phthalate	0.36	0.49	1.2	0.49	0.66
Di-n-octyl phthalate	-0.013	0.024	-0.013	0.004	-0.012

[a] SVOC = semivolatile organic compound; °C = degrees Celsius; NR = not reported

[b] Sum15PAH = Sum of 15 of the 16 EPA 'priority' PAHs, including Acenaphthylene, Anthracene, Benz[a]anthracene, Benzo[a]pyrene, Benzo(b)fluoranthene, Benzo[ghi]perylene, Benzo(k)fluoranthene, Chrysene, Dibenz[a,h]anthracene, Fluoranthene, Fluorene, Indeno(1,2,3-cd)pyrene, Naphthalene, Phenanthrene, Pyrene

[c] DBA + ICDP = Sum of Dibenz[a,h]anthracene and Indeno(1,2,3-cd)pyrene

Table J-9. SVOC 25 °C Chamber Emission Factor Time Series Test Results for Tire Crumb Rubber Infill Collected from a Synthetic Turf Field[a]

Chemical	Emission Factor – 2 Hr in Test Chamber (ng/g/h)	Emission Factor – 5.5 Hr in Test Chamber (ng/g/h)	Emission Factor – 9 Hr in Test Chamber (ng/g/h)	Emission Factor – 24 Hr in Test Chamber (ng/g/h)	Emission Factor – 48 Hr in Test Chamber (ng/g/h)
Phenanthrene	0	0.010	-0.0034	0.0033	0.070
Fluoranthene	-0.0017	0.0017	0.0017	-0.0017	-0.0017
Pyrene	0	0.0034	0.0034	0.0033	0.0033
Benzo[a]pyrene	0	0	0	0	0
Benzo[ghi]perylene	0	0	0	0	0
Sum15PAH[b]	0.26	0.31	0.28	0.26	0.35
Benzothiazole	7.6	6.7	6.8	6.5	5.5
Dibutyl phthalate	0.12	-0.021	0.28	0.27	0.59
Aniline	0.81	0.78	0.56	0.74	0.55
4-tert-octylphenol	0.068	0.014	-0.0025	0.057	0.0075
Naphthalene	0.014	0.051	0.031	0.027	0.037
1-Methylnaphthalene	0.019	0.013	0.019	0.012	0.0091
2-Methylnaphthalene	0.029	0.022	0.032	0.022	0.015
Acenaphthylene	0.013	0.013	0.013	0.0091	0.0091
Fluorene	0.0050	0.0050	0.0050	-0.0017	0.0083
Anthracene	-0.00084	-0.00084	-0.00084	-0.00083	-0.00083
1-Methylphenanthrene	0.0034	0	0	0.0033	0.0033
2-Methylphenanthrene	0	0	0	0	0
3-Methylphenanthrene	0.00084	0.00084	0.00084	0.00083	0.00083
Benz(a)anthracene	0	0	0	0	0
Chrysene	0	-0.0034	0	0	-0.0033
Benzo(b)fluoranthene	0	0	0	0	0
Benzo(k)fluoranthene	0	0	0	0	0
Benzo(e)pyrene	0	0	0	0	0
DBA + ICDP[c]	0	0	0	0	0
Coronene	0	0	0	0	0
Dibenzothiophene	-0.00084	-0.00084	0.0025	-0.00083	0.0025
n-Butylbenzene	-0.72	-0.75	-0.73	-0.76	-0.74
Dimethyl phthalate	0.00084	0.00084	0.0042	0.00083	0.00083
Diisobutyl phthalate	0.028	-0.11	0.24	0.27	0.56
Di-n-octyl phthalate	0.028	-0.013	-0.013	-0.012	0.011

[a] SVOC = semivolatile organic compound; °C = degrees Celsius

[b] Sum15PAH = Sum of 15 of the 16 EPA 'priority' PAHs, including Acenaphthylene, Anthracene, Benz[a]anthracene, Benzo[a]pyrene, Benzo(b)fluoranthene, Benzo[ghi]perylene, Benzo(k)fluoranthene, Chrysene, Dibenz[a,h]anthracene, Fluoranthene, Fluorene, Indeno(1,2,3-cd)pyrene, Naphthalene, Phenanthrene, Pyrene

[c] DBA + ICDP = Sum of Dibenz[a,h]anthracene and Indeno(1,2,3-cd)pyrene

Table J-10. SVOC 60 °C Chamber Emission Factor Time Series Test Results for Tire Crumb Rubber Infill Collected from a Synthetic Turf Field[a]

Chemical	Emission Factor 2 Hr in Test Chamber (ng/g/h)	Emission Factor 5.5 Hr in Test Chamber (ng/g/h)	Emission Factor 9 Hr in Test Chamber (ng/g/h)	Emission Factor 24 Hr in Test Chamber (ng/g/h)	Emission Factor 48 Hr in Test Chamber (ng/g/h)
Phenanthrene	0.28	0.27	0.31	0.26	0.27
Fluoranthene	0.11	0.11	0.10	0.11	0.11
Pyrene	0.29	0.29	0.31	0.30	0.29
Benzo[a]pyrene	0	0	0	0	0
Benzo[ghi]perylene	0	0	0	0	0
Sum15PAH[b]	1.2	1.3	1.4	1.3	1.2
Benzothiazole	82	125	54	74	80
Dibutyl phthalate	0.18	0.01	0.42	0.39	0.27
Aniline	6.9	5.0	4.4	3.5	4.3
4-tert-octylphenol	8.4	5.1	7.2	6.8	6.1
Naphthalene	0.014	0.14	0.099	0.11	0.068
1-Methylnaphthalene	0.20	0.16	0.16	0.16	0.099
2-Methylnaphthalene	0.24	0.21	0.22	0.21	0.13
Acenaphthylene	0.23	0.19	0.22	0.18	0.18
Fluorene	0.069	0.059	0.079	0.061	0.062
Anthracene	0.020	0.023	0.026	0.019	0.019
1-Methylphenanthrene	0.083	0.074	0.074	0.086	0.080
2-Methylphenanthrene	0.091	0.091	0.094	0.090	0.083
3-Methylphenanthrene	0.15	0.14	0.15	0.14	0.14
Benz(a)anthracene	0	0	0	0	0
Chrysene	0	0.0034	0.0034	0.0033	0.0033
Benzo(b)fluoranthene	0	0	0	0	0
Benzo(k)fluoranthene	0	0	0	0	0
Benzo(e)pyrene	0	0	0	0	0
DBA + ICDP[c]	0	0	0	0	0
Coronene	0	0	0	0	0
Dibenzothiophene	0.038	0.036	0.040	0.036	0.036
n-Butylbenzene	-0.70	-0.73	-0.75	-0.73	-0.73
Dimethyl phthalate	-0.0025	0.00084	0.0042	0.00083	0.0042
Diisobutyl phthalate	0.20	0.041	0.75	0.56	0.24
Di-n-octyl phthalate	-0.013	0.018	0.0076	0.0075	-0.013

[a] SVOC = semivolatile organic compound; °C = degrees Celsius

[b] Sum15PAH = Sum of 15 of the 16 EPA 'priority' PAHs, including Acenaphthylene, Anthracene, Benz[a]anthracene, Benzo[a]pyrene, Benzo(b)fluoranthene, Benzo[ghi]perylene, Benzo(k)fluoranthene, Chrysene, Dibenz[a,h]anthracene, Fluoranthene, Fluorene, Indeno(1,2,3-cd)pyrene, Naphthalene, Phenanthrene, Pyrene

[c] DBA + ICDP = Sum of Dibenz[a,h]anthracene and Indeno(1,2,3-cd)pyrene

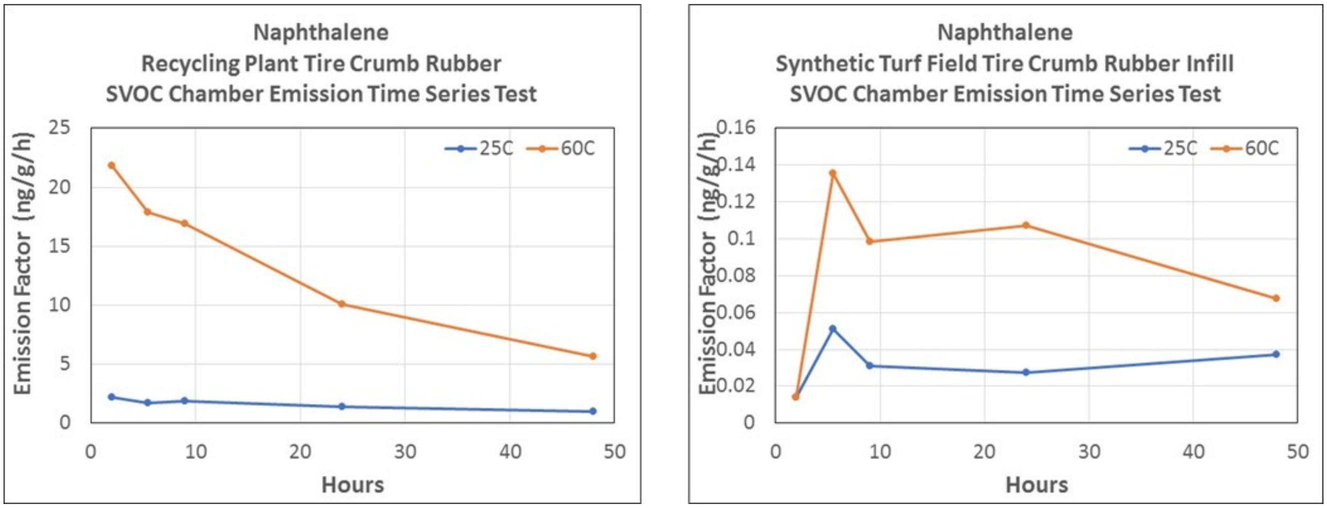


Figure J-8. Chamber emission factor time series test results for naphthalene from recycling plant tire crumb rubber (left) and synthetic turf field tire crumb rubber infill (right). [SVOC = semivolatile organic compound; 25C = 25 degrees Celsius; 60C = 60 degrees Celsius]

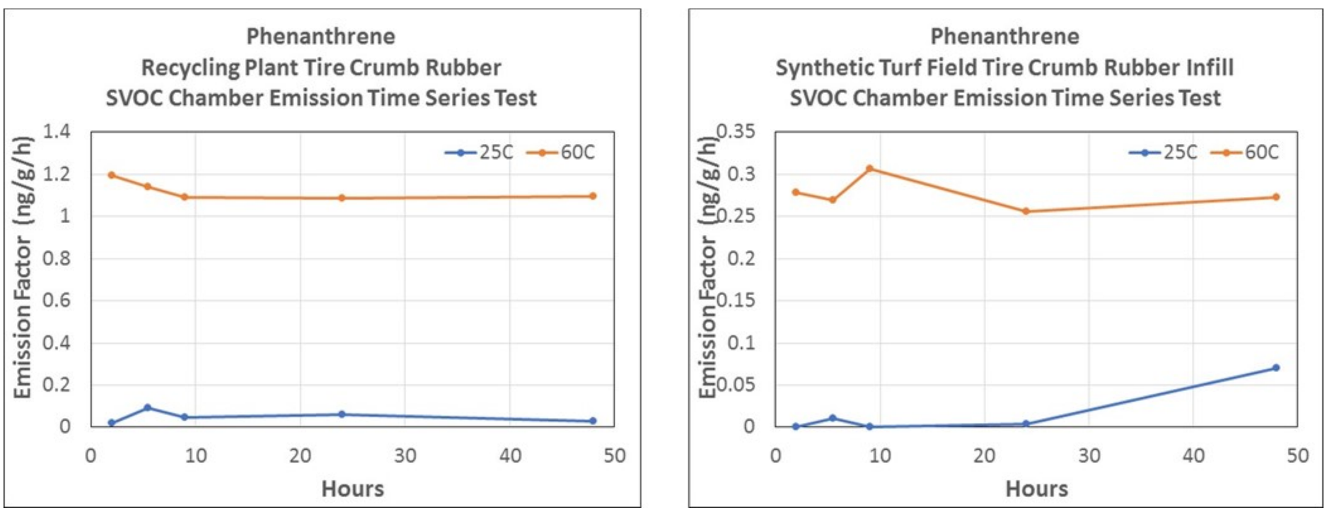


Figure J-9. Chamber emission factor time series test results for phenanthrene from recycling plant tire crumb rubber (left) and synthetic turf field tire crumb rubber infill (right). [SVOC = semivolatile organic compound; 25C = 25 degrees Celsius; 60C = 60 degrees Celsius]

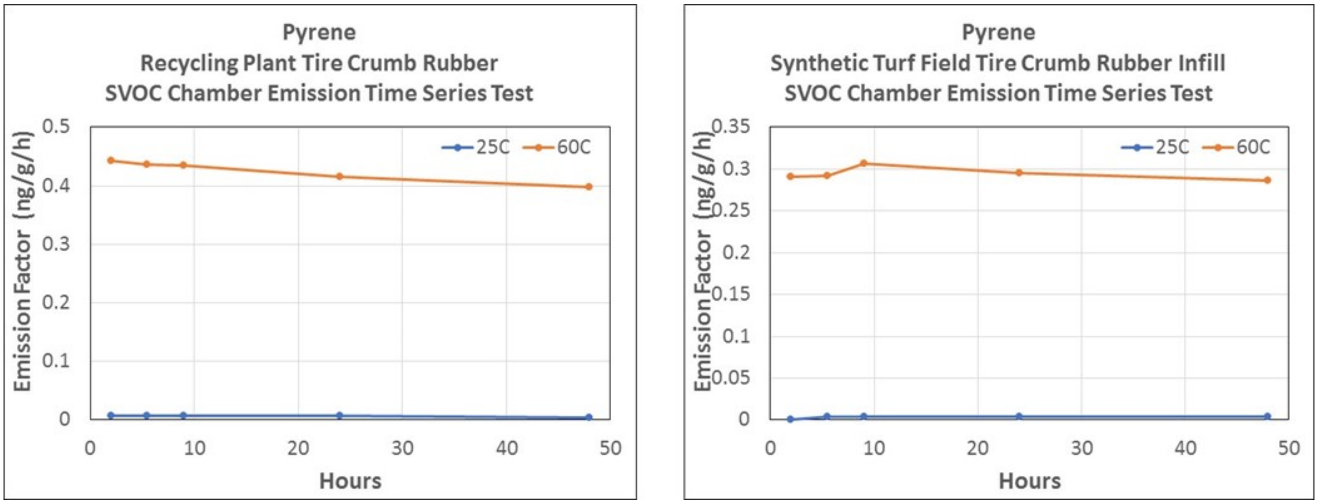


Figure J-10. Chamber emission factor time series test results for pyrene from recycling plant tire crumb rubber (left) and synthetic turf field tire crumb rubber infill (right). [SVOC = semivolatile organic compound; 25C = 25 degrees Celsius; 60C = 60 degrees Celsius]

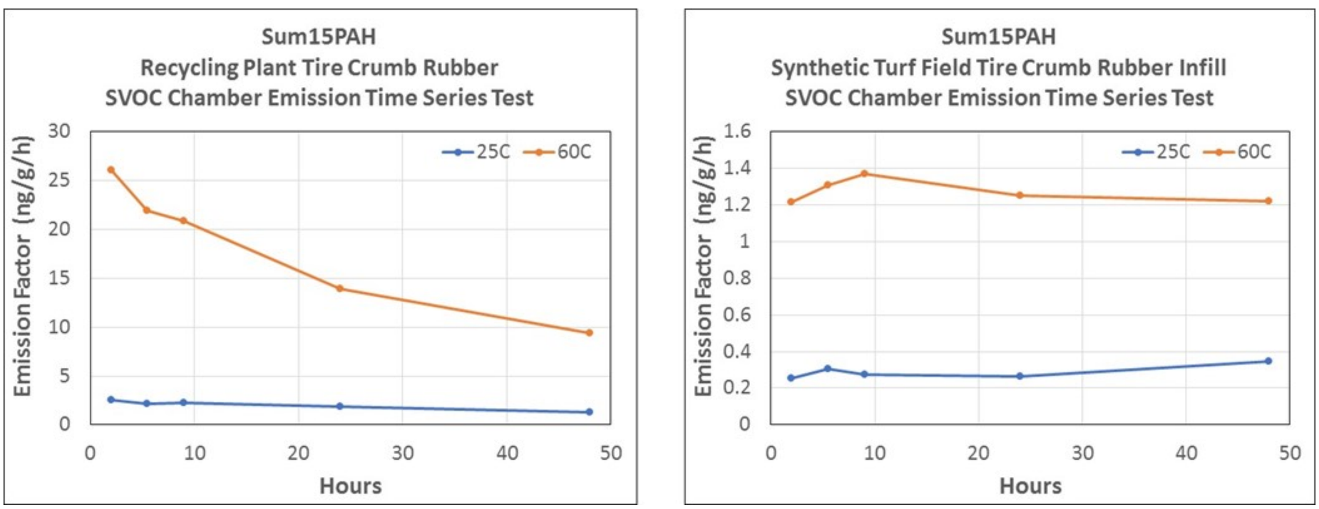


Figure J-11. Chamber emission factor time series test results for the sum of 15 PAH compounds from recycling plant tire crumb rubber (left) and synthetic turf field tire crumb rubber infill (right). [Sum15PAH = Sum of 15 of the 16 EPA 'priority' PAHs, including Acenaphthylene, Anthracene, Benz[a]anthracene, Benzo[a]pyrene, Benzo(b)fluoranthene, Benzo[ghi]perylene, Benzo(k)fluoranthene, Chrysene, Dibenz[a,h]anthracene, Fluoranthene, Fluorene, Indeno(1,2,3-cd)pyrene, Naphthalene, Phenanthrene, Pyrene; SVOC = semivolatile organic compound; 25C = 25 degrees Celsius; 60C = 60 degrees Celsius]

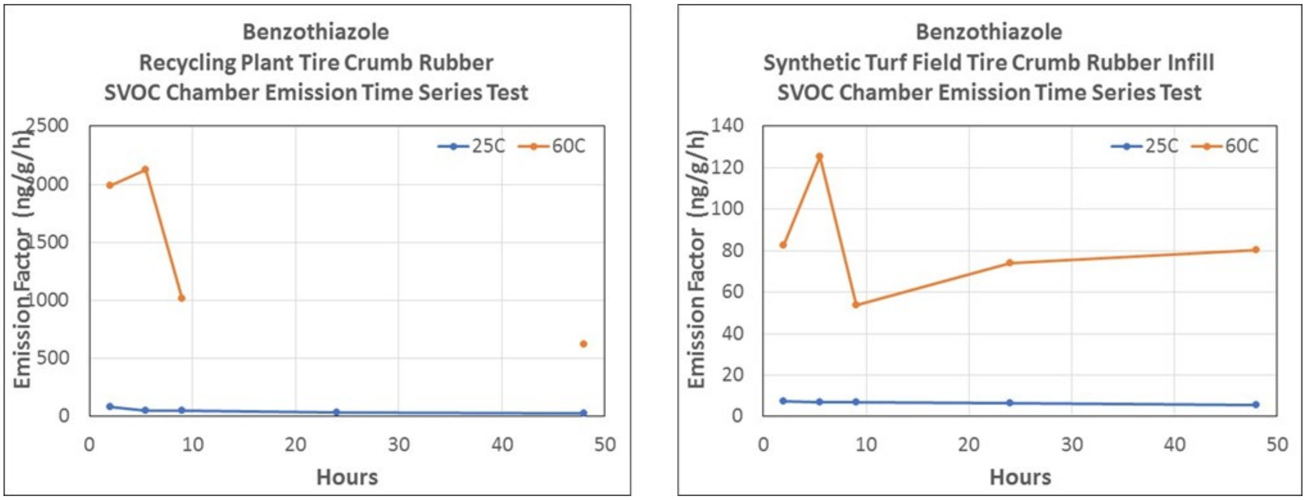


Figure J-12. Chamber emission factor time series test results for benzothiazole from recycling plant tire crumb rubber (left) and synthetic turf field tire crumb rubber infill (right). [SVOC = semivolatile organic compound; 25C = 25 degrees Celsius; 60C = 60 degrees Celsius]

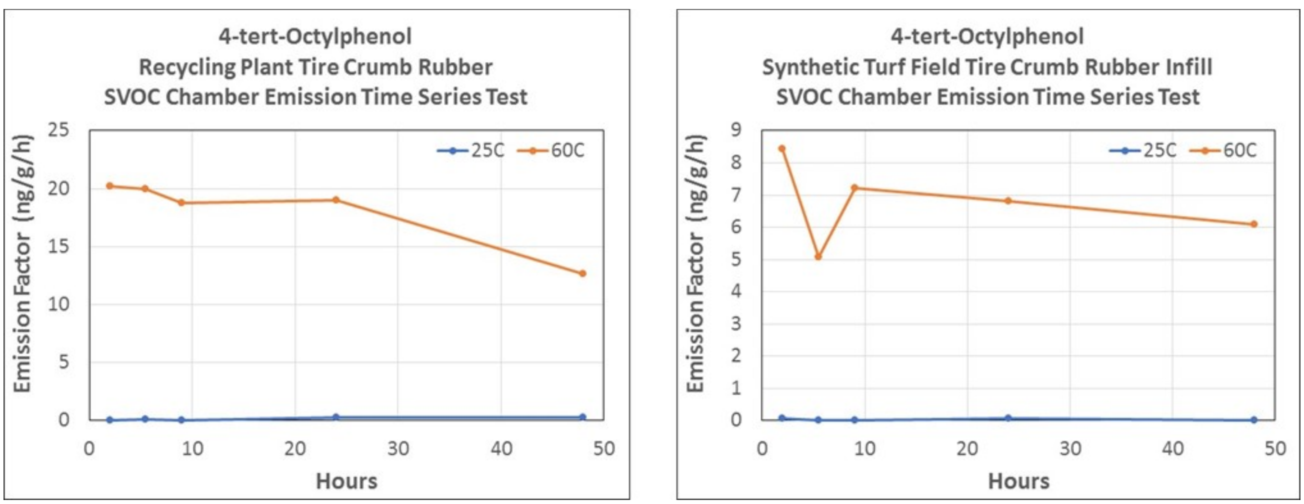


Figure J-13. Chamber emission factor time series test results for 4-tert-octylphenol from recycling plant tire crumb rubber (left) and synthetic turf field tire crumb rubber infill (right). [SVOC = semivolatile organic compound; 25C = 25 degrees Celsius; 60C = 60 degrees Celsius]

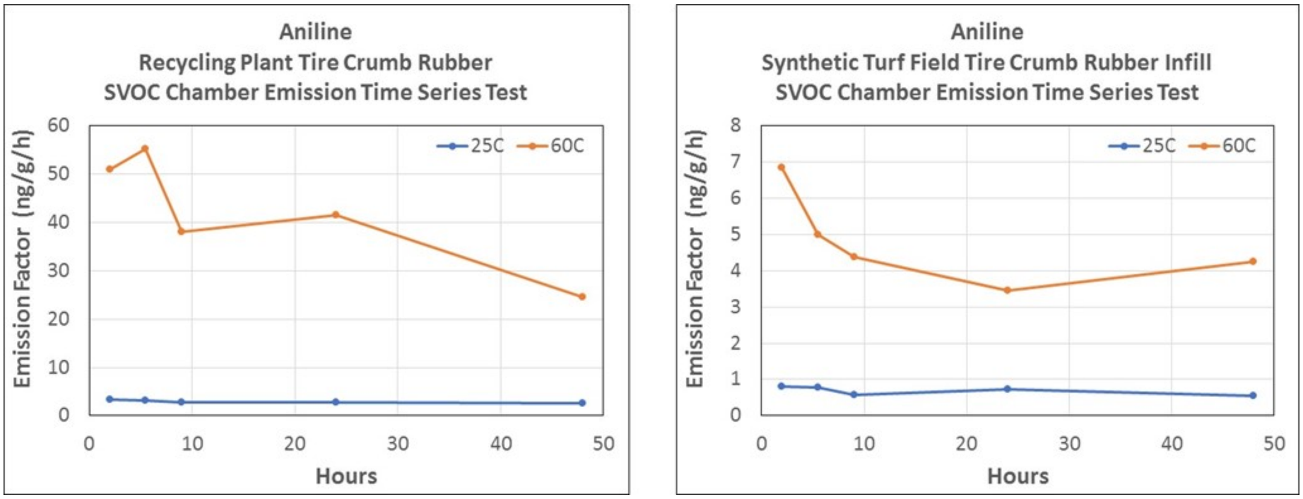


Figure J-14. Chamber emission factor time series test results for aniline from recycling plant tire crumb rubber (left) and synthetic turf field tire crumb rubber infill (right). [SVOC = semivolatile organic compound; 25C = 25 degrees Celsius; 60C = 60 degrees Celsius]

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Appendix K

Tire Crumb Rubber Measurement Results – Differences Between Recycling Plants and Synthetic Turf Fields

Table K-1. Comparison of Metal ICP/MS Analysis Results Between Tire Rubber Collected from Tire Recycling Plants and Tire Crumb Rubber Infill Composite Samples from Synthetic Turf Fields[a,b,c]

Analyte	Recycling Plants Mean (mg/kg)	Recycling Plants Standard Deviation (mg/kg)	Synthetic Turf Fields Mean (mg/kg)	Synthetic Turf Fields Standard Deviation (mg/kg)	t-test p-value[d]
Arsenic	0.30	0.088	0.38	0.20	0.2261
Cadmium	0.55	0.13	0.95	0.68	0.0002
Chromium	1.8	0.70	1.6	0.84	NR
Cobalt	190	87	140	60	0.0056
Lead	13	10	24	26	0.0060
Zinc	17000	3500	15000	3000	0.0063
Aluminum	1000	510	1300	740	0.1907
Antimony	1.2	0.41	0.95	0.43	0.0097
Barium	7.4	7.9	8.3	5.3	0.0923
Beryllium	0.015	0.0071	0.008	0.03	NR
Copper	42	22	26	12	0.0003
Iron	490	290	610	400	0.2118
Magnesium	290	78	330	230	0.7467
Manganese	5.7	2.1	7.7	5.2	0.0403
Molybdenum	0.22	0.09	0.16	0.064	0.0013
Nickel	3.2	1.0	2.7	0.89	0.0397
Rubidium	1.8	0.46	1.9	0.58	0.5729
Strontium	2.9	0.68	3.4	1.4	0.1584
Tin	1.8	0.64	1.6	1.1	NR
Vanadium	1.7	0.64	1.9	0.87	NR

[a] ICP/MS= inductive coupled plasma/mass spectrometry

[b] Recycling Plants (n=27); Synthetic Turf Fields (n=40)

[c] NR = not reported; one or more measurement results were ≤0, precluding ln-transformed testing for the complete data set

[d] Statistical tests performed using ln-transformed measurement values

Table K-2. Comparison of Metal XRF Analysis Results Between Tire Rubber Collected from Tire Recycling Plants and Tire Crumb Rubber Infill Composite Samples from Synthetic Turf Fields[a,b]

Analyte	Recycling Plants Mean (mg/kg)	Recycling Plants Standard Deviation (mg/kg)	Synthetic Turf Fields Mean (mg/kg)	Synthetic Turf Fields Standard Deviation (mg/kg)	t-test p-value[c]
Chromium	15	4.0	14	2.9	0.0702
Cobalt	58	35	39	17	0.0208
Lead	35	8.6	36	22	0.463
Zinc	39000	8800	33000	7100	0.0019
Barium	60	20	60	16	0.9424
Copper	200	80	120	44	<0.0001
Iron	1500	1100	1300	550	0.5811
Molybdenum	54	7.0	47	13	0.0071
Rubidium	86	34	56	29	0.0001
Strontium	8.6	2.1	14	13	0.0212

[a] XRF= X-ray fluorescence spectrometry

[b] Recycling Plants (n=27); Synthetic Turf Fields (n=40)

[c] Statistical tests performed using ln-transformed measurement values.

Table K-3. Comparison of SVOC GC/MS/MS Analysis Results Between Tire Rubber Solvent Extracts for Samples Collected from Tire Recycling Plants and Synthetic Turf Fields[a,b]

Analyte	Recycling Plants – n	Recycling Plants Mean (mg/kg)	Recycling Plants Standard Deviation (mg/kg)	Synthetic Turf Fields – n	Synthetic Turf Fields Mean (mg/kg)	Synthetic Turf Fields Standard Deviation (mg/kg)	t-test p-value[c]
Phenanthrene	27	3.6	1.3	40	2.3	2.6	<0.0001
Fluoranthene	27	6.1	1.7	40	4.5	2.6	0.001
Pyrene	27	18	2.4	40	12	6.2	<0.0001
Benzo[a]pyrene	27	0.74	0.39	40	0.78	0.52	0.9556
Benzo[ghi]perylene	27	1.3	0.59	40	1.3	0.64	0.5983
Sum15PAH[d]	27	41	8.9	40	29	15	<0.0001
Benzothiazole	27	79	19	40	11	13	<0.0001
Dibutyl phthalate	27	0.68	0.44	40	1.5	1.5	0.6508
Bis(2-ethylhexyl) phthalate	27	12	14	40	43	42	<0.0001
Aniline	27	3.8	1.8	40	0.67	0.53	<0.0001
4-tert-octylphenol	27	30	6.2	40	9.8	9.7	<0.0001
n-Hexadecane	27	3.6	1.8	40	0.94	1.3	<0.0001
Naphthalene	27	1.4	0.75	40	0.034	0.041	<0.0001
1-Methylnaphthalene	27	1.6	1.3	40	0.05	0.10	<0.0001
2-Methylnaphthalene	27	1.8	1.3	40	0.083	0.17	<0.0001
Acenaphthylene	27	0.37	0.085	40	0.046	0.057	<0.0001
Fluorene	27	0.37	0.14	40	0.18	0.28	<0.0001
Anthracene	27	0.59	0.40	40	0.52	0.75	0.0041

Table K-3 Continued

Analyte	Recycling Plants n	Recycling Plants Mean (mg/kg)	Recycling Plants Standard Deviation (mg/kg)	Synthetic Turf Fields n	Synthetic Turf Fields Mean (mg/kg)	Synthetic Turf Fields Standard Deviation (mg/kg)	t-test p-value[c]
1-Methylphenanthrene	27	1.4	0.53	40	1.6	1.3	0.4311
2-Methylphenanthrene	27	1.4	0.8	40	3.0	4.6	0.3292
3-Methylphenanthrene	27	2.1	1.1	40	2.3	2.1	0.3725
Benz(a)anthracene	27	1.1	0.57	40	2.2	1.4	0.0002
Chrysene	27	4.3	1.7	40	2.5	1.8	<0.0001
Benzo(b)fluoranthene	27	1.6	1.0	40	1.3	0.8	0.147
Benzo(k)fluoranthene	27	0.44	0.19	40	0.45	0.31	0.6553
Benzo(e)pyrene	27	1.7	1.1	40	1.9	0.98	0.2047
DBA + ICDP[e]	27	0.35	0.21	40	0.54	0.31	0.0076
Coronene	27	0.82	0.48	40	0.54	0.31	0.0014
Dibenzothiophene	27	0.42	0.13	40	0.31	0.35	0.0004
Dimethyl phthalate	27	0.040	0.022	40	0.027	0.061	NR
Diethyl phthalate	27	0.091	0.17	34	0.52	2.4	NR
Diisobutyl phthalate	27	0.50	0.39	40	1.2	1.8	0.568
Benzyl butyl phthalate	27	0.64	0.37	40	1.2	2.0	0.757
Di-n-octyl phthalate	27	0.32	0.19	40	0.25	0.24	NR
Bis(2,2,6,6-tetramethyl-4-piperidyl) sebacate	21	0.44	0.30	39	0.78	0.89	NR
Cyclohexylisothiocyanate	27	0.98	0.33	40	0.25	0.18	NR

[a] SVOC = semivolatile organic compound; GC/MS/MS = gas chromatography/tandem mass spectrometry

[b] NR = not reported; one or more measurement results were ≤0, precluding ln-transformed testing for the complete data set.

[c] Statistical tests performed using ln-transformed measurement values.

[d] Sum15PAH = Sum of 15 of the 16 EPA ‘priority’ PAHs, including Acenaphthylene, Anthracene, Benz[a]anthracene, Benzo[a]pyrene, Benzo(b)fluoranthene, Benzo[ghi]perylene, Benzo(k)fluoranthene, Chrysene, Dibenz[a,h]anthracene, Fluoranthene, Fluorene, Indeno(1,2,3-cd)pyrene, Naphthalene, Phenanthrene, Pyrene

[e] DBA + ICDP = Sum of Dibenz[a,h]anthracene and Indeno(1,2,3-cd)pyrene

Table K-4. Comparison of VOC 25 °C Emission Factor Results Between Tire Rubber Collected from Tire Recycling Plants and Tire Crumb Rubber Infill Composite Samples from Synthetic Turf Fields [a,b,c]

Analyte	Recycling Plants Mean (mg/kg)	Recycling Plants Standard Deviation (mg/kg)	Synthetic Turf Fields Mean (mg/kg)	Synthetic Turf Fields Standard Deviation (mg/kg)	t-test p-value[d]
Benzothiazole	150	41	25	28	NR
o-Xylene	0.21	0.20	0.032	0.09	NR
SumBTEX[e]	1.7	1.3	0.31	0.84	NR
Trichlorofluoromethane (Freon 11)	0.16	0.55	0.034	0.66	NR
Dichlorodifluoromethane (Freon 12)	0.029	0.053	-0.022	0.049	NR

[a] VOC = volatile organic compound; °C = degrees Celsius

[b] Recycling Plants (n=27); Synthetic Turf Fields (n=38)

[c] NR = not reported; one or more measurement results were ≤0, precluding ln-transformed testing for the complete data set.

[d] Statistical tests performed using ln-transformed measurement values.

[e] SumBTEX = Sum of benzene, toluene, ethylbenzene, m/p-xylene, and o-xylene

Table K-5. Comparison of VOC 60 °C Emission Factor Results Between Tire Rubber Collected from Tire Recycling Plants and Tire Crumb Rubber Infill Composite Samples from Synthetic Turf Fields [a,b]

Analyte	Recycling Plants – n	Recycling Plants Mean (mg/kg)	Recycling Plants Standard Deviation (mg/kg)	Synthetic Turf Fields – n	Synthetic Turf Fields Mean (mg/kg)	Synthetic Turf Fields Standard Deviation (mg/kg)	t-test p-value[c]
Formaldehyde	27	40	16	40	16	9.5	NR
Metyl isobutyl ketone	27	140	15	37	42	26	<0.0001
Benzothiazole	27	220	8.3	37	56	39	<0.0001
Styrene	27	1.1	0.58	37	0.45	0.41	NR
Toluene	27	1.1	0.95	37	0.15	0.31	NR
Ethylbenzene	27	-0.0055	0.26	37	-0.082	0.22	NR
m/p-Xylene	27	1.2	0.71	37	0.24	1.0	NR
o-Xylene	27	-0.4	0.43	37	-0.35	0.66	NR
SumBTEX[d]	27	2.1	2.2	37	-0.085	2.2	NR
trans-2-Butene	27	-0.22	0.25	37	-0.25	0.24	NR
cis-2-Butene	27	-0.2	0.21	37	-0.23	0.21	NR
Tetrachloroethylene	27	0.14	0.23	37	0.0035	0.032	NR
p-Dichlorobenzene	27	0.019	0.12	37	0.079	0.23	NR
Trichlorofluoromethane (Freon 11)	27	0.23	0.58	37	0.079	0.64	NR
Dichlorodifluoromethane (Freon 12)	27	0.041	0.047	37	-0.0050	0.038	NR

[a] VOC = volatile organic compound; °C = degrees Celsius

[b] NR = not reported; one or more measurement results were ≤0, precluding ln-transformed testing for the complete data set.

[c] Statistical tests performed using ln-transformed measurement values.

[d] SumBTEX = Sum of benzene, toluene, ethylbenzene, m/p-xylene, and o-xylene

Table K-6. Comparison of SVOC 25 °C Emission Factor Results Between Tire Rubber Collected from Tire Recycling Plants and Tire Crumb Rubber Infill Composite Samples from Synthetic Turf Fields [a,b]

Analyte	Recycling Plants n	Recycling Plants Mean (mg/kg)	Recycling Plants Standard Deviation (mg/kg)	Synthetic Turf Fields n	Synthetic Turf Fields Mean (mg/kg)	Synthetic Turf Fields Standard Deviation (mg/kg)	t-test p-value[c]
Phenanthrene	27	-0.0071	0.070	40	0.025	0.049	NR
Sum15PAH[d]	27	2.3	1.1	40	0.62	0.63	<0.0001
Benzothiazole	27	41	26	40	4.2	5.2	NR
Dibutyl phthalate	27	-0.021	0.67	40	-0.011	0.38	NR
Aniline	27	3.5	2.0	40	0.34	0.45	NR
4-tert-octylphenol	27	0.47	0.25	40	0.85	3.3	NR
Naphthalene	27	1.9	1.1	40	0.14	0.37	NR
1-Methylnaphthalene	27	0.97	0.73	40	0.034	0.09	NR
2-Methylnaphthalene	27	1.6	1.2	40	0.064	0.17	NR
Fluorene	27	0.016	0.0099	40	0.011	0.019	NR
n-Butylbenzene	27	0.56	0.50	40	0.019	0.12	NR
Diisobutyl phthalate	27	-0.044	0.26	40	0.014	0.24	NR

[a] VOC = volatile organic compound; °C = degrees Celsius

[b] NR = not reported; one or more measurement results were ≤0, precluding ln-transformed testing for the complete data set.

[c] Statistical tests performed using ln-transformed measurement values.

[d] Sum15PAH = Sum of 15 of the 16 EPA 'priority' PAHs, including Acenaphthylene, Anthracene, Benz[a]anthracene, Benzo[a]pyrene, Benzo(b)fluoranthene, Benzo[ghi]perylene, Benzo(k)fluoranthene, Chrysene, Dibenz[a,h]anthracene, Fluoranthene, Fluorene, Indeno(1,2,3-cd)pyrene, Naphthalene, Phenanthrene, Pyrene

Table K-7. Comparison of SVOC 60 °C Emission Factor Results Between Tire Rubber Collected from Tire Recycling Plants and Tire Crumb Rubber Infill Composite Samples from Synthetic Turf Fields[a,b]

Analyte	Recycling Plants – n	Recycling Plants Mean (mg/kg)	Recycling Plants Standard Deviation (mg/kg)	Synthetic Turf Fields – n	Synthetic Turf Fields Mean (mg/kg)	Synthetic Turf Fields Standard Deviation (mg/kg)	t-test p-value[c]
Phenanthrene	26	0.83	0.34	40	0.58	0.71	NR
Fluoranthene	26	0.16	0.054	40	0.16	0.11	NR
Pyrene	26	0.34	0.072	40	0.29	0.21	NR
Sum15PAH[d]	26	13	7.0	40	2.0	1.9	<0.0001
Benzothiazole	26	520	340	40	34	50	NR
Dibutyl phthalate	26	0.21	0.72	40	0.14	0.41	NR
Aniline	26	23	7.2	40	3.5	5.1	NR
4-tert-octylphenol	26	20	8.8	40	5.8	5.5	NR
Naphthalene	26	9.5	6.9	40	-0.14	0.56	NR
1-Methylnaphthalene	26	7.5	5.9	40	0.24	0.63	NR
2-Methylnaphthalene	26	11	11	40	0.46	1.3	NR
Acenaphthylene	26	0.93	0.34	40	0.10	0.18	NR
Fluorene	26	0.33	0.14	40	0.19	0.35	NR
1-Methylphenanthrene	26	0.12	0.052	40	0.14	0.13	NR
2-Methylphenanthrene	26	0.18	0.10	40	0.23	0.28	NR
3-Methylphenanthrene	26	0.28	0.17	40	0.37	0.44	NR
Dibenzothiophene	26	0.11	0.043	40	0.087	0.12	NR
n-Butylbenzene	26	1.1	1.0	40	-0.0037	0.027	NR
Dimethyl phthalate	26	0.037	0.058	40	0.016	0.027	NR
Diisobutyl phthalate	26	0.15	0.40	40	0.11	0.31	NR

[a] SVOC = semivolatile organic compound; °C = degrees Celsius

[b] NR = not reported; one or more measurement results were ≤0, precluding ln-transformed testing for the complete data set.

[c] Statistical tests performed using ln-transformed measurement values.

[d] Sum15PAH = Sum of 15 of the 16 EPA ‘priority’ PAHs, including Acenaphthylene, Anthracene, Benz[a]anthracene, Benzo[a]pyrene, Benzo(b)fluoranthene, Benzo[ghi]perylene, Benzo(k)fluoranthene, Chrysene, Dibenz[a,h]anthracene, Fluoranthene, Fluorene, Indeno(1,2,3-cd)pyrene, Naphthalene, Phenanthrene, Pyrene

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Appendix L

Tire Crumb Rubber Measurement Results – Replicate and Duplicate Analysis Precision and Homogeneity

Table L-1. Precision and Variability of Tire Crumb Rubber Sample Digestion Metals Measurements by ICP/MS[a,b,c]

Chemical	Replicate Sample Digest Analysis %RSD – n	Replicate Sample Digest Analysis %RSD – Mean	Replicate Sample Digest Analysis %RSD – Minimum	Replicate Sample Digest Analysis %RSD – Maximum	Duplicate Tire Crumb Sample Analysis %RSD – n	Duplicate Tire Crumb Sample Analysis %RSD – Mean	Duplicate Tire Crumb Sample Analysis %RSD – Minimum	Duplicate Tire Crumb Sample Analysis %RSD – Maximum
Arsenic	10	1.3	0.33	3.6	10	32	7.1	58
Cadmium	10	0.47	0.021	1.4	10	20	4.4	37
Chromium	11	1.5	0.05	5.8	8	15	1.5	33
Cobalt	11	0.72	0.12	2.3	9	13	2.4	29
Lead	10	1.3	0.32	3.1	10	25	0.2	96
Zinc	11	0.81	0.17	2.6	9	4.8	1	8.7
Aluminum	12	12	0.11	140	9	26	2.2	52
Antimony	10	0.51	0.076	1.9	10	23	4.7	71
Barium	10	1.4	0.097	2.9	10	9.3	2.6	15
Beryllium	9	17	5.9	27	8	25	7.1	56
Copper	11	0.82	0.064	2	9	7.5	0.98	25
Iron	11	0.7	0.015	2.4	9	13	0.29	33
Magnesium	11	0.75	0.084	2.3	9	12	0.6	45
Manganese	11	0.61	0.048	1.5	9	14	2.4	59
Molybdenum	10	3.2	0.61	20	10	20	0.18	94
Nickel	11	1.9	0.076	9.2	9	19	8.5	30
Rubidium	10	0.85	0.088	1.7	10	7.7	0.22	25
Selenium	9	18	0.75	32	9	53	2.6	110
Strontium	10	0.73	0.11	2.3	10	9.3	2.1	30
Tin	11	3.1	0.59	7	8	33	7.9	53
Vanadium	11	2.5	0.57	7.1	8	16	1.5	26

[a] ICP/MS = inductively coupled plasma/mass spectrometry

[b] Replicate Sample Digest Analysis = replicate analyses of the same digest from a sample; %RSD is the percent relative standard deviation between pairs of measurements.

[c] Duplicate Tire Crumb Sample Analysis = two different portions of tire crumb rubber samples from the same bottle extracted and analyzed separately; %RSD is the percent relative standard deviation between pairs of measurements.

Table L-2. Precision and Variability of Tire Crumb Rubber Sample Solvent Extract SVOC Measurements by GC/MS/MS[a,b,c]

Chemical	Replicate Sample Extract Analysis %RSD – n	Replicate Sample Extract Analysis %RSD – Mean	Replicate Sample Extract Analysis %RSD – Minimum	Replicate Sample Extract Analysis %RSD – Maximum	Duplicate Tire Crumb Sample Analysis %RSD – n	Duplicate Tire Crumb Sample Analysis %RSD – Mean	Duplicate Tire Crumb Sample Analysis %RSD – Minimum	Duplicate Tire Crumb Sample Analysis %RSD – Maximum
Phenanthrene	7	13	3.3	25	101	4.8	0.12	40
Fluoranthene	7	15	0.96	49	101	4.9	0.015	50
Pyrene	7	32	4.3	120	101	5.1	0.016	52
Benzo[a]pyrene	7	34	0.00077	63	101	20	0.35	64
Benzo[ghi]perylene	7	34	16	47	100	17	0.18	130
Sum15PAH[d]	7	21	0.8	110	101	5.1	0.035	49
Benzothiazole	7	29	0.28	72	101	8.9	0.19	78
Dibutyl phthalate	7	13	0.000062	71	101	11	0.031	71
Bis(2-ethylhexyl) phthalate	7	31	0.62	82	100	14	0.076	130
Aniline	7	11	0.0013	27	101	7.8	0.13	37
4-tert-octylphenol	7	63	37	110	101	8.3	0.02	41
n-Hexadecane	7	12	0.0006	51	96	10	0.0038	130
Naphthalene	7	10	0.00011	42	101	12	0.049	62
1-Methylnaphthalene	6	10	0.00037	32	101	10	0	64
2-Methylnaphthalene	7	13	0.00073	41	99	11	0.0042	58
Acenaphthylene	7	3.8	0.000089	20	101	5.4	0.013	45
Fluorene	7	10	0.00041	30	101	13	0.05	130
Anthracene	7	4.6	0.00033	31	100	14	0.023	73
1-Methylphenanthrene	7	9.7	0.00049	23	101	7.4	0.041	38
2-Methylphenanthrene	7	12	0.48	29	101	9.8	0.1	63
3-Methylphenanthrene	7	25	5.5	57	101	6.2	0.13	65
Benz(a)anthracene	7	17	0.2	40	101	13	0.098	92
Chrysene	7	17	9.2	35	101	10	0.076	84
Benzo(b)fluoranthene	7	24	0.0003	59	101	20	0.52	89
Benzo(k)fluoranthene	7	3.4	0.00019	14	100	18	0.029	94
Benzo(e)pyrene	7	29	6.3	50	101	18	0.15	120
DBA + ICDP[e]	7	31	0.00046	52	98	25	0.33	87

Table L-2 Continued

Chemical	Replicate Sample Extract Analysis %RSD – n	Replicate Sample Extract Analysis %RSD – Mean	Replicate Sample Extract Analysis %RSD – Minimum	Replicate Sample Extract Analysis %RSD – Maximum	Duplicate Tire Crumb Sample Analysis %RSD – n	Duplicate Tire Crumb Sample Analysis %RSD – Mean	Duplicate Tire Crumb Sample Analysis %RSD – Minimum	Duplicate Tire Crumb Sample Analysis %RSD – Maximum
Coronene	7	28	0.00014	60	100	18	0.038	120
Dibenzothiophene	7	4.2	0.0002	26	101	4.6	0.058	36
n-Butylbenzene	1	0.032	0.032	0.032	31	14	0.9	47
Dimethyl phthalate	5	12	0.003	45	74	8	0.091	63
Diethyl phthalate	4	11	0.00028	43	71	17	0.017	140
Diisobutyl phthalate	7	12	0.000036	78	101	9.3	0.2	67
Benzyl butyl phthalate	7	5.9	0.00016	17	99	14	0.021	120
Di-n-octyl phthalate	7	8.8	0.000053	62	99	32	0.056	120
2,6-Di-tert-butyl-p-cresol	3	11	5.5	19	38	8.8	0.27	44
Bis(2,2,6,6-tetramethyl-4-piperidyl) sebacate	5	16	0.00019	58	82	17	0.027	110
Cyclohexylisothiocyanate	6	13	0.0004	34	86	12	0.093	85

[a] SVOC = semivolatile organic compound; GC/MS/MS = gas chromatography/tandem mass spectrometry

[b] Replicate Sample Extract Analysis = replicate analyses of the same extract from a sample; %RSD is the percent relative standard deviation between pairs of measurements.

[c] Duplicate Tire Crumb Sample Analysis = two different portions of tire crumb rubber samples from the same bottle extracted and analyzed separately; %RSD is the percent relative standard deviation between pairs of measurements.

[d] Sum15PAH = Sum of 15 of the 16 EPA 'priority' PAHs, including Acenaphthylene, Anthracene, Benz[a]anthracene, Benzo[a]pyrene, Benzo(b)fluoranthene, Benzo[ghi]perylene, Benzo(k)fluoranthene, Chrysene, Dibenz[a,h]anthracene, Fluoranthene, Fluorene, Indeno(1,2,3-cd)pyrene, Naphthalene, Phenanthrene, Pyrene

[e] DBA + ICDP = Sum of Dibenz[a,h]anthracene and Indeno(1,2,3-cd)pyrene

Table L-3. Precision and Variability of 25 °C Chamber Emission VOC Measurements by GC/TOFMS[a,b,c]

Chemical	Duplicate Chamber Sample Analysis %RSD – n	Duplicate Chamber Sample Analysis %RSD – Mean	Duplicate Chamber Sample Analysis %RSD – Minimum	Duplicate Chamber Sample Analysis %RSD – Maximum	Repeated Chamber Emission Experiment %RSD – n	Repeated Chamber Emission Experiment %RSD – Mean	Repeated Chamber Emission Experiment %RSD – Minimum	Repeated Chamber Emission Experiment %RSD – Maximum
Formaldehyde	6	51	13	91	2	7.8	5.6	10
Metyl isobutyl ketone	17	45	1.1	130	4	10	2.1	21
Benzothiazole	18	17	0.79	91	4	6.8	1.4	18
1,3-Butadiene	1	65	65	65	1	82	82	82
Styrene	6	56	3.8	110	2	46	16	77
Benzene	6	67	22	86	1	140	140	140
Toluene	7	45	0.26	110	2	6.6	2.7	10
Ethylbenzene	8	59	0.1	140	2	67	36	98
m/p-Xylene	12	40	0.12	130	3	63	1.2	110
o-Xylene	12	28	0.22	110	3	68	12	110
SumBTEX[d]	10	59	2.4	140	3	57	12	100
trans-2-Butene	6	37	1.8	89	1	5.5	5.5	5.5
cis-2-Butene	6	56	19	97	1	9.9	9.9	9.9
4-Ethyltoluene	7	44	0.36	130	2	42	18	67
1,3,5-Trimethylbenzene	6	27	2.7	140	2	27	8	46
1,1-Dichloroethane	19	2	0.21	15	4	1.7	0.04	3.5
cis-1,2-Dichloroethene	16	2	0.21	15	2	1	0.04	2
Carbon Tetrachloride	1	8.9	8.9	8.9	0	-	-	-
1,2-Dichloropropane	17	2.1	0.21	15	2	2.3	1.2	3.5
Trichloroethylene	2	25	20	29	2	28	21	34
Tetrachloroethylene	2	17	0.6	33	2	35	15	55
Chlorobenzene	3	110	110	110	2	88	84	91
m-Dichlorobenzene	2	63	41	86	3	58	26	90
p-Dichlorobenzene	8	51	7.2	96	3	64	22	110
o-Dichlorobenzene	1	100	100	100	3	80	66	100

Table L-3 Continued

Chemical	Duplicate Chamber Sample Analysis %RSD – n	Duplicate Chamber Sample Analysis %RSD – Mean	Duplicate Chamber Sample Analysis %RSD – Minimum	Duplicate Chamber Sample Analysis %RSD – Maximum	Repeated Chamber Emission Experiment %RSD – n	Repeated Chamber Emission Experiment %RSD – Mean	Repeated Chamber Emission Experiment %RSD – Minimum	Repeated Chamber Emission Experiment %RSD – Maximum
Trichlorofluoromethane (Freon 11)	14	19	3.2	56	1	19	19	19
Dichlorodifluoromethane (Freon 12)	4	54	10	130	1	85	85	85
Trichlorotrifluoroethane (Freon 113)	7	52	9.4	110	2	35	24	46

[a] °C = degrees Celsius; VOC = volatile organic compound; GC/TOFMS = gas chromatography/time-of-flight mass spectrometry

[b] Duplicate Chamber Sample Analysis = two samples collected from the chamber air at the same time during the same chamber experiment; %RSD is the percent relative standard deviation between pairs of measurements.

[c] Repeated Chamber Emission Experiment = two completely different chamber experiments using different portions of tire crumb rubber samples from the same bottle; %RSD is the percent relative standard deviation between pairs of measurements.

[d] SumBTEX = Sum of benzene, toluene, ethylbenzene, m/p-xylene, and o-xylene

Table L-4. Precision and Variability of 60 °C Chamber Emission VOC Measurements by GC/TOFMS[a,b,c]

Chemical	Duplicate Chamber Sample Analysis %RSD – n	Duplicate Chamber Sample Analysis %RSD – Mean	Duplicate Chamber Sample Analysis %RSD – Minimum	Duplicate Chamber Sample Analysis %RSD – Maximum	Repeated Chamber Emission Experiment %RSD – n	Repeated Chamber Emission Experiment %RSD – Mean	Repeated Chamber Emission Experiment %RSD – Minimum	Repeated Chamber Emission Experiment %RSD – Maximum
Formaldehyde	10	11	0.34	31	5	9.7	1.2	30
Metyl isobutyl ketone	17	17	0.55	85	4	29	7.1	87
Benzothiazole	17	8.8	0.47	43	4	3.4	2	7.4
1,3-Butadiene	3	100	76	130	1	11	11	11
Styrene	14	14	1.7	43	4	46	11	130
Benzene	8	60	1.4	130	1	11	11	11
Toluene	11	40	4.1	120	2	50	45	55
Ethylbenzene	4	51	33	89	0	-	-	-

Table L-4 Continued

Chemical	Duplicate Chamber Sample Analysis %RSD – n	Duplicate Chamber Sample Analysis %RSD – Mean	Duplicate Chamber Sample Analysis %RSD – Minimum	Duplicate Chamber Sample Analysis %RSD – Maximum	Repeated Chamber Emission Experiment %RSD – n	Repeated Chamber Emission Experiment %RSD – Mean	Repeated Chamber Emission Experiment %RSD – Minimum	Repeated Chamber Emission Experiment %RSD – Maximum
m/p-Xylene	9	16	0.58	30	2	65	55	75
o-Xylene	3	45	6.9	69	0	-	-	-
SumBTEX[d]	6	36	9.4	83	1	29	29	29
trans-2-Butene	3	100	84	120	0	-	-	-
cis-2-Butene	2	97	96	98	0	-	-	-
4-Ethyltoluene	8	60	9.3	120	2	49	22	75
1,3,5-Trimethylbenzene	9	59	10	130	1	32	32	32
cis-1,2-Dichloroethene	12	11	0.41	110	2	1.5	1	2
1,1,1-Trichloroethane	16	1.8	0.41	10	4	1.7	1	2.4
Carbon Tetrachloride	3	7.2	1.2	11	1	41	41	41
1,2-Dichloropropane	13	1.1	0.41	2.3	3	1.6	1	2.4
Trichloroethylene	7	43	4.7	130	1	20	20	20
Tetrachloroethylene	7	60	5.9	120	1	36	36	36
Chlorobenzene	4	60	22	100	3	89	46	110
m-Dichlorobenzene	8	110	39	140	2	110	98	110
p-Dichlorobenzene	10	30	1.5	79	3	72	30	120
o-Dichlorobenzene	7	97	25	140	2	120	110	130
Trichlorofluoromethane (Freon 11)	13	22	0.22	92	2	13	3.6	23
Dichlorodifluoromethane (Freon 12)	4	39	11	68	2	130	120	140
Trichlorotrifluoroethane (Freon 113)	9	58	0.84	130	1	47	47	47

[a] °C = degrees Celsius; VOC = volatile organic compound; GC/TOFMS = gas chromatography/time-of-flight mass spectrometry

[b] Duplicate Chamber Sample Analysis = two samples collected from the chamber air at the same time during the same chamber experiment; %RSD is the percent relative standard deviation between pairs of measurements.

[c] Repeated Chamber Emission Experiment = two completely different chamber experiments using different portions of tire crumb rubber samples from the same bottle; %RSD is the percent relative standard deviation between pairs of measurements.

[d] SumBTEX = Sum of benzene, toluene, ethylbenzene, m/p-xylene, and o-xylene

Table L-5. Precision of Replicate Extracts Analyses for Chamber Emission SVOC Measurements by GC/MS/MS[a,b]

Chemical	n	Replicate Emission Sample Extract Analysis %RSD - Mean	Replicate Emission Sample Extract Analysis %RSD - Minimum	Replicate Emission Sample Extract Analysis %RSD - Maximum
Phenanthrene	3	0.43	0.013	1.2
Fluoranthene	2	0.12	0.096	0.14
Pyrene	3	31	0.013	94
Benzo[a]pyrene	1	1.3	1.3	1.3
Benzo[ghi]perylene	2	8.2	5.9	10
Sum15PAH[c]	4	0.91	0.058	3.4
Benzothiazole	4	14	0.0024	42
Dibutyl phthalate	2	23	0.3	46
Bis(2-ethylhexyl) phthalate	2	38	0.024	76
Aniline	4	2.7	0.0035	11
4-tert-octylphenol	3	0.092	0.0046	0.25
n-Hexadecane	3	68	0.016	140
Naphthalene	3	0.61	0.061	1.7
1-Methylnaphthalene	4	1.6	0.32	5.2
2-Methylnaphthalene	4	0.69	0.025	2.1
Acenaphthylene	3	1.1	0.32	1.9
Fluorene	3	2.4	0.4	6.1
Anthracene	3	8.2	0.34	24
1-Methylphenanthrene	3	9.7	0.11	29
2-Methylphenanthrene	3	0.63	0.17	1.5
3-Methylphenanthrene	3	5.1	0.067	15
Benz(a)anthracene	2	0.84	0.32	1.4
Chrysene	3	3	1.2	6.2
Benzo(b)fluoranthene	1	1	1	1
Benzo(k)fluoranthene	1	3.1	3.1	3.1
Benzo(e)pyrene	1	12	12	12
DBA + ICDP[d]	1	7.3	7.3	7.3
Coronene	1	5.1	5.1	5.1
Dibenzothiophene	4	18	0.43	61
2-Bromomethylnaphthalene	1	0.13	0.13	0.13
n-Butylbenzene	2	0.83	0.29	1.4
Dimethyl phthalate	3	4.5	3.9	5.3
Diisobutyl phthalate	2	0.29	0.15	0.43
Benzyl butyl phthalate	1	0.033	0.033	0.033
Di-n-octyl phthalate	1	2.2	2.2	2.2
2,6-Di-tert-butyl-p-cresol	2	0.14	0.054	0.23

[a] SVOC = semivolatile organic compound; GC/MS/MS = gas chromatography/tandem mass spectrometry

[b] Replicate analyses of the same extract from an emission sample; %RSD is the percent relative standard deviation between pairs of measurements.

[c] Sum15PAH = Sum of 15 of the 16 EPA 'priority' PAHs, including Acenaphthylene, Anthracene, Benz[a]anthracene, Benzo[a]pyrene, Benzo(b)fluoranthene, Benzo[ghi]perylene, Benzo(k)fluoranthene, Chrysene, Dibenz[a,h]anthracene, Fluoranthene, Fluorene, Indeno(1,2,3-cd)pyrene, Naphthalene, Phenanthrene, Pyrene

[d] DBA + ICDP = Sum of Dibenz[a,h]anthracene and Indeno(1,2,3-cd)pyrene

Table L-6. Variability of 25 °C and 60 °C Chamber Emission SVOC Measurements by GC/MS/MS[a,b]

Chemical	25 °C Repeated Chamber Emission Experiment %RSD – n	25 °C Repeated Chamber Emission Experiment %RSD – Mean	25 °C Repeated Chamber Emission Experiment %RSD – Minimum	25 °C Repeated Chamber Emission Experiment %RSD – Maximum	60 °C Repeated Chamber Emission Experiment %RSD – n	60 °C Repeated Chamber Emission Experiment %RSD – Mean	60 °C Repeated Chamber Emission Experiment %RSD – Minimum	60 °C Repeated Chamber Emission Experiment %RSD – Maximum
Phenanthrene	3	50	18	76	5	8.4	0.23	16
Fluoranthene	4	29	22	42	5	21	7.4	35
Pyrene	3	30	8.7	54	5	18	8	30
Sum15PAH[c]	6	35	1.4	84	6	30	9.7	72
Benzothiazole	5	28	10	48	5	37	15	65
Dibutyl phthalate	2	130	130	130	0	N/A	N/A	N/A
Aniline	5	30	6.4	56	5	35	17	59
4-tert-octylphenol	5	74	24	130	5	18	11	27
Naphthalene	2	9.7	1.9	18	2	23	23	23
1-Methylnaphthalene	3	41	6.8	88	4	16	6.1	36
2-Methylnaphthalene	3	28	4.3	42	3	11	5.2	20
Acenaphthylene	5	29	0.68	89	5	14	0.51	31
Fluorene	5	28	12	62	5	18	0.35	72
Anthracene	1	30	30	30	2	22	15	30
1-Methylphenanthrene	3	39	8.3	56	5	14	2.4	26
2-Methylphenanthrene	3	75	31	140	5	5.6	3.2	13
3-Methylphenanthrene	0	N/A	N/A	N/A	5	20	5.6	45
Dibenzothiophene	3	28	24	32	5	12	0.54	24
n-Butylbenzene	3	11	5.7	18	3	38	1.5	110
Dimethyl phthalate	1	140	140	140	4	47	2.4	97
Diisobutyl phthalate	1	98	98	98	3	50	20	110

[a] °C = degrees Celsius; SVOC = semivolatile organic compound; GC/MS/MS = gas chromatography/tandem mass spectrometry; N/A = not applicable

[b] Two completely different chamber experiments using different portions of tire crumb rubber samples from the same bottle; %RSD is the percent relative standard deviation between pairs of measurements.

[c] Sum15PAH = Sum of 15 of the 16 EPA 'priority' PAHs, including Acenaphthylene, Anthracene, Benz[a]anthracene, Benzo[a]pyrene, Benzo(b)fluoranthene, Benzo[ghi]perylene, Benzo(k)fluoranthene, Chrysene, Dibenz[a,h]anthracene, Fluoranthene, Fluorene, Indeno(1,2,3-cd)pyrene, Naphthalene, Phenanthrene, Pyrene

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Appendix M

Tire Crumb Rubber Measurement Results – Within and Between Recycling Plant Variability

Table M-1. Within- and Between-Recycling Plant Variability for Metal ICP/MS Analysis Results for Tire Crumb Rubber Collected from Tire Recycling Plants[a]

Analyte	Number of Plants	Number of Samples per Plant	Between Plant % Variance	Within Plant % Variance
Arsenic	9	3	38	62
Cadmium	9	3	27	73
Chromium	9	3	61	39
Cobalt	9	3	46	54
Lead	9	3	8	92
Zinc	9	3	71	29
Aluminum	9	3	34	66
Antimony	9	3	63	37
Barium	9	3	0	100
Beryllium	9	3	20	80
Copper	9	3	67	33
Iron	9	3	15	85
Magnesium	9	3	14	86
Manganese	9	3	0	100
Molybdenum	9	3	66	34
Nickel	9	3	67	33
Rubidium	9	3	68	32
Strontium	9	3	45	55
Tin	9	3	7	93
Vanadium	9	3	33	67

[a] ICP/MS = inductively coupled plasma/mass spectrometry

Table M-2. Within- and Between-Recycling Plant Variability for Metal XRF Analysis Results for Tire Crumb Rubber Collected from Tire Recycling Plants[a]

Analyte	Number of Plants	Number of Samples per Plant	Between Plant % Variance	Within Plant % Variance
Chromium	9	3	48	52
Cobalt	9	3	29	71
Lead	9	3	25	75
Zinc	9	3	56	44
Barium	9	3	0	100
Copper	9	3	61	39
Iron	9	3	17	83
Molybdenum	9	3	46	54
Rubidium	9	3	67	33
Strontium	9	3	62	38

[a] XRF = X-ray fluorescence spectrometry

Table M-3. Within- and Between-Recycling Plant Variability for SVOC Extraction GC/MS/MS Analysis Results for Tire Crumb Rubber Collected from Tire Recycling Plants[a]

Analyte	Number of Plants	Number of Samples per Plant	Between Plant % Variance	Within Plant % Variance
Phenanthrene	9	3	37	63
Fluoranthene	9	3	64	36
Pyrene	9	3	60	40
Benzo[a]pyrene	9	3	39	61
Benzo[ghi]perylene	9	3	59	41
Sum15PAH[b]	9	3	54	46
Benzothiazole	9	3	76	24
Dibutyl phthalate	9	3	91	9
Bis(2-ethylhexyl) phthalate	9	3	17	83
Aniline	9	3	84	16
4-tert-octylphenol	9	3	80	20
n-Hexadecane	9	3	77	23
Naphthalene	9	3	63	37
1-Methylnaphthalene	9	3	63	37
2-Methylnaphthalene	9	3	66	34
Acenaphthylene	9	3	78	22
Fluorene	9	3	33	67
Anthracene	9	3	41	59
1-Methylphenanthrene	9	3	63	37
2-Methylphenanthrene	9	3	39	61
3-Methylphenanthrene	9	3	35	65
Benz(a)anthracene	9	3	55	45
Chrysene	9	3	38	62
Benzo(b)fluoranthene	9	3	46	54
Benzo(k)fluoranthene	9	3	46	54
Benzo(e)pyrene	9	3	38	62
DBA + ICDP[c]	9	3	57	43
Coronene	9	3	59	41
Dibenzothiophene	9	3	29	71
n-Butylbenzene	9	3	67	33
Dimethyl phthalate	9	3	96	4
Diethyl phthalate	9	3	7	93
Diisobutyl phthalate	9	3	52	48
Benzyl butyl phthalate	9	3	92	8
Di-n-octyl phthalate	9	3	51	49
2,6-Di-tert-butyl-p-cresol	9	3	94	6
Bis(2,2,6,6-tetramethyl-4-piperidyl) sebacate	7	3	70	30
Cyclohexylisothiocyanate	9	3	90	10

[a] SVOC = semivolatile organic compound; GC/MS/MS= gas chromatography/tandem mass spectrometry

[b]Sum15PAH = Sum of 15 of the 16 EPA 'priority' PAHs, including Acenaphthylene, Anthracene, Benz[a]anthracene, Benzo[a]pyrene, Benzo(b)fluoranthene, Benzo[ghi]perylene, Benzo(k)fluoranthene, Chrysene, Dibenz[a,h]anthracene, Fluoranthene, Fluorene, Indeno(1,2,3-cd)pyrene, Naphthalene, Phenanthrene, Pyrene

[c] DBA + ICDP = Sum of Dibenz[a,h]anthracene and Indeno(1,2,3-cd)pyrene

Table M-4. Within- and Between-Recycling Plant Variability for VOC 25 °C Emission Factor Analysis Results for Tire Crumb Rubber Collected from Tire Recycling Plants[a]

Analyte	Number of Plants	Number of Samples per Plant	Between Plant % Variance	Within Plant % Variance
Metyl isobutyl ketone	9	3	19	81
Benzothiazole	9	3	8	92
Styrene	9	3	16	84
Toluene	9	3	43	57
m/p-Xylene	9	3	29	71
o-Xylene	9	3	26	74
SumBTEX[b]	9	3	36	64
trans-2-Butene	9	3	34	66
cis-2-Butene	9	3	22	78
4-Ethyltoluene	9	3	0	100
1,3,5-Trimethylbenzene	9	3	0	100
Tetrachloroethylene	9	3	37	63
Trichlorofluoromethane (Freon 11)	9	3	93	7
Dichlorodifluoromethane (Freon 12)	9	3	89	11

[a] VOC = volatile organic compound; °C = degrees Celsius

[b] SumBTEX = Sum of benzene, toluene, ethylbenzene, m/p-xylene, and o-xylene

Table M-5. Within- and Between-Recycling Plant Variability for VOC 60 °C Emission Factor Analysis Results for Tire Crumb Rubber Collected from Tire Recycling Plants[a]

Analyte	Number of Plants	Number of Samples per Plant	Between Plant % Variance	Within Plant % Variance
Formaldehyde	9	3	76	24
Metyl isobutyl ketone	9	3	45	55
Benzothiazole	9	3	0	100
Styrene	9	3	88	12
Benzene	9	3	63	37
Toluene	9	3	62	38
Ethylbenzene	9	3	47	53
m/p-Xylene	9	3	16	84
o-Xylene	9	3	44	56
SumBTEX[b]	9	3	60	40
trans-2-Butene	9	3	84	16
cis-2-Butene	9	3	80	20
1,3,5-Trimethylbenzene	9	3	25	75
Tetrachloroethylene	9	3	57	43
p-Dichlorobenzene	9	3	1	99
Trichlorofluoromethane (Freon 11)	9	3	88	12
Dichlorodifluoromethane (Freon 12)	9	3	47	53

[a] SVOC = semivolatile organic compound; °C = degrees Celsius

[b] SumBTEX = Sum of benzene, toluene, ethylbenzene, m/p-xylene, and o-xylene

Table M-6. Within- and Between-Recycling Plant Variability for SVOC 25 °C Emission Factor Analysis Results for Tire Crumb Rubber Collected from Tire Recycling Plants[a]

Analyte	Number of Plants	Number of Samples per Plant	Between Plant % Variance	Within Plant % Variance
Phenanthrene	9	3	90	10
Sum15PAH[b]	9	3	61	39
Benzothiazole	9	3	47	53
Dibutyl phthalate	9	3	14	86
Aniline	9	3	84	16
4-tert-octylphenol	9	3	54	46
Naphthalene	9	3	62	38
1-Methylnaphthalene	9	3	67	33
2-Methylnaphthalene	9	3	70	30
Acenaphthylene	9	3	78	22
Fluorene	9	3	31	69
n-Butylbenzene	9	3	59	41
Diisobutyl phthalate	9	3	0	100

[a] SVOC = semivolatile organic compound; °C = degrees Celsius

[b] Sum15PAH = Sum of 15 of the 16 EPA 'priority' PAHs, including Acenaphthylene, Anthracene, Benz[a]anthracene, Benzo[a]pyrene, Benzo(b)fluoranthene, Benzo[ghi]perylene, Benzo(k)fluoranthene, Chrysene, Dibenz[a,h]anthracene, Fluoranthene, Fluorene, Indeno(1,2,3-cd)pyrene, Naphthalene, Phenanthrene, Pyrene

Table M-7. Within- and Between-Recycling Plant Variability for SVOC 60 °C Emission Factor Analysis Results for Tire Crumb Rubber Collected from Tire Recycling Plants[a]

Analyte	Number of Plants	Number of Samples per Plant	Between Plant % Variance	Within Plant % Variance
Phenanthrene	9	2	15	85
Fluoranthene	9	2	54	46
Pyrene	9	2	56	44
Sum15PAH[b]	9	2	47	53
Benzothiazole	9	2	60	40
Dibutyl phthalate	9	2	25	75
Aniline	9	2	55	45
4-tert-octylphenol	9	2	51	49
Naphthalene	9	2	48	52
1-Methylnaphthalene	9	2	53	47
2-Methylnaphthalene	9	2	81	19
Acenaphthylene	9	2	63	37
Fluorene	9	2	15	85
Anthracene	9	2	34	66
1-Methylphenanthrene	9	2	0	100
2-Methylphenanthrene	9	2	0	100
3-Methylphenanthrene	9	2	0	100
Dibenzothiophene	9	2	0	100

Table M-7 Continued

Analyte	Number of Plants	Number of Samples per Plant	Between Plant % Variance	Within Plant % Variance
n-Butylbenzene	9	2	61	39
Dimethyl phthalate	9	2	88	12
Diisobutyl phthalate	9	2	0	100
Di-n-octyl phthalate	9	2	9	91

[a] SVOC = semivolatile organic compound; °C = degrees Celsius

[b] Sum15PAH = Sum of 15 of the 16 EPA 'priority' PAHs, including Acenaphthylene, Anthracene, Benz[a]anthracene, Benzo[a]pyrene, Benzo(b)fluoranthene, Benzo[ghi]perylene, Benzo(k)fluoranthene, Chrysene, Dibenz[a,h]anthracene, Fluoranthene, Fluorene, Indeno(1,2,3-cd)pyrene, Naphthalene, Phenanthrene, Pyrene

Appendix N

Tire Crumb Rubber Measurement Results – Within and Between Synthetic Turf Field Variability

Table N-1. Within- and Between-Field Variability for Metal ICP/MS Analysis Results for Tire Crumb Rubber Infill Collected from Synthetic Turf Fields[a]

Analyte	Number of Fields	Number of Samples per Field	Between Field % Variance	Within Field % Variance
Arsenic	5	7	5	95
Cadmium	5	7	6	94
Chromium	5	7	13	87
Cobalt	5	7	65	35
Lead	5	7	48	52
Zinc	5	7	60	40
Aluminum	5	7	55	45
Antimony	5	7	24	76
Barium	5	7	16	84
Beryllium	5	7	39	61
Copper	5	7	79	21
Iron	5	7	0	100
Magnesium	5	7	7	93
Manganese	5	7	6	94
Molybdenum	5	7	6	94
Nickel	5	7	24	76
Rubidium	5	7	83	17
Strontium	5	7	48	52
Tin	5	7	26	74
Vanadium	5	7	36	64

[a] ICP/MS = inductively coupled plasma/mass spectrometry

Table N-2. Within- and Between-Field Variability for Metal XRF Analysis Results for Tire Crumb Rubber Infill Collected from Synthetic Turf Fields[a]

Analyte	Number of Fields	Number of Samples per Field	Between Field % Variance	Within Field % Variance
Chromium	5	7	72	28
Cobalt	5	7	66	34
Lead	5	7	43	57
Zinc	5	7	90	10
Barium	5	7	56	44
Copper	5	7	87	13
Iron	5	7	24	76
Molybdenum	5	7	68	32
Rubidium	5	7	78	22
Strontium	5	7	91	9

[a] XRF = x-ray fluorescence

Table N-3. Within- and Between-Field Variability for SVOC Extraction GC/MS/MS Analysis Results for Tire Crumb Rubber Infill Collected from Synthetic Turf Fields[a]

Analyte	Number of Fields	Number of Samples per Field	Between Field % Variance	Within Field % Variance
Phenanthrene	5	7	98	2
Fluoranthene	5	7	95	5
Pyrene	5	7	98	2
Benzo[a]pyrene	5	7	77	23
Benzo[ghi]perylene	5	7	83	17
Sum15PAH[b]	5	7	99	1
Benzothiazole	5	7	90	10
Dibutyl phthalate	5	7	88	12
Bis(2-ethylhexyl) phthalate	5	7	100	0
Aniline	5	7	82	18
4-tert-octylphenol	5	7	91	9
n-Hexadecane	5	7	98	2
Naphthalene	5	7	96	4
1-Methylnaphthalene	5	7	95	5
2-Methylnaphthalene	5	7	94	6
Acenaphthylene	5	7	97	3
Fluorene	5	7	98	2
Anthracene	5	7	95	5
1-Methylphenanthrene	5	7	94	6
2-Methylphenanthrene	5	7	73	27
3-Methylphenanthrene	5	7	92	8
Benz(a)anthracene	5	7	17	83
Chrysene	5	7	80	20
Benzo(b)fluoranthene	5	7	86	14
Benzo(k)fluoranthene	5	7	87	13
Benzo(e)pyrene	5	7	91	9
DBA + ICDP[c]	5	7	74	26
Coronene	5	7	73	27
Dibenzothiophene	5	7	99	1
Dimethyl phthalate	5	7	54	46
Diethyl phthalate	5	7	81	19
Diisobutyl phthalate	5	7	98	2
Benzyl butyl phthalate	5	7	65	35
Di-n-octyl phthalate	5	7	96	4
Bis(2,2,6,6-tetramethyl-4-piperidyl) sebacate	5	7	16	84
Cyclohexylisothiocyanate	5	7	52	48

[a] SVOC = semivolatile organic compound; GC/MS/MS = gas chromatography/tandem mass spectrometry

[b] Sum15PAH = Sum of 15 of the 16 EPA 'priority' PAHs, including Acenaphthylene, Anthracene, Benz[a]anthracene, Benzo[a]pyrene, Benzo(b)fluoranthene, Benzo[ghi]perylene, Benzo(k)fluoranthene, Chrysene, Dibenz[a,h]anthracene, Fluoranthene, Fluorene, Indeno(1,2,3-cd)pyrene, Naphthalene, Phenanthrene, Pyrene

[c] DBA + ICDP = Sum of Dibenz[a,h]anthracene and Indeno(1,2,3-cd)pyrene

Table N-4. Within- and Between-Field Variability for VOC 25 °C Emission Factor Analysis Results for Tire Crumb Rubber Infill Collected from Synthetic Turf Fields[a]

Analyte	Number of Fields	Number of Samples per Field	Between Field % Variance	Within Field % Variance
Benzothiazole	5	3	98	2
o-Xylene	5	3	24	76
SumBTEX[b]	5	3	30	70
Trichlorofluoromethane (Freon 11)	5	3	100	0
Dichlorodifluoromethane (Freon 12)	5	3	5	95

[a] VOC = volatile organic compound; °C = degrees Celsius

[b] SumBTEX = Sum of benzene, toluene, ethylbenzene, m/p-xylene, and o-xylene

Table N-5. Within- and Between- Field Variability for VOC 60 °C Emission Factor Analysis Results for Tire Crumb Rubber Infill Collected from Synthetic Turf Fields[a]

Analyte	Number of Fields	Number of Samples per Field	Between Field % Variance	Within Field % Variance
Formaldehyde	5	3	34	66
Metyl isobutyl ketone	5	3	91	9
Benzothiazole	5	3	98	2
Styrene	5	3	95	5
Toluene	5	3	26	74
Ethylbenzene	5	3	82	18
m/p-Xylene	5	3	85	15
o-Xylene	5	3	72	28
SumBTEX[b]	5	3	86	14
trans-2-Butene	5	3	46	54
cis-2-Butene	5	3	49	51
Tetrachloroethylene	5	3	86	14
Chlorobenzene	5	3	0	100
p-Dichlorobenzene	5	3	0	100
Trichlorofluoromethane (Freon 11)	5	3	99	1
Dichlorodifluoromethane (Freon 12)	5	3	9	91

[a] VOC = volatile organic compound; °C = degrees Celsius

[b] SumBTEX = Sum of benzene, toluene, ethylbenzene, m/p-xylene, and o-xylene

Table N-6. Within- and Between-Field Variability for SVOC 25 °C Emission Factor Analysis Results for Tire Crumb Rubber Infill Collected from Synthetic Turf Fields[a]

Analyte	Number of Fields	Number of Samples per Field	Between Field % Variance	Within Field % Variance
Phenanthrene	5	3	10	90
Sum15PAH[b]	5	3	91	9
Benzothiazole	5	3	96	4
Dibutyl phthalate	5	3	0	100
Aniline	5	3	94	6
4-tert-octylphenol	5	3	70	30
Naphthalene	5	3	68	32
1-Methylnaphthalene	5	3	77	23
2-Methylnaphthalene	5	3	71	29
Fluorene	5	3	65	35
n-Butylbenzene	5	3	23	77
Diisobutyl phthalate	5	3	0	100

[a] SVOC = semivolatile organic compound; °C = degrees Celsius

[b] Sum15PAH = Sum of 15 of the 16 EPA 'priority' PAHs, including Acenaphthylene, Anthracene, Benz[a]anthracene, Benzo[a]pyrene, Benzo(b)fluoranthene, Benzo[ghi]perylene, Benzo(k)fluoranthene, Chrysene, Dibenz[a,h]anthracene, Fluoranthene, Fluorene, Indeno(1,2,3-cd)pyrene, Naphthalene, Phenanthrene, Pyrene

Table N-7. Within- and Between-Field Variability for SVOC 60 °C Emission Factor Analysis Results for Tire Crumb Rubber Infill Collected from Synthetic Turf Fields[a]

Analyte	Number of Fields	Number of Samples per Field	Between Field % Variance	Within Field % Variance
Phenanthrene	5	3	92	8
Fluoranthene	5	3	97	3
Pyrene	5	3	99	1
Sum15PAH[b]	5	3	97	3
Benzothiazole	5	3	94	6
Dibutyl phthalate	5	3	80	20
Aniline	5	3	99	1
4-tert-octylphenol	5	3	96	4
Naphthalene	5	3	97	3
1-Methylnaphthalene	5	3	97	3
2-Methylnaphthalene	5	3	95	5
Acenaphthylene	5	3	98	2
Fluorene	5	3	98	2
1-Methylphenanthrene	5	3	92	8
2-Methylphenanthrene	5	3	45	55
3-Methylphenanthrene	5	3	98	2
Dibenzothiophene	5	3	98	2
n-Butylbenzene	5	3	0	100
Dimethyl phthalate	5	3	63	37
Diisobutyl phthalate	5	3	88	12

[a] SVOC = semivolatile organic compound; °C = degrees Celsius

[b] Sum15PAH = Sum of 15 of the 16 EPA 'priority' PAHs, including Acenaphthylene, Anthracene, Benz[a]anthracene, Benzo[a]pyrene, Benzo(b)fluoranthene, Benzo[ghi]perylene, Benzo(k)fluoranthene, Chrysene, Dibenz[a,h]anthracene, Fluoranthene, Fluorene, Indeno(1,2,3-cd)pyrene, Naphthalene, Phenanthrene, Pyrene

Appendix O

Tire Crumb Rubber Measurement Results – Differences Between Outdoor and Indoor Synthetic Turf Fields

Table O-1. Comparison of Metals Analyzed by ICP/MS in Tire Crumb Rubber Infill Collected at Outdoor and Indoor Synthetic Turf Fields[a,b]

Analyte	Outdoor Fields Mean (mg/kg)	Outdoor Fields Standard Deviation (mg/kg)	Indoor Fields Mean (mg/kg)	Indoor Fields Standard Deviation (mg/kg)	F-test p-value[c,d]
Arsenic	0.39	0.18	0.37	0.23	0.488
Cadmium	0.86	0.45	1.1	0.96	0.3997
Chromium	1.7	0.88	1.5	0.8	NR
Cobalt	140	60	140	63	0.8128
Lead	20	14	31	39	0.4709
Zinc	15000	3300	15000	2600	0.6996
Aluminum	1400	810	1100	590	0.3431
Antimony	0.91	0.43	1.0	0.42	0.2828
Barium	8.6	5.5	7.8	5.1	0.631
Beryllium	0.011	0.033	0.0035	0.025	NR
Copper	26	11	25	15	0.3715
Iron	710	460	430	170	0.0129
Magnesium	320	190	340	300	0.9777
Manganese	8.5	6.3	6.3	2.0	0.2704
Molybdenum	0.15	0.067	0.16	0.061	0.7457
Nickel	2.5	0.78	3.1	0.96	0.0754
Rubidium	2.0	0.62	1.6	0.42	0.0287
Strontium	3.4	1.6	3.4	1.2	0.7799
Tin	1.6	1.1	1.6	1.0	NR
Vanadium	2.0	1.0	1.7	0.43	NR

[a] ICP/MS = inductively coupled plasma/mass spectrometry

[b] Outdoor Fields (n=25); Indoor Fields (n=15)

[c] Statistical tests performed using ln-transformed measurement values

[d] NR = not reported; one or more measurement results were ≤0, precluding ln-transformed testing for the complete data set

Table O-2. Comparison of Metals Analyzed by XRF in Tire Crumb Rubber Infill Collected at Outdoor and Indoor Synthetic Turf Fields[a,b]

Analyte	Outdoor Fields Mean (mg/kg)	Outdoor Fields Standard Deviation (mg/kg)	Indoor Fields Mean (mg/kg)	Indoor Fields Standard Deviation (mg/kg)	F-test p-value[c]
Chromium	14	3.0	14	2.9	0.9667
Cobalt	40	17	36	17	0.4099
Lead	31	13	45	31	0.1433
Zinc	33000	7900	34000	5800	0.458
Barium	57	16	64	15	0.1521
Copper	130	46	120	41	0.4724
Iron	1300	640	1100	320	0.2353
Molybdenum	47	15	46	9.8	0.809
Rubidium	58	34	52	19	0.8533
Strontium	15	13	12	13	0.4236

[a] XRF = X-ray fluorescence spectrometry

[b] Outdoor Fields (n=25); Indoor Fields (n=15)

[c] Statistical tests performed using ln-transformed measurement values.

Table O-3. Comparison of SVOCs in Extracts Analyzed by GC/MS/MS for Tire Crumb Rubber Infill Collected at Outdoor and Indoor Synthetic Turf Fields[a,b]

Analyte	Outdoor Fields Mean (mg/kg)	Outdoor Fields Standard Deviation (mg/kg)	Indoor Fields Mean (mg/kg)	Indoor Fields Standard Deviation (mg/kg)	F-test p-value[c,d]
Phenanthrene	0.76	0.71	4.8	2.6	<0.0001
Fluoranthene	3.5	2.3	6.2	2.2	0.0004
Pyrene	8.8	3.9	19	3.7	<0.0001
Benzo[a]pyrene	0.66	0.37	0.98	0.67	0.0375
Benzo[ghi]perylene	1.1	0.54	1.6	0.68	0.0315
Sum15PAH[e]	21	9.4	42	12	<0.0001
Benzothiazole	5.6	9.2	19	14	<0.0001
Dibutyl phthalate	0.63	0.70	2.9	1.4	<0.0001
Bis(2-ethylhexyl) phthalate	29	27	65	53	0.0185
Aniline	0.38	0.24	1.2	0.54	<0.0001
4-tert-octylphenol	3.5	2.2	20	7.9	<0.0001
n-Hexadecane	0.20	0.2	2.2	1.3	<0.0001
Naphthalene	0.014	0.0082	0.067	0.053	<0.0001
1-Methylnaphthalene	0.0085	0.011	0.12	0.14	<0.0001
2-Methylnaphthalene	0.016	0.016	0.20	0.24	<0.0001
Acenaphthylene	0.020	0.017	0.090	0.072	<0.0001
Fluorene	0.036	0.054	0.43	0.34	<0.0001
Anthracene	0.13	0.13	1.2	0.91	<0.0001
1-Methylphenanthrene	0.87	0.63	2.8	1.2	<0.0001
2-Methylphenanthrene	1.2	1.4	5.9	6.4	<0.0001
3-Methylphenanthrene	1.2	1.1	4.2	2.2	<0.0001
Benz(a)anthracene	2.2	1.3	2.3	1.6	0.8612

Table O-3 Continued

Analyte	Outdoor Fields Mean (mg/kg)	Outdoor Fields Standard Deviation (mg/kg)	Indoor Fields Mean (mg/kg)	Indoor Fields Standard Deviation (mg/kg)	F-test p-value[c,d]
Chrysene	2.0	1.7	3.4	1.6	0.0033
Benzo(b)fluoranthene	1.2	0.74	1.6	0.82	0.0237
Benzo(k)fluoranthene	0.38	0.29	0.58	0.31	0.0113
Benzo(e)pyrene	1.6	0.92	2.4	0.91	0.0088
DBA + ICDP[f]	0.48	0.30	0.65	0.31	0.0564
Coronene	0.45	0.28	0.69	0.31	0.0085
Dibenzothiophene	0.096	0.092	0.66	0.33	<0.0001
Dimethyl phthalate	0.0043	0.0069	0.065	0.09	NR
Diethyl phthalate	-0.0055	0.010	1.5	4.0	NR
Diisobutyl phthalate	0.36	0.34	2.7	2.3	<0.0001
Benzyl butyl phthalate	0.44	0.40	2.4	2.8	<0.0001
Di-n-octyl phthalate	0.13	0.12	0.44	0.26	NR
Bis(2,2,6,6-tetramethyl-4-piperidyl) sebacate	0.96	1.0	0.49	0.62	NR
Cyclohexylisothiocyanate	0.16	0.10	0.40	0.19	NR

[a] SVOC = semivolatile organic compound; GC/MS/MS= gas chromatography/tandem mass spectrometry

[b] Outdoor Fields (n=25); Indoor Fields (n=15)

[c] Statistical tests performed using ln-transformed measurement values

[d] NR = not reported; one or more measurement results were ≤0, precluding ln-transformed testing for the complete data set

[e] Sum15PAH = Sum of 15 of the 16 EPA 'priority' PAHs, including Acenaphthylene, Anthracene, Benz[a]anthracene, Benzo[a]pyrene, Benzo(b)fluoranthene, Benzo[ghi]perylene, Benzo(k)fluoranthene, Chrysene, Dibenz[a,h]anthracene, Fluoranthene, Fluorene, Indeno(1,2,3-cd)pyrene, Naphthalene, Phenanthrene, Pyrene

[f] DBA + ICDP = Sum of Dibenz[a,h]anthracene and Indeno(1,2,3-cd)pyrene

Table O-4. Comparison of VOC 25 °C Emission Factors for Tire Crumb Rubber Infill Collected at Outdoor and Indoor Synthetic Turf Fields[a,b]

Analyte	Outdoor Fields Mean (ng/g/h)	Outdoor Fields Standard Deviation (ng/g/h)	Indoor Fields Mean (ng/g/h)	Indoor Fields Standard Deviation (ng/g/h)	F-test p-value[c,d]
Benzothiazole	9.4	16	51	26	NR
o-Xylene	0.0024	0.068	0.081	0.10	NR
SumBTEX[e]	0.22	0.98	0.46	0.51	NR
Trichlorofluoromethane (Freon 11)	-0.15	0.63	0.35	0.61	NR
Dichlorodifluoromethane (Freon 12)	-0.027	0.040	-0.014	0.062	NR

[a] VOC = volatile organic compound; °C = degrees Celsius

[b] Outdoor Fields (n=24–25); Indoor Fields (n=13–15)

[c] Statistical tests performed using ln-transformed measurement values

[d] NR = not reported; one or more measurement results were ≤0, precluding ln-transformed testing for the complete data set

[e] SumBTEX = Sum of benzene, toluene, ethylbenzene, m/p-xylene, and o-xylene

Table O-5. Comparison of VOC 60 °C Emission Factors for Tire Crumb Rubber Infill Collected at Outdoor and Indoor Synthetic Turf Fields[a,b]

Analyte	Outdoor Fields Mean (ng/g/h)	Outdoor Fields Standard Deviation (ng/g/h)	Indoor Fields Mean (ng/g/h)	Indoor Fields Standard Deviation (ng/g/h)	F-test p-value[c,d]
Formaldehyde	12	5.7	23	10	NR
Metyl isobutyl ketone	28	16	68	20	<0.0001
Benzothiazole	35	31	95	9.6	<0.0001
Styrene	0.24	0.29	0.84	0.29	NR
Toluene	0.11	0.33	0.24	0.24	NR
Ethylbenzene	-0.12	0.20	-0.0059	0.26	NR
m/p-Xylene	0.043	0.97	0.61	0.97	NR
o-Xylene	-0.39	0.70	-0.27	0.60	NR
SumBTEX[e]	-0.44	2.2	0.58	2.1	NR
trans-2-Butene	-0.25	0.28	-0.26	0.16	NR
cis-2-Butene	-0.23	0.25	-0.24	0.15	NR
Tetrachloroethylene	-0.0013	0.033	0.012	0.027	NR
Chlorobenzene	0.0036	0.038	-0.015	0.088	NR
p-Dichlorobenzene	0.028	0.17	0.17	0.29	NR
Trichlorofluoromethane (Freon 11)	-0.12	0.60	0.44	0.57	NR
Dichlorodifluoromethane (Freon 12)	-0.0029	0.033	-0.009	0.047	NR

[a] VOC = volatile organic compound; °C = degrees Celsius

[b] Outdoor Fields (n=24–25); Indoor Fields (n=13–15)

[c] Statistical tests performed using ln-transformed measurement values

[d] NR = not reported; one or more measurement results were ≤0, precluding ln-transformed testing for the complete data set

[e] SumBTEX = Sum of benzene, toluene, ethylbenzene, m/p-xylene, and o-xylene

Table O-6. Comparison of SVOC 25 °C Emission Factors for Tire Crumb Rubber Infill Collected at Outdoor and Indoor Synthetic Turf Fields[a,b]

Analyte	Outdoor Fields Mean (ng/g/h)	Outdoor Fields Standard Deviation (ng/g/h)	Indoor Fields Mean (ng/g/h)	Indoor Fields Standard Deviation (ng/g/h)	F-test p-value [c,d]
Phenanthrene	0.017	0.05	0.038	0.045	NR
Sum15PAH[e]	0.56	0.56	0.72	0.74	0.323
Benzothiazole	1.5	2.6	8.7	5.3	NR
Dibutyl phthalate	0.088	0.36	-0.18	0.36	NR
Aniline	0.088	0.20	0.77	0.42	NR
4-tert-octylphenol	0.65	3.2	1.2	3.5	NR
Naphthalene	0.087	0.24	0.23	0.52	NR
1-Methylnaphthalene	0.0055	0.035	0.082	0.13	NR
2-Methylnaphthalene	0.0084	0.071	0.16	0.24	NR
Fluorene	0.0026	0.013	0.025	0.020	NR
n-Butylbenzene	-0.0019	0.025	0.053	0.19	NR
Diisobutyl phthalate	0.046	0.24	-0.039	0.23	NR

[a] SVOC = semivolatile organic compound; °C = degrees Celsius

[b] Outdoor Fields (n=25); Indoor Fields (n=15)

[c] Statistical tests performed using ln-transformed measurement values

[d] NR = not reported; one or more measurement results were ≤0, precluding ln-transformed testing for the complete data set

[e] Sum15PAH = Sum of 15 of the 16 EPA 'priority' PAHs, including Acenaphthylene, Anthracene, Benz[a]anthracene, Benzo[a]pyrene, Benzo(b)fluoranthene, Benzo[ghi]perylene, Benzo(k)fluoranthene, Chrysene, Dibenz[a,h]anthracene, Fluoranthene, Fluorene, Indeno(1,2,3-cd)pyrene, Naphthalene, Phenanthrene, Pyrene

Table O-7. Comparison of SVOC 60 °C Emission Factors for Tire Crumb Rubber Infill Collected at Outdoor and Indoor Synthetic Turf Fields[a,b]

Analyte	Outdoor Fields Mean (ng/g/h)	Outdoor Fields Standard Deviation (ng/g/h)	Indoor Fields Mean (ng/g/h)	Indoor Fields Standard Deviation (ng/g/h)	F-test p-value [c,d]
Phenanthrene	0.17	0.22	1.2	0.75	NR
Fluoranthene	0.11	0.085	0.23	0.11	NR
Pyrene	0.20	0.14	0.44	0.24	NR
Sum15PAH[e]	1.0	0.65	3.6	2.1	<0.0001
Benzothiazole	9.7	11	74	64	NR
Dibutyl phthalate	0.11	0.43	0.2	0.39	NR
Aniline	0.79	1.0	8.0	6.1	NR
4-tert-octylphenol	2.9	3.1	11	5.0	NR
Naphthalene	-0.23	0.50	0.022	0.63	NR
1-Methylnaphthalene	0.0092	0.053	0.62	0.92	NR
2-Methylnaphthalene	0.0081	0.084	1.2	1.9	NR
Acenaphthylene	0.026	0.034	0.23	0.25	NR
Fluorene	0.026	0.041	0.46	0.47	NR
1-Methylphenanthrene	0.074	0.063	0.26	0.13	NR
2-Methylphenanthrene	0.092	0.10	0.46	0.32	NR
3-Methylphenanthrene	0.17	0.19	0.71	0.52	NR
Dibenzothiophene	0.020	0.025	0.20	0.12	NR
n-Butylbenzene	-0.010	0.015	0.0075	0.038	NR
Dimethyl phthalate	0.0011	0.0097	0.040	0.030	NR
Diisobutyl phthalate	0.022	0.28	0.25	0.30	NR

[a] SVOC = semivolatile organic compound; °C = degrees Celsius

[b] Outdoor Fields (n=25); Indoor Fields (n=15)

[c] Statistical tests performed using ln-transformed measurement values

[d] NR = not reported; one or more measurement results were ≤0, precluding ln-transformed testing for the complete data set

[e] Sum15PAH = Sum of 15 of the 16 EPA ‘priority’ PAHs, including Acenaphthylene, Anthracene, Benz[a]anthracene, Benzo[a]pyrene, Benzo(b)fluoranthene, Benzo[ghi]perylene, Benzo(k)fluoranthene, Chrysene, Dibenz[a,h]anthracene, Fluoranthene, Fluorene, Indeno(1,2,3-cd)pyrene, Naphthalene, Phenanthrene, Pyrene

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Appendix P

Tire Crumb Rubber Measurement Results – Differences Among Synthetic Turf Fields with Different Installation Ages

Table P-1. Comparison of Metals Analyzed by ICP/MS in Tire Crumb Rubber Infill Collected from Synthetic Turf Fields in Three Field Installation Age Groups[a,b]

Analyte	2004–2008 Mean (mg/kg)	2004–2008 Standard Deviation (mg/kg)	2009–2012 Mean (mg/kg)	2009–2012 Standard Deviation (mg/kg)	2013–2016 Mean (mg/kg)	2013–2016 Standard Deviation (mg/kg)	F-test p-value[c,d]
Arsenic	0.39	0.15	0.42	0.25	0.30	0.10	0.4723
Cadmium	0.97	0.45	1.1	0.91	0.72	0.37	0.3463
Chromium	1.8	1.0	1.7	0.79	1.3	0.68	NR
Cobalt	150	46	100	56	170	56	0.0006
Lead	33	42	25	20	13	4.6	0.079
Zinc	15000	2700	14000	2600	16000	3400	0.0501
Aluminum	1200	550	1500	840	1100	720	0.4202
Antimony	0.95	0.57	0.99	0.37	0.90	0.38	0.8238
Barium	9.1	5.7	7.9	3.2	8.4	7.6	0.6328
Beryllium	0.0014	0.029	0.013	0.028	0.0057	0.036	NR
Copper	26	13	22	12	30	11	0.1642
Iron	590	320	580	380	660	520	0.9428
Magnesium	380	340	280	100	360	260	0.4142
Manganese	7.8	2.7	7.4	4.4	8.2	8.0	0.7714
Molybdenum	0.17	0.069	0.16	0.068	0.14	0.054	0.7477
Nickel	2.6	0.78	2.8	0.99	2.6	0.87	0.937
Rubidium	1.8	0.34	1.8	0.67	2.1	0.61	0.3395
Strontium	3.7	1.3	3.5	1.7	3	1.0	0.3637
Tin	1.5	1.1	1.8	1.1	1.3	1.0	NR
Vanadium	1.8	0.66	2	1.0	1.7	0.86	NR

[a] ICP/MS = inductively coupled plasma/mass spectrometry

[b] Fields installed 2004–2008 (n=11); 2009–2012 (n=18); 2013–2016 (n=11)

[c] Statistical tests performed using ln-transformed measurement values

[d] NR = not reported; one or more measurement results were ≤0, precluding ln-transformed testing for the complete data set.

Table P-2. Comparison of Metals Analyzed by XRF in Tire Crumb Rubber Infill Collected from Synthetic Turf Fields in Three Field Installation Age Groups[a,b]

Analyte	2004–2008 Mean (mg/kg)	2004–2008 Standard Deviation (mg/kg)	2009–2012 Mean (mg/kg)	2009–2012 Standard Deviation (mg/kg)	2013–2016 Mean (mg/kg)	2013–2016 Standard Deviation (mg/kg)	F-test p-value[c]
Chromium	14	2.7	13	3.2	15	2.3	0.1121
Cobalt	39	16	32	16	49	17	0.0629
Lead	38	26	41	24	27	12	0.2297
Zinc	33000	7200	31000	6300	37000	7500	0.1074
Barium	60	14	64	17	52	13	0.0958
Copper	120	40	110	36	150	51	0.0389
Iron	1400	840	1200	410	1100	370	0.6262
Molybdenum	42	17	49	12	48	12	0.1688
Rubidium	50	22	50	17	72	45	0.3837
Strontium	18	18	12	7.4	13	15	0.391

[a] XRF = X-ray fluorescence spectrometry

[b] Fields installed 2004–2008 (n=11); 2009–2012 (n=18); 2013–2016 (n=11)

[c] Statistical tests performed using ln-transformed measurement values.

Table P-3. Comparison of SVOCs in Extracts Analyzed by GC/MS/MS in Tire Crumb Rubber Infill Collected from Synthetic Turf Fields in Three Field Installation Age Groups[a,b]

Analyte	2004–2008 Mean (mg/kg)	2004–2008 Standard Deviation (mg/kg)	2009–2012 Mean (mg/kg)	2009–2012 Standard Deviation (mg/kg)	2013–2016 Mean (mg/kg)	2013–2016 Standard Deviation (mg/kg)	F-test p-value[c,d]
Phenanthrene	2.1	2.2	3.0	3.3	1.3	0.93	0.389
Fluoranthene	3.6	2.6	5.1	2.9	4.5	1.7	0.1098
Pyrene	11	7.8	14	6.6	12	2.9	0.2171
Benzo[a]pyrene	0.59	0.24	0.95	0.62	0.68	0.48	0.0531
Benzo[ghi]perylene	1.4	0.7	1.5	0.59	0.88	0.47	0.0232
Sum15PAH[e]	25	16	33	17	26	8.2	0.2033
Benzothiazole	7.5	7.2	12	16	12	12	0.4355
Dibutyl phthalate	1.9	2.1	1.5	1.4	1.1	0.84	0.8196
Bis(2-ethylhexyl) phthalate	61	60	45	34	20	21	0.0215
Aniline	0.55	0.37	0.81	0.71	0.58	0.25	0.563
4-tert-octylphenol	11	11	12	11	5.0	2.4	0.4372
n-Hexadecane	0.95	0.85	1.3	1.7	0.43	0.41	0.5861
Naphthalene	0.029	0.024	0.047	0.056	0.017	0.011	0.1423
1-Methylnaphthalene	0.039	0.041	0.079	0.14	0.014	0.016	0.3953
2-Methylnaphthalene	0.058	0.057	0.14	0.24	0.023	0.023	0.254
Acenaphthylene	0.036	0.033	0.061	0.078	0.031	0.019	0.7372
Fluorene	0.17	0.23	0.26	0.37	0.069	0.075	0.605
Anthracene	0.46	0.59	0.75	0.97	0.21	0.16	0.3112
1-Methylphenanthrene	1.4	1.3	2.0	1.6	1.1	0.53	0.2175
2-Methylphenanthrene	2.4	2.4	4.0	6.4	1.9	1.9	0.5348
3-Methylphenanthrene	1.9	1.7	2.9	2.7	1.8	1.1	0.292

Table P-3 Continued

Analyte	2004–2008 Mean (mg/kg)	2004–2008 Standard Deviation (mg/kg)	2009–2012 Mean (mg/kg)	2009–2012 Standard Deviation (mg/kg)	2013–2016 Mean (mg/kg)	2013–2016 Standard Deviation (mg/kg)	F-test p-value [c,d]
Benz(a)anthracene	2.1	1.2	2.4	1.6	2.0	1.3	0.8282
Chrysene	1.7	1.3	3.2	1.9	2.3	1.8	0.0776
Benzo(b)fluoranthene	1.1	0.58	1.6	0.82	1.2	0.91	0.1455
Benzo(k)fluoranthene	0.36	0.24	0.53	0.30	0.42	0.37	0.1254
Benzo(e)pyrene	1.6	0.8	2.3	0.97	1.6	1.0	0.0888
DBA + ICDP[f]	0.51	0.31	0.60	0.34	0.48	0.29	0.7038
Coronene	0.56	0.35	0.62	0.29	0.39	0.27	0.0562
Dibenzothiophene	0.29	0.29	0.41	0.44	0.17	0.12	0.3689
Dimethyl phthalate	0.011	0.015	0.049	0.087	0.0072	0.0067	NR
Diethyl phthalate	0.17	0.25	1.0	3.5	0.018	0.085	NR
Diisobutyl phthalate	1.3	1.6	1.5	2.3	0.67	0.56	0.6687
Benzyl butyl phthalate	1.9	3.4	0.94	1.1	0.79	0.49	0.7288
Di-n-octyl phthalate	0.35	0.35	0.22	0.14	0.19	0.20	NR
Bis(2,2,6,6-tetramethyl-4-piperidyl) sebacate	0.26	0.18	0.99	1.0	0.99	0.93	NR
Cyclohexylisothiocyanate	0.25	0.15	0.27	0.25	0.21	0.066	NR

[a] SVOC = semivolatile organic compound; GC/MS/MS= gas chromatography/tandem mass spectrometry

[b] Fields installed 2004–2008 (n=11); 2009–2012 (n=18); 2013–2016 (n=11)

[c] Statistical tests performed using ln-transformed measurement values

[d] NR = not reported; one or more measurement results were ≤0, precluding ln-transformed testing for the complete data set [e] Sum15PAH = Sum of 15 of the 16 EPA 'priority' PAHs, including Acenaphthylene, Anthracene, Benz[a]anthracene, Benzo[a]pyrene, Benzo(b)fluoranthene, Benzo[ghi]perylene, Benzo(k)fluoranthene, Chrysene, Dibenz[a,h]anthracene, Fluoranthene, Fluorene, Indeno(1,2,3-cd)pyrene, Naphthalene, Phenanthrene, Pyrene

[f] DBA + ICDP = Sum of Dibenz[a,h]anthracene and Indeno(1,2,3-cd)pyrene

Table P-4. Comparison of VOC 25 °C Emission Factor Results for Tire Crumb Rubber Infill Collected from Synthetic Turf Fields in Three Field Installation Age Groups[a,b]

Analyte	2004–2008 Mean (ng/g/h)	2004–2008 Standard Deviation (ng/g/h)	2009–2012 Mean (ng/g/h)	2009–2012 Standard Deviation (ng/g/h)	2013–2016 Mean (ng/g/h)	2013–2016 Standard Deviation (ng/g/h)	F-test p-value [c,d]
Benzothiazole	25	26	26	34	22	22	NR
o-Xylene	0.054	0.083	0.042	0.11	-0.012	0.053	NR
SumBTEX[e]	0.25	0.91	0.39	0.72	0.22	1.0	NR
Trichlorofluoromethane (Freon 11)	0.32	0.66	0.069	0.66	-0.34	0.55	NR
Dichlorodifluoromethane (Freon 12)	-0.035	0.061	-0.014	0.033	-0.022	0.059	NR

[a] VOC = volatile organic compound; °C = degrees Celsius

[b] Fields installed 2004–2008 (n=11); 2009–2012 (n=18); 2013–2016 (n=11)

[c] Statistical tests performed using ln-transformed measurement values

[d] NR = not reported; one or more measurement results were ≤0, precluding ln-transformed testing for the complete data set

[e] SumBTEX = Sum of benzene, toluene, ethylbenzene, m/p-xylene, and o-xylene

Table P-5. Comparison of VOC 60 °C Emission Factor Results for Tire Crumb Rubber Infill Collected from Synthetic Turf Fields in Three Field Installation Age Groups[a,b]

Analyte	2004–2008 Mean (ng/g/h)	2004–2008 Standard Deviation (ng/g/h)	2009–2012 Mean (ng/g/h)	2009–2012 Standard Deviation (ng/g/h)	2013–2016 Mean (ng/g/h)	2013–2016 Standard Deviation (ng/g/h)	F-test p-value [c,d]
Formaldehyde	17	5.6	18	13	13	3.7	NR
Metyl isobutyl ketone	50	29	39	27	40	20	0.5356
Benzothiazole	63	44	49	40	59	34	0.8176
Styrene	0.53	0.39	0.51	0.46	0.26	0.28	NR
Toluene	0.092	0.16	0.14	0.31	0.25	0.42	NR
Ethylbenzene	-0.11	0.22	-0.067	0.24	-0.071	0.23	NR
m/p-Xylene	0.29	1.1	0.33	1.1	0.059	0.82	NR
o-Xylene	-0.30	0.75	-0.28	0.70	-0.52	0.51	NR
SumBTEX[e]	-0.26	2.0	0.055	2.5	-0.11	2.0	NR
trans-2-Butene	-0.34	0.18	-0.19	0.25	-0.27	0.27	NR
cis-2-Butene	-0.31	0.16	-0.18	0.22	-0.24	0.25	NR
Tetrachloroethylene	0.011	0.044	0.00032	0.029	0.00069	0.02	NR
Chlorobenzene	-0.015	0.062	0.013	0.067	-0.014	0.04	NR
p-Dichlorobenzene	0.08	0.22	0.073	0.28	0.086	0.15	NR
Trichlorofluoromethane (Freon 11)	0.36	0.65	0.12	0.61	-0.31	0.52	NR
Dichlorodifluoromethane (Freon 12)	-0.016	0.050	0.0027	0.040	-0.0054	0.013	NR

[a] VOC = volatile organic compound; °C = degrees Celsius

[b] Fields installed 2004–2008 (n=11); 2009–2012 (n=18); 2013–2016 (n=11)

[c] Statistical tests performed using ln-transformed measurement values

[d] NR = not reported; one or more measurement results were ≤0, precluding ln-transformed testing for the complete data set

[e] SumBTEX = Sum of benzene, toluene, ethylbenzene, m/p-xylene, and o-xylene

Table P-6. Comparison of SVOC 25 °C Emission Factor Results for Tire Crumb Rubber Infill Collected from Synthetic Turf Fields in Three Field Installation Age Groups[a,b]

Analyte	2004–2008 Mean (ng/g/h)	2004–2008 Standard Deviation (ng/g/h)	2009–2012 Mean (ng/g/h)	2009–2012 Standard Deviation (ng/g/h)	2013–2016 Mean (ng/g/h)	2013–2016 Standard Deviation (ng/g/h)	F-test p-value [c,d]
Phenanthrene	0.027	0.035	0.032	0.045	0.012	0.066	NR
Sum15PAH[e]	0.73	0.83	0.58	0.55	0.58	0.56	0.7377
Benzothiazole	3.7	4.5	5.2	6.3	3.2	3.5	NR
Dibutyl phthalate	-0.031	0.25	0.029	0.42	-0.056	0.43	NR
Aniline	0.46	0.53	0.34	0.48	0.24	0.26	NR
4-tert-octylphenol	0.12	0.15	0.9	3.3	1.5	4.8	NR
Naphthalene	0.28	0.57	0.096	0.27	0.067	0.24	NR
1-Methylnaphthalene	0.043	0.036	0.050	0.13	-0.0015	0.036	NR
2-Methylnaphthalene	0.088	0.084	0.098	0.23	-0.014	0.074	NR
Fluorene	0.012	0.016	0.017	0.023	0.00006	0.011	NR
n-Butylbenzene	-0.00027	0.0089	0.046	0.17	-0.0074	0.028	NR
Diisobutyl phthalate	-0.074	0.13	0.087	0.26	-0.018	0.26	NR

[a] SVOC = semivolatile organic compound; °C = degrees Celsius

[b] Fields installed 2004–2008 (n=11); 2009–2012 (n=18); 2013–2016 (n=11)

[c] Statistical tests performed using ln-transformed measurement values

[d] NR = not reported; one or more measurement results were ≤0, precluding ln-transformed testing for the complete data set

[e] Sum15PAH = Sum of 15 of the 16 EPA 'priority' PAHs, including Acenaphthylene, Anthracene, Benz[a]anthracene, Benzo[a]pyrene, Benzo(b)fluoranthene, Benzo[ghi]perylene, Benzo(k)fluoranthene, Chrysene, Dibenz[a,h]anthracene, Fluoranthene, Fluorene, Indeno(1,2,3-cd)pyrene, Naphthalene, Phenanthrene, Pyrene

Table P-7. Comparison of SVOC 60 °C Emission Factor Results for Tire Crumb Rubber Infill Collected from Synthetic Turf Fields in Three Field Installation Age Groups[a,b]

Analyte	2004–2008 Mean (ng/g/h)	2004–2008 Standard Deviation (ng/g/h)	2009–2012 Mean (ng/g/h)	2009–2012 Standard Deviation (ng/g/h)	2013–2016 Mean (ng/g/h)	2013–2016 Standard Deviation (ng/g/h)	F-test p-value [c,d]
Phenanthrene	0.46	0.51	0.81	0.93	0.31	0.27	NR
Fluoranthene	0.13	0.10	0.19	0.13	0.13	0.088	NR
Pyrene	0.21	0.20	0.35	0.24	0.27	0.15	NR
Sum15PAH[e]	1.6	1.2	2.6	2.5	1.4	0.77	0.2777
Benzothiazole	21	25	51	69	18	14	NR
Dibutyl phthalate	0.048	0.21	0.19	0.52	0.17	0.39	NR
Aniline	3.0	3.7	5.0	6.8	1.5	1.4	NR
4-tert-octylphenol	5.7	6.2	6.9	6.3	4.2	2.9	NR
Naphthalene	-0.14	0.51	-0.00068	0.57	-0.35	0.58	NR
1-Methylnaphthalene	0.13	0.16	0.43	0.90	0.033	0.057	NR
2-Methylnaphthalene	0.21	0.28	0.88	1.9	0.039	0.072	NR
Acenaphthylene	0.067	0.064	0.15	0.25	0.049	0.043	NR
Fluorene	0.14	0.16	0.30	0.49	0.056	0.053	NR
1-Methylphenanthrene	0.13	0.12	0.19	0.16	0.094	0.069	NR
2-Methylphenanthrene	0.17	0.18	0.32	0.36	0.14	0.14	NR
3-Methylphenanthrene	0.25	0.26	0.52	0.57	0.24	0.24	NR
Dibenzothiophene	0.075	0.076	0.12	0.15	0.037	0.033	NR
n-Butylbenzene	0.0014	0.030	-0.0046	0.032	-0.0073	0.014	NR
Dimethyl phthalate	0.016	0.027	0.021	0.032	0.0067	0.019	NR
Diisobutyl phthalate	0.074	0.26	0.16	0.35	0.055	0.29	NR

[a] SVOC = semivolatile organic compound; °C = degrees Celsius

[b] Fields installed 2004–2008 (n=11); 2009–2012 (n=18); 2013–2016 (n=11)

[c] Statistical tests performed using ln-transformed measurement values

[d] NR = not reported; one or more measurement results were ≤0, precluding ln-transformed testing for the complete data set

[e] Sum15PAH = Sum of 15 of the 16 EPA ‘priority’ PAHs, including Acenaphthylene, Anthracene, Benz[a]anthracene, Benzo[a]pyrene, Benzo(b)fluoranthene, Benzo[ghi]perylene, Benzo(k)fluoranthene, Chrysene, Dibenz[a,h]anthracene, Fluoranthene, Fluorene, Indeno(1,2,3-cd)pyrene, Naphthalene, Phenanthrene, Pyrene

Table P-8. Comparison of Metals Analyzed by ICP/MS in Tire Crumb Rubber Infill Collected from Outdoor Synthetic Turf Fields in Three Field Installation Age Groups[a,b]

Analyte	2004–2008 Mean (mg/kg)	2004–2008 Standard Deviation (mg/kg)	2009–2012 Mean (mg/kg)	2009–2012 Standard Deviation (mg/kg)	2013–2016 Mean (mg/kg)	2013–2016 Standard Deviation (mg/kg)	F-test p-value [c,d]
Arsenic	0.43	0.12	0.46	0.22	0.29	0.094	0.0618
Cadmium	0.96	0.30	0.94	0.56	0.73	0.39	0.3877
Chromium	2.1	0.83	1.9	0.98	1.3	0.71	NR
Cobalt	160	45	87	29	170	59	0.0002
Lead	22	4.1	25	20	13	4.7	0.09
Zinc	13000	1700	13000	2800	17000	3400	0.02
Aluminum	1400	680	1700	880	1100	750	0.1507
Antimony	0.80	0.60	0.95	0.41	0.92	0.39	0.6376
Barium	8.6	2.9	9.0	3.3	8.3	8.0	0.3767
Beryllium	0.014	0.0081	0.016	0.038	0.0037	0.037	NR
Copper	26	8.7	21	9.8	31	11	0.0539
Iron	830	310	700	460	670	550	0.4439
Magnesium	280	48	300	120	360	270	0.765
Manganese	8.8	2.9	8.7	5.6	8.2	8.4	0.5984
Molybdenum	0.16	0.053	0.16	0.085	0.14	0.057	0.7452
Nickel	2.6	0.88	2.4	0.76	2.5	0.84	0.9051
Rubidium	1.8	0.38	2.1	0.74	2.0	0.62	0.8065
Strontium	3.6	1.0	3.8	2.2	3.0	1.1	0.4458
Tin	1.3	0.61	1.9	1.4	1.4	1.0	NR
Vanadium	2.1	0.83	2.1	1.3	1.7	0.9	NR

[a] ICP/MS = inductively coupled plasma/mass spectrometry

[b] Outdoor fields installed 2004–2008 (n=5); 2009–2012 (n=10); 2013–2016 (n=10)

[c] Statistical tests performed using ln-transformed measurement values

[d] NR = not reported; one or more measurement results were ≤0, precluding ln-transformed testing for the complete data set

Table P-9. Comparison of Metals Analyzed by XRF in Tire Crumb Rubber Infill Collected from Outdoor Synthetic Turf Fields in Three Field Installation Age Groups[a,b]

Analyte	2004–2008 Mean (mg/kg)	2004–2008 Standard Deviation (mg/kg)	2009-2012 Mean (mg/kg)	2009-2012 Standard Deviation (mg/kg)	2013–2016 Mean (mg/kg)	2013–2016 Standard Deviation (mg/kg)	F-test p-value[c]
Chromium	14	1.7	13	3.9	14	2.4	0.2588
Cobalt	38	14	33	16	49	18	0.1183
Lead	29	13	38	14	26	12	0.1714
Zinc	29000	7400	30000	6800	37000	7900	0.0534
Barium	63	18	64	19	48	4.3	0.0541
Copper	100	31	110	34	150	51	0.0237
Iron	1800	1100	1300	470	1100	390	0.2264
Molybdenum	32	19	52	14	49	11	0.0077
Rubidium	46	28	54	19	70	46	0.5513
Strontium	27	24	15	8.8	8.4	2.7	0.014

[a] XRF = X-ray fluorescence spectrometry

[b] Outdoor fields installed 2004–2008 (n=5); 2009–2012 (n=10); 2013–2016 (n=10)

[c] Statistical tests performed using ln-transformed measurement values

Table P-10. Comparison of SVOCs in Extracts Analyzed by GC/MS/MS in Tire Crumb Rubber Infill Collected from Outdoor Synthetic Turf Fields in Three Field Installation Age Groups[a,b]

Analyte	2004–2008 Mean (mg/kg)	2004–2008 Standard Deviation (mg/kg)	2009-2012 Mean (mg/kg)	2009-2012 Standard Deviation (mg/kg)	2013–2016 Mean (mg/kg)	2013–2016 Standard Deviation (mg/kg)	F-test p-value [c,d]
Phenanthrene	0.18	0.13	0.64	0.44	1.2	0.87	0.0001
Fluoranthene	1.4	0.71	3.5	2.5	4.6	1.8	0.0002
Pyrene	3.5	0.74	8.6	2.8	12	2.8	<0.0001
Benzo[a]pyrene	0.46	0.12	0.73	0.26	0.70	0.51	0.2415
Benzo[ghi]perylene	1.1	0.41	1.4	0.54	0.84	0.48	0.07
Sum15PAH[e]	11	3.8	22	8.7	25	8.5	0.0004
Benzothiazole	1.0	0.58	2.3	1.4	11	13	0.0002
Dibutyl phthalate	0.074	0.043	0.58	0.70	0.95	0.72	0.0034
Bis(2-ethylhexyl) phthalate	33	34	41	29	15	16	0.029
Aniline	0.18	0.10	0.31	0.18	0.54	0.23	0.0005
4-tert-octylphenol	1.1	1.2	3.6	1.9	4.6	2.0	0.0001
n-Hexadecane	0.13	0.027	0.11	0.067	0.33	0.27	0.0212
Naphthalene	0.0088	0.006	0.015	0.0059	0.015	0.01	0.1061
1-Methylnaphthalene	0.0035	0.0023	0.0057	0.0022	0.014	0.017	0.0708
2-Methylnaphthalene	0.0083	0.0055	0.013	0.0051	0.022	0.024	0.2075
Acenaphthylene	0.0079	0.0021	0.013	0.0068	0.032	0.020	0.0002
Fluorene	0.0065	0.0042	0.027	0.031	0.061	0.074	0.0039
Anthracene	0.033	0.021	0.14	0.13	0.18	0.14	0.0012
1-Methylphenanthrene	0.29	0.15	1.0	0.76	1.0	0.49	0.0009
2-Methylphenanthrene	0.45	0.22	1.1	0.58	1.8	2.0	0.0259

Table P-10 Continued

Analyte	2004–2008 Mean (mg/kg)	2004–2008 Standard Deviation (mg/kg)	2009-2012 Mean (mg/kg)	2009-2012 Standard Deviation (mg/kg)	2013–2016 Mean (mg/kg)	2013–2016 Standard Deviation (mg/kg)	F-test p-value [c,d]
3-Methylphenanthrene	0.36	0.14	1.3	1.3	1.6	0.95	0.0007
Benz(a)anthracene	1.6	1.1	2.4	1.4	2.2	1.3	0.4013
Chrysene	1.1	0.60	2.3	1.8	2.2	1.9	0.2017
Benzo(b)fluoranthene	0.81	0.44	1.3	0.62	1.2	0.96	0.2939
Benzo(k)fluoranthene	0.23	0.19	0.40	0.21	0.43	0.39	0.1316
Benzo(e)pyrene	1.2	0.44	1.9	0.87	1.6	1.1	0.3032
DBA + ICDP[f]	0.46	0.32	0.50	0.34	0.46	0.29	0.9801
Coronene	0.41	0.19	0.58	0.32	0.34	0.24	0.1236
Dibenzothiophene	0.017	0.013	0.081	0.057	0.15	0.11	<0.0001
Dimethyl phthalate	0.0014	0.0024	0.0040	0.0091	0.006	0.0056	NR
Diethyl phthalate	0.003	0.0041	-0.0066	0.011	-0.0079	0.0097	NR
Diisobutyl phthalate	0.043	0.017	0.35	0.34	0.53	0.33	0.0001
Benzyl butyl phthalate	0.056	0.041	0.38	0.34	0.69	0.39	0.0002
Di-n-octyl phthalate	0.053	0.049	0.15	0.11	0.15	0.15	NR
Bis(2,2,6,6-tetramethyl-4-piperidyl) sebacate	0.30	0.22	1.2	1.2	1.1	0.92	NR
Cyclohexylisothiocyanate	0.15	0.14	0.11	0.11	0.20	0.067	NR

[a] SVOC = semivolatile organic compound; GC/MS/MS= gas chromatography/tandem mass spectrometry

[b] Outdoor fields installed 2004–2008 (n=5); 2009–2012 (n=10); 2013–2016 (n=10)

[c] Statistical tests performed using ln-transformed measurement values

[d] NR = not reported; one or more measurement results were ≤0, precluding ln-transformed testing for the complete data set

[e] Sum15PAH = Sum of 15 of the 16 EPA 'priority' PAHs, including Acenaphthylene, Anthracene, Benz[a]anthracene, Benzo[a]pyrene, Benzo(b)fluoranthene, Benzo[ghi]perylene, Benzo(k)fluoranthene, Chrysene, Dibenz[a,h]anthracene, Fluoranthene, Fluorene, Indeno(1,2,3-cd)pyrene, Naphthalene, Phenanthrene, Pyrene

[f] DBA + ICDP = Sum of Dibenz[a,h]anthracene and Indeno(1,2,3-cd)pyrene

Table P-11. Comparison of VOC 25 °C Emission Factor Results for Tire Crumb Rubber Infill Collected from Outdoor Synthetic Turf Fields in Three Field Installation Age Groups[a,b]

Analyte	2004–2008 Mean (mg/kg)	2004–2008 Standard Deviation (mg/kg)	2009-2012 Mean (mg/kg)	2009-2012 Standard Deviation (mg/kg)	2013–2016 Mean (mg/kg)	2013–2016 Standard Deviation (mg/kg)	F-test p-value [c,d]
Benzothiazole	2.6	6.0	3.5	4	20	23	NR
o-Xylene	0.073	0.10	-0.012	0.041	-0.021	0.047	NR
SumBTEX[e]	0.47	1.4	0.11	0.77	0.19	1.1	NR
Trichlorofluoromethane (Freon 11)	0.11	0.70	-0.013	0.7	-0.46	0.44	NR
Dichlorodifluoromethane (Freon 12)	-0.016	0.031	-0.029	0.029	-0.030	0.055	NR

[a] VOC = volatile organic compound; °C = degrees Celsius

[b] Outdoor fields installed 2004–2008 (n=5); 2013–2016 (n=9–10)

[c] Statistical tests performed using ln-transformed measurement values

[d] NR = not reported; one or more measurement results were ≤0, precluding ln-transformed testing for the complete data set

[e] SumBTEX = Sum of benzene, toluene, ethylbenzene, m/p-xylene, and o-xylene

Table P-12. Comparison of VOC 60 °C Emission Factor Results for Tire Crumb Rubber Infill Collected from Outdoor Synthetic Turf Fields in Three Field Installation Age Groups[a,b]

Analyte	2004–2008 Mean (mg/kg)	2004–2008 Standard Deviation (mg/kg)	2009-2012 Mean (mg/kg)	2009-2012 Standard Deviation (mg/kg)	2013–2016 Mean (mg/kg)	2013–2016 Standard Deviation (mg/kg)	F-test p-value [c,d]
Formaldehyde	15	7.7	10	6.3	12	3.3	NR
Metyl isobutyl ketone	22	5.3	22	8.4	39	21	0.061
Benzothiazole	27	41	20	14	55	33	0.0709
Styrene	0.27	0.32	0.26	0.36	0.20	0.21	NR
Toluene	0.073	0.21	-0.013	0.24	0.27	0.44	NR
Ethylbenzene	-0.14	0.19	-0.13	0.22	-0.11	0.21	NR
m/p-Xylene	0.14	1.3	0.11	1.1	-0.089	0.71	NR
o-Xylene	-0.18	1.0	-0.3	0.74	-0.62	0.44	NR
SumBTEX[e]	-0.45	2.4	-0.51	2.5	-0.36	1.9	NR
trans-2-Butene	-0.35	0.19	-0.17	0.31	-0.29	0.28	NR
cis-2-Butene	-0.31	0.17	-0.16	0.27	-0.26	0.26	NR
Tetrachloroethylene	0.022	0.065	-0.014	0.011	0.00008	0.022	NR
Chlorobenzene	0.029	0.059	0.00089	0.023	-0.0074	0.036	NR
p-Dichlorobenzene	0.000017	0.26	0.0074	0.14	0.067	0.15	NR
Trichlorofluoromethane (Freon 11)	0.12	0.61	0.037	0.67	-0.42	0.40	NR
Dichlorodifluoromethane (Freon 12)	-0.0065	0.017	0.0022	0.050	-0.0067	0.013	NR

[a] VOC = volatile organic compound; °C = degrees Celsius

[b] Outdoor fields installed 2004–2008 (n=5); 2009–2012 (n=10); 2013–2016 (n=9–10)

[c] Statistical tests performed using ln-transformed measurement values

[d] NR = not reported; one or more measurement results were ≤0, precluding ln-transformed testing for the complete data set

[e] SumBTEX = Sum of benzene, toluene, ethylbenzene, m/p-xylene, and o-xylene

Table P-13. Comparison of SVOC 25 °C Emission Factor Results for Tire Crumb Rubber Infill Collected from Outdoor Synthetic Turf Fields in Three Field Installation Age Groups[a,b]

Analyte	2004–2008 Mean (mg/kg)	2004–2008 Standard Deviation (mg/kg)	2009-2012 Mean (mg/kg)	2009-2012 Standard Deviation (mg/kg)	2013–2016 Mean (mg/kg)	2013–2016 Standard Deviation (mg/kg)	F-test p-value [c,d]
Phenanthrene	0.0064	0.023	0.027	0.038	0.013	0.070	NR
Sum15PAH[e]	0.63	0.29	0.49	0.67	0.61	0.58	0.3117
Benzothiazole	0.065	0.14	0.70	0.46	3.1	3.7	NR
Dibutyl phthalate	0.076	0.34	0.16	0.38	0.021	0.37	NR
Aniline	0.011	0.065	0.00092	0.084	0.21	0.26	NR
4-tert-octylphenol	0.010	0.044	0.0012	0.12	1.6	5.0	NR
Naphthalene	0.16	0.13	0.071	0.27	0.067	0.26	NR
1-Methylnaphthalene	0.035	0.044	0.00011	0.020	-0.0039	0.037	NR
2-Methylnaphthalene	0.069	0.090	0.0052	0.033	-0.019	0.075	NR
Fluorene	0.0037	0.019	0.0047	0.011	0.00002	0.012	NR
n-Butylbenzene	0.00050	0.010	0.0045	0.026	-0.0095	0.028	NR
Diisobutyl phthalate	-0.042	0.18	0.13	0.23	0.0041	0.27	NR

[a] SVOC = semivolatile organic compound; °C = degrees Celsius

[b] Outdoor fields installed 2004–2008 (n=5); 2009–2012 (n=10); 2013–2016 (n=10)

[c] Statistical tests performed using ln-transformed measurement values

[d] NR = not reported; one or more measurement results were ≤0, precluding ln-transformed testing for the complete data set

[e] Sum15PAH = Sum of 15 of the 16 EPA 'priority' PAHs, including Acenaphthylene, Anthracene, Benz[a]anthracene, Benzo[a]pyrene, Benzo(b)fluoranthene, Benzo[ghi]perylene, Benzo(k)fluoranthene, Chrysene, Dibenz[a,h]anthracene, Fluoranthene, Fluorene, Indeno(1,2,3-cd)pyrene, Naphthalene, Phenanthrene, Pyrene

Table P-14. Comparison of SVOC 60 °C Emission Factor Results for Tire Crumb Rubber Infill Collected from <u>Outdoor</u> Synthetic Turf Fields in Three Field Installation Age Groups[a,b]

Analyte	2004–2008 Mean (mg/kg)	2004–2008 Standard Deviation (mg/kg)	2009-2012 Mean (mg/kg)	2009-2012 Standard Deviation (mg/kg)	2013–2016 Mean (mg/kg)	2013–2016 Standard Deviation (mg/kg)	F-test p-value [c,d]
Phenanthrene	0.0023	0.095	0.15	0.17	0.28	0.27	NR
Fluoranthene	0.059	0.037	0.11	0.091	0.13	0.092	NR
Pyrene	0.12	0.050	0.19	0.13	0.26	0.16	NR
Sum15PAH[e]	0.54	0.029	0.97	0.48	1.3	0.80	0.0774
Benzothiazole	2.4	1.1	6.0	5.8	17	14	NR
Dibutyl phthalate	-0.14	0.11	0.21	0.53	0.14	0.40	NR
Aniline	0.17	0.096	0.48	0.43	1.4	1.4	NR
4-tert-octylphenol	0.47	0.37	2.9	3.6	4.0	2.9	NR
Naphthalene	-0.22	0.49	-0.08	0.4	-0.38	0.59	NR
1-Methylnaphthalene	-0.022	0.073	0.0041	0.020	0.030	0.059	NR
2-Methylnaphthalene	-0.052	0.15	0.015	0.035	0.031	0.071	NR
Acenaphthylene	0.0081	0.0028	0.012	0.0076	0.050	0.045	NR
Fluorene	-0.0048	0.031	0.020	0.025	0.048	0.048	NR
1-Methylphenanthrene	0.028	0.0084	0.086	0.069	0.084	0.065	NR
2-Methylphenanthrene	0.027	0.0059	0.099	0.092	0.12	0.13	NR
3-Methylphenanthrene	0.041	0.0078	0.18	0.18	0.22	0.23	NR
Dibenzothiophene	0.0020	0.0065	0.018	0.018	0.032	0.030	NR
n-Butylbenzene	-0.015	0.024	-0.0092	0.011	-0.0090	0.013	NR
Dimethyl phthalate	-0.00092	0.0087	0.0017	0.011	0.0016	0.0095	NR
Diisobutyl phthalate	-0.081	0.23	0.049	0.29	0.048	0.31	NR

[a] SVOC = semivolatile organic compound; °C = degrees Celsius

[b] Outdoor fields installed 2004–2008 (n=11); 2009–2012 (n=18); 2013–2016 (n=11)

[c] Statistical tests performed using ln-transformed measurement values

[d] NR = not reported; one or more measurement results were ≤0, precluding ln-transformed testing for the complete data set

[e] Sum15PAH = Sum of 15 of the 16 EPA ‘priority’ PAHs, including Acenaphthylene, Anthracene, Benz[a]anthracene, Benzo[a]pyrene, Benzo(b)fluoranthene, Benzo[ghi]perylene, Benzo(k)fluoranthene, Chrysene, Dibenz[a,h]anthracene, Fluoranthene, Fluorene, Indeno(1,2,3-cd)pyrene, Naphthalene, Phenanthrene, Pyrene

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Appendix Q

Tire Crumb Rubber Measurement Results – Differences Among Synthetic Turf Fields in Different U.S. Census Regions

Table Q-1. Comparison of Metals Analyzed by ICP/MS in Tire Crumb Rubber Infill Collected at Synthetic Turf Fields in Four Geographic Regions[a,b]

Analytes	Northeast Mean (mg/kg)	Northeast Standard Deviation (mg/kg)	South Mean (mg/kg)	South Standard Deviation (mg/kg)	Midwest Mean (mg/kg)	Midwest Standard Deviation (mg/kg)	West Mean (mg/kg)	West Standard Deviation (mg/kg)	F-test p-value [c,d]
Arsenic	0.36	0.13	0.33	0.23	0.43	0.29	0.42	0.11	0.2021
Cadmium	1.1	0.49	0.75	0.41	1.3	1.2	0.78	0.38	0.1562
Chromium	1.9	0.68	1.3	1.1	1.5	0.51	2.0	0.78	NR
Cobalt	110	43	140	55	150	84	150	59	0.3609
Lead	20	16	18	13	25	22	34	44	0.5454
Zinc	14000	2400	15000	3500	17000	3000	14000	2400	0.1387
Aluminum	1300	910	1300	650	1000	800	1400	690	0.3681
Antimony	1.1	0.50	0.93	0.44	0.95	0.28	0.88	0.46	0.6493
Barium	8.0	2.0	10	8.4	6.0	2.4	8.2	3.0	0.4157
Beryllium	0.014	0.021	-0.0093	0.044	0.0094	0.0073	0.023	0.013	NR
Copper	26	12	27	14	28	15	23	7.3	0.9566
Iron	690	440	580	480	410	170	720	370	0.1118
Magnesium	280	57	310	250	420	410	330	100	0.5941
Manganese	8.5	5.1	7.9	7.8	6.1	2.3	8.0	2.4	0.4026
Molybdenum	0.18	0.042	0.13	0.087	0.16	0.029	0.16	0.064	0.1136
Nickel	2.8	0.63	2.1	0.70	3.6	0.76	2.7	0.85	0.001
Rubidium	1.6	0.34	1.8	0.71	1.8	0.49	2.2	0.51	0.0442
Strontium	4.1	1.8	3.1	1.4	3.5	1.6	3.2	0.85	0.2841
Tin	1.6	0.59	1.6	1.3	1.3	0.89	1.7	1.3	NR
Vanadium	2	1.1	1.6	0.88	1.7	0.58	2.3	0.74	NR

[a] ICP/MS = inductively coupled plasma/mass spectrometry

[b] Northeast (n=9); South (n=13); Midwest (n=8); West (n=10)

[c] Statistical tests performed using ln-transformed measurement values

[d] NR = not reported; one or more measurement results were ≤0, precluding ln-transformed testing for the complete data set

Table Q-2. Comparison of Metals Analyzed by XRF in Tire Crumb Rubber Infill Collected at Synthetic Turf Fields in Four Geographic Regions[a,b]

Analytes	Northeast Mean (mg/kg)	Northeast Standard Deviation (mg/kg)	South Mean (mg/kg)	South Standard Deviation (mg/kg)	Midwest Mean (mg/kg)	Midwest Standard Deviation (mg/kg)	West Mean (mg/kg)	West Standard Deviation (mg/kg)	F-test p-value[c]
Chromium	14	2.3	14	2.8	14	3.3	13	3.4	0.419
Cobalt	29	16	42	16	42	17	40	18	0.2355
Lead	38	28	35	20	36	11	37	28	0.94
Zinc	29000	6700	34000	7400	37000	6400	33000	6700	0.0767
Barium	59	17	58	15	64	13	60	19	0.8035
Copper	100	36	130	51	130	37	120	44	0.179
Iron	1400	440	1200	780	1100	380	1200	420	0.406
Molybdenum	41	10	48	13	46	7.3	50	19	0.6138
Rubidium	41	15	54	39	62	31	67	19	0.071
Strontium	12	4.3	10	6.5	8.2	1.9	25	22	0.0045

[a] XRF = X-ray fluorescence spectrometry

[b] Northeast (n=9); South (n=13); Midwest (n=8); West (n=10)

[c] Statistical tests performed using ln-transformed measurement values.

Table Q-3. Comparison of SVOCs in Extracts Analyzed by GC/MS/MS for Tire Crumb Rubber Infill Collected at Synthetic Turf Fields in Four Geographic Regions[a,b]

Analytes	Northeast Mean (mg/kg)	Northeast Standard Deviation (mg/kg)	South Mean (mg/kg)	South Standard Deviation (mg/kg)	Midwest Mean (mg/kg)	Midwest Standard Deviation (mg/kg)	West Mean (mg/kg)	West Standard Deviation (mg/kg)	F-test p-value [c,d]
Phenanthrene	3.8	4.2	1.3	1.3	3.3	2.3	1.4	1.4	0.1894
Fluoranthene	5.1	3.4	5.2	2.6	4.9	1.9	2.8	1.3	0.0494
Pyrene	13	8.3	12	5.3	16	4.8	9.9	5.6	0.1743
Benzo[a]pyrene	1.1	0.80	0.80	0.49	0.69	0.27	0.57	0.25	0.1887
Benzo[ghi]perylene	1.5	0.37	1.4	0.83	1.1	0.63	1.2	0.57	0.4213
Sum15PAH[e]	33	21	29	12	34	12	22	11	0.1567
Benzothiazole	13	19	8.6	12	15	12	7.7	6.4	0.3539
Dibutyl phthalate	2	2.5	1.0	1.1	1.8	1.1	1.4	1.2	0.3835
Bis(2-ethylhexyl) phthalate	33	26	47	51	45	55	43	36	0.9489
Aniline	0.75	0.75	0.57	0.33	0.98	0.68	0.50	0.31	0.2898
4-tert-octylphenol	8.0	6.7	8.2	11	19	11	6.5	6.6	0.0392
n-Hexadecane	1.3	1.8	0.52	0.90	1.6	1.4	0.68	0.80	0.0665
Naphthalene	0.038	0.043	0.017	0.0093	0.069	0.068	0.024	0.021	0.047
1-Methylnaphthalene	0.10	0.17	0.011	0.011	0.094	0.10	0.019	0.030	0.0294
2-Methylnaphthalene	0.13	0.21	0.018	0.016	0.20	0.28	0.033	0.042	0.0255
Acenaphthylene	0.067	0.086	0.028	0.020	0.08	0.072	0.023	0.020	0.0911
Fluorene	0.38	0.51	0.079	0.098	0.26	0.19	0.089	0.11	0.1874
Anthracene	1.0	1.3	0.24	0.25	0.68	0.60	0.31	0.39	0.2131
1-Methylphenanthrene	2.1	1.9	1.3	0.88	1.9	1.2	1.2	1.1	0.2871
2-Methylphenanthrene	6.9	8.5	1.4	0.91	2.4	1.5	2.1	2.3	0.0938

Table Q-3 Continued

Analytes	Northeast Mean (mg/kg)	Northeast Standard Deviation (mg/kg)	South Mean (mg/kg)	South Standard Deviation (mg/kg)	Midwest Mean (mg/kg)	Midwest Standard Deviation (mg/kg)	West Mean (mg/kg)	West Standard Deviation (mg/kg)	F-test p-value [c,d]
3-Methylphenanthrene	3.1	3.1	1.7	1.3	2.9	2.4	2.0	1.7	0.6722
Benz(a)anthracene	3.1	1.4	2.3	1.4	1.6	1.2	1.8	1.1	0.0451
Chrysene	2.4	1.9	2.9	2.1	2.8	1.3	1.9	1.7	0.4118
Benzo(b)fluoranthene	1.4	1.0	1.6	0.93	1.2	0.53	1.0	0.48	0.3877
Benzo(k)fluoranthene	0.49	0.43	0.56	0.35	0.44	0.16	0.28	0.13	0.0971
Benzo(e)pyrene	2.0	0.96	2.1	1.2	1.9	0.91	1.5	0.72	0.5566
DBA + ICDP[f]	0.47	0.18	0.64	0.38	0.53	0.32	0.49	0.32	0.8927
Coronene	0.46	0.14	0.58	0.43	0.59	0.25	0.51	0.32	0.8249
Dibenzothiophene	0.48	0.55	0.18	0.20	0.45	0.30	0.21	0.22	0.2496
Dimethyl phthalate	0.066	0.11	0.0054	0.0051	0.044	0.059	0.0055	0.0088	NR
Diethyl phthalate	0.13	0.19	1.2	4.1	0.33	0.27	0.029	0.099	NR
Diisobutyl phthalate	2.1	3.1	0.72	0.70	1.6	1.7	0.91	1.0	0.49
Benzyl butyl phthalate	1.1	1.6	0.76	0.75	2.3	3.9	0.82	0.65	0.2073
Di-n-octyl phthalate	0.18	0.31	0.23	0.23	0.38	0.13	0.22	0.22	NR
Bis(2,2,6,6-tetramethyl-4-piperidyl) sebacate	0.52	0.27	1.2	1.1	0.55	0.80	0.76	0.98	NR
Cyclohexylisothiocyanate	0.30	0.31	0.18	0.086	0.32	0.19	0.24	0.12	NR

[a] SVOC = semivolatile organic compound; GC/MS/MS= gas chromatography/tandem mass spectrometry

[b] Northeast (n=9); South (n=13); Midwest (n=8); West (n=10)

[c] Statistical tests performed using ln-transformed measurement values

[d] NR = not reported; one or more measurement results were ≤0, precluding ln-transformed testing for the complete data set

[e] Sum15PAH = Sum of 15 of the 16 EPA ‘priority’ PAHs, including Acenaphthylene, Anthracene, Benz[a]anthracene, Benzo[a]pyrene, Benzo(b)fluoranthene, Benzo[ghi]perylene, Benzo(k)fluoranthene, Chrysene, Dibenz[a,h]anthracene, Fluoranthene, Fluorene, Indeno(1,2,3-cd)pyrene, Naphthalene, Phenanthrene, Pyrene

[f] DBA + ICDP = Sum of Dibenz[a,h]anthracene and Indeno(1,2,3-cd)pyrene

Table Q-4. Comparison of VOC 25 °C Emission Factor Results for Tire Crumb Rubber Infill Collected at Synthetic Turf Fields in Four Geographic Regions[a,b]

Analytes	Northeast Mean (mg/kg)	Northeast Standard Deviation (mg/kg)	South Mean (mg/kg)	South Standard Deviation (mg/kg)	Midwest Mean (mg/kg)	Midwest Standard Deviation (mg/kg)	West Mean (mg/kg)	West Standard Deviation (mg/kg)	F-test p-value[c,d]
Benzothiazole	23	31	15	22	46	38	21	18	NR
o-Xylene	0.068	0.12	0.005	0.081	0.04	0.097	0.03	0.068	NR
SumBTEX[e]	0.17	0.53	0.12	0.89	0.37	0.61	0.63	1.1	NR
Trichlorofluoromethane (Freon 11)	0.061	0.84	-0.33	0.51	0.67	0.12	-0.028	0.63	NR
Dichlorodifluoromethane (Freon 12)	-0.019	0.023	-0.039	0.069	-0.0071	0.028	-0.013	0.044	NR

[a] VOC = volatile organic compound; °C = degrees Celsius

[b] Northeast (n=8); South (n=13); Midwest (n=8); West (n=9)

[c] Statistical tests performed using ln-transformed measurement values

[d] NR = not reported; one or more measurement results were ≤0, precluding ln-transformed testing for the complete data set [e] SumBTEX = Sum of benzene, toluene, ethylbenzene, m/p-xylene, and o-xylene

Table Q-5. Comparison of VOC 60 °C Emission Factor Results for Tire Crumb Rubber Infill Collected at Synthetic Turf Fields in Four Geographic Regions[a,b]

Analytes	Northeast Mean (mg/kg)	Northeast Standard Deviation (mg/kg)	South Mean (mg/kg)	South Standard Deviation (mg/kg)	Midwest Mean (mg/kg)	Midwest Standard Deviation (mg/kg)	West Mean (mg/kg)	West Standard Deviation (mg/kg)	F-test p-value[c,d]
Formaldehyde	20	18	12	4.9	19	4.7	16	2.3	NR
Methyl isobutyl ketone	37	31	33	19	67	26	38	22	0.0267
Benzothiazole	37	43	44	38	81	38	62	32	0.0393
Styrene	0.57	0.44	0.21	0.30	0.78	0.42	0.41	0.34	NR
Toluene	0.032	0.18	0.074	0.35	0.29	0.30	0.22	0.29	NR
Ethylbenzene	-0.074	0.24	-0.20	0.17	0.038	0.20	-0.023	0.25	NR
m/p-Xylene	0.20	0.83	-0.34	0.66	0.78	0.97	0.60	1.2	NR
o-Xylene	-0.31	0.46	-0.72	0.47	-0.19	0.56	-0.024	0.87	NR
SumBTEX[e]	-0.31	1.8	-1.2	1.7	1.0	2.0	0.67	2.5	NR
trans-2-Butene	-0.21	0.12	-0.32	0.31	-0.19	0.12	-0.24	0.27	NR
cis-2-Butene	-0.18	0.11	-0.30	0.27	-0.18	0.10	-0.21	0.24	NR
Tetrachloroethylene	-0.0064	0.017	-0.0003	0.023	0.014	0.033	0.0062	0.046	NR
Chlorobenzene	-0.0058	0.049	-0.019	0.040	0.015	0.099	0.0050	0.049	NR
p-Dichlorobenzene	0.0063	0.22	-0.018	0.16	0.26	0.31	0.10	0.16	NR
Trichlorofluoromethane (Freon 11)	0.31	0.73	-0.33	0.50	0.71	0.22	-0.033	0.56	NR
Dichlorodifluoromethane (Freon 12)	-0.0072	0.019	-0.024	0.039	0.017	0.031	0.0032	0.043	NR

[a] VOC = volatile organic compound; °C = degrees Celsius

[b] Northeast (n=6–9); South (n=13); Midwest (n=8); West (n=10)

[c] Statistical tests performed using ln-transformed measurement values

[d] NR = not reported; one or more measurement results were ≤0, precluding ln-transformed testing for the complete data set

[e] SumBTEX = Sum of benzene, toluene, ethylbenzene, m/p-xylene, and o-xylene

Table Q-6. Comparison of SVOC 25 °C Emission Factor Results for Tire Crumb Rubber Infill Collected at Synthetic Turf Fields in Four Geographic Regions[a,b]

Analytes	Northeast Mean (mg/kg)	Northeast Standard Deviation (mg/kg)	South Mean (mg/kg)	South Standard Deviation (mg/kg)	Midwest Mean (mg/kg)	Midwest Standard Deviation (mg/kg)	West Mean (mg/kg)	West Standard Deviation (mg/kg)	F-test p-value[c,d]
Phenanthrene	0.021	0.074	0.040	0.055	0.028	0.025	0.0056	0.011	NR
Sum15PAH[e]	0.71	0.37	0.92	0.97	0.37	0.23	0.35	0.15	0.0403
Benzothiazole	4.8	6.5	2.8	3.6	7.9	6.7	2.5	2.9	NR
Dibutyl phthalate	0.095	0.41	0.15	0.37	-0.27	0.27	-0.11	0.33	NR
Aniline	0.25	0.38	0.19	0.28	0.82	0.57	0.24	0.36	NR
4-tert-octylphenol	1.7	4.6	1.3	4.4	0.23	0.16	0.061	0.082	NR
Naphthalene	0.13	0.24	0.29	0.58	0.062	0.18	0.021	0.12	NR
1-Methylnaphthalene	0.09	0.16	0.0094	0.039	0.040	0.067	0.011	0.027	NR
2-Methylnaphthalene	0.13	0.23	0.018	0.093	0.12	0.26	0.018	0.047	NR
Fluorene	0.025	0.032	0.0071	0.011	0.012	0.014	0.0031	0.0097	NR
n-Butylbenzene	0.078	0.25	-0.0018	0.028	0.0050	0.019	0.0026	0.020	NR
Diisobutyl phthalate	0.0091	0.30	0.081	0.27	-0.14	0.082	0.058	0.18	NR

[a] SVOC = semivolatile organic compound; °C = degrees Celsius

[b] Northeast (n=9); South (n=13); Midwest (n=8); West (n=10)

[c] Statistical tests performed using ln-transformed measurement values

[d] NR = not reported; one or more measurement results were ≤0, precluding ln-transformed testing for the complete data set

[e] Sum15PAH = Sum of 15 of the 16 EPA 'priority' PAHs, including Acenaphthylene, Anthracene, Benz[a]anthracene, Benzo[a]pyrene, Benzo(b)fluoranthene, Benzo[ghi]perylene, Benzo(k)fluoranthene, Chrysene, Dibenz[a,h]anthracene, Fluoranthene, Fluorene, Indeno(1,2,3-cd)pyrene, Naphthalene, Phenanthrene, Pyrene

Table Q-7. Comparison of SVOC 60 °C Emission Factor Results for Tire Crumb Rubber Infill Collected at Synthetic Turf Fields in Four Geographic Regions[a,b]

Analytes	Northeast Mean (mg/kg)	Northeast Standard Deviation (mg/kg)	South Mean (mg/kg)	South Standard Deviation (mg/kg)	Midwest Mean (mg/kg)	Midwest Standard Deviation (mg/kg)	West Mean (mg/kg)	West Standard Deviation (mg/kg)	F-test p-value[c,d]
Phenanthrene	1.0	1.2	0.35	0.44	0.71	0.57	0.35	0.36	NR
Fluoranthene	0.23	0.15	0.16	0.10	0.13	0.081	0.11	0.093	NR
Pyrene	0.42	0.29	0.29	0.19	0.26	0.18	0.20	0.14	NR
Sum15PAH[e]	3.2	3.2	1.5	1.0	2.4	1.6	1.2	0.7	0.4212
Benzothiazole	49	75	15	15	70	64	16	12	NR
Dibutyl phthalate	0.14	0.34	0.27	0.31	-0.037	0.45	0.13	0.55	NR
Aniline	6.2	8.1	1.0	1.2	6.5	5.3	1.9	2.2	NR
4-tert-octylphenol	6.3	6.5	6.2	6.4	7.3	5.1	3.8	3.5	NR
Naphthalene	-0.38	0.52	-0.37	0.63	0.34	0.53	0.012	0.086	NR
1-Methylnaphthalene	0.55	1.2	0.042	0.062	0.42	0.49	0.060	0.12	NR
2-Methylnaphthalene	0.78	1.7	0.076	0.099	1.2	2.1	0.087	0.18	NR
Acenaphthylene	0.20	0.32	0.044	0.042	0.16	0.16	0.037	0.039	NR
Fluorene	0.44	0.67	0.072	0.089	0.23	0.17	0.078	0.10	NR
1-Methylphenanthrene	0.21	0.19	0.12	0.098	0.15	0.12	0.12	0.11	NR
2-Methylphenanthrene	0.38	0.44	0.14	0.16	0.25	0.25	0.19	0.20	NR
3-Methylphenanthrene	0.64	0.71	0.26	0.28	0.35	0.37	0.29	0.27	NR
Dibenzothiophene	0.16	0.19	0.046	0.063	0.11	0.092	0.054	0.060	NR
n-Butylbenzene	-0.025	0.030	-0.0021	0.0069	0.024	0.035	-0.0084	0.015	NR
Dimethyl phthalate	0.018	0.025	0.0034	0.0082	0.043	0.038	0.0082	0.024	NR
Diisobutyl phthalate	0.17	0.39	0.19	0.28	0.03	0.21	0.019	0.32	NR

[a] SVOC = semivolatile organic compound; °C = degrees Celsius

[b] Northeast (n=9); South (n=13); Midwest (n=8); West (n=10)

[c] Statistical tests performed using ln-transformed measurement values

[d] NR = not reported; one or more measurement results were ≤0, precluding ln-transformed testing for the complete data set

[e] Sum15PAH = Sum of 15 of the 16 EPA 'priority' PAHs, including Acenaphthylene, Anthracene, Benz[a]anthracene, Benzo[a]pyrene, Benzo(b)fluoranthene, Benzo[ghi]perylene, Benzo(k)fluoranthene, Chrysene, Dibenz[a,h]anthracene, Fluoranthene, Fluorene, Indeno(1,2,3-cd)pyrene, Naphthalene, Phenanthrene, Pyrene

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Appendix R
Non-Targeted Screening Analysis
Results for SVOCs and VOCs

R.1 Non-Targeted Analysis

In this study we selected a subset of tire crumb rubber samples from recycling plants and a subset of tire crumb rubber infill samples from indoor and outdoor synthetic turf fields for non-targeted screening analysis. This strategy allows assessment of chemicals potentially associated with 'fresh' recycled tire material and to see whether those chemicals are also observed in the infill collected at synthetic turf fields. It also allows the reverse assessment – chemicals found in synthetic turf field infill samples that are not observed in the recycling plant samples – to better assess the extent that chemicals from sources other than the tire crumb rubber material are appearing in the infill.

Six tire recycling plant samples, five outdoor field infill samples, and five indoor field infill samples were selected for non-targeted screening analyses. Non-targeted analyses were performed for solvent extract samples by both GC/MS and LC/TOFMS. Non-targeted analyses were also performed for chamber emission test samples generated at 60° C using GC/MS and LC/TOFMS methods for SVOCs, and by GC/TOFMS for VOCs. The highly tentative non-targeted screening results for each type of analysis are shown in Tables R-1 to R-7.

Emphasizing that these non-targeted screening analysis chemical identifications are highly tentative, it is not recommended that these results be used for cumulative exposure assessment, toxicity information collation, or risk assessment at this time. Additional work would be needed to build upon these results for more certain chemical identity confirmations and determination or estimations of relative amounts.

Table R-1. Non-Targeted Analysis SVOC Results for Tire Crumb Rubber Extracts by GC/MS – Highly Tentative Screening Results[a,b,c]

Tentative Chemical Identification • Match Factor >50% • Minimum Frequency = 3 • In Order of Retention Time	CAS Number[d]	Recycling Plants Frequency	Recycling Plants Mean Area Counts	Indoor Fields Frequency	Indoor Fields Mean Area Counts	Outdoor Fields Frequency	Outdoor Fields Mean Area Counts	Reagent Blanks Mean Area Counts
Nonane, 2,6-dimethyl-	17302-28-2	0	N/A	2	2.0E+05	4	3.3E+05	0
1-Octanol, 2-butyl-	3913-02-8	0	N/A	2	1.8E+05	3	1.5E+05	0
Dodecane, 4,6-dimethyl-	61141-72-8	0	N/A	1	1.2E+05	5	8.4E+04	0
Benzothiazole	95-16-9	6	4.9E+06	3	1.8E+06	1	2.8E+05	0
Benzene, 1,3-bis(1,1-dimethylethyl)-	1014-60-4	1	8.9E+05	3	9.8E+05	4	1.3E+06	0
1-Decanol, 2-methyl-	18675-24-6	0	N/A	4	2.0E+05	6	2.2E+05	0
Cyclohexanamine, N-cyclohexyl-	101-83-7	4	3.0E+06	3	1.4E+06	2	1.5E+06	0
Quinoline, 1,2-dihydro-2,2,4-trimethyl-	147-47-7	3	1.5E+06	0	N/A	1	1.0E+05	0
7-Methoxy-2,2,4,8-tetramethyltricyclo[5.3.1.0(4,11)]undecane	1000140-32-8	6	1.1E+06	3	7.2E+05	1	9.3E+04	0
Phthalimide	85-41-6	3	1.1E+06	0	N/A	0	N/A	0
1-Decanol, 2-hexyl-	2425-77-6	0	N/A	3	6.8E+04	2	9.6E+04	0
Phenol, 4-(1,1,3,3-tetramethylbutyl)- (*Alternate name: 4-tert-octylphenol)*	140-66-9	6	7.7E+06	5	3.9E+06	4	8.0E+05	0
cis-11-Eicosenoic acid	5561-99-9	3	1.7E+06	0	N/A	0	N/A	0
2-Dodecen-1-yl(-)succinic anhydride	19780-11-1	0	N/A	1	5.6E+04	3	1.3E+05	0
3,5-di-tert-Butyl-4-hydroxybenzaldehyde	1620-98-0	1	5.0E+05	3	3.1E+05	0	N/A	0
1-Heptatriacotanol	105794-58-9	0	N/A	1	2.5E+04	5	2.2E+05	0
Octadecane	593-45-3	3	2.6E+05	2	1.5E+05	1	1.9E+05	0
Heptadecane, 9-hexyl-	55124-79-3	1	8.8E+05	4	5.7E+05	3	2.8E+05	0
Nonadecane	629-92-5	4	7.3E+05	3	4.4E+05	1	4.0E+05	0
Hexadecanoic acid, methyl ester	112-39-0	5	1.0E+06	3	6.2E+05	1	7.2E+04	0
1H-Cyclopropa[l]phenanthrene,1a,9b-dihydro-	949-41-7	0	N/A	3	2.7E+05	0	N/A	0
Eicosane	112-95-8	3	8.8E+05	0	N/A	1	7.5E+05	0
Benzothiazole, 2-phenyl-	883-93-2	3	7.0E+05	1	1.2E+06	2	5.8E+05	0
10,18-Bisnorabieta-8,11,13-triene	32624-67-2	1	3.8E+05	2	5.6E+05	3	4.6E+05	0
8,11-Octadecadienoic acid, methyl ester	56599-58-7	3	2.2E+05	0	N/A	0	N/A	0
Fluoranthene	206-44-0	1	3.5E+06	2	1.7E+06	4	1.8E+06	0
Heneicosane	629-94-7	4	1.4E+06	2	5.0E+05	4	4.9E+05	0
Heptacosane	593-49-7	4	2.1E+06	3	9.4E+05	0	N/A	0
Phorbol	17673-25-5	1	9.4E+04	3	1.3E+05	3	5.9E+04	0

Table R-1 Continued

Tentative Chemical Identification • Match Factor >50% • Minimum Frequency = 3 • In Order of Retention Time	CAS Number	Recycling Plants Frequency	Recycling Plants Mean Area Counts	Indoor Fields Frequency	Indoor Fields Mean Area Counts	Outdoor Fields Frequency	Outdoor Fields Mean Area Counts	Reagent Blanks Mean Area Counts
Methyl stearate	112-61-8	5	1.1E+06	3	7.5E+05	1	5.5E+05	0
Silane, diethylheptyloxy(3-methylbutoxy)-	1000362-99-7	3	3.1E+06	2	2.8E+06	2	1.6E+06	0
Silane, diethylisobutoxyoctyloxy-	1000363-06-4	3	2.6E+06	2	1.4E+06	1	2.0E+06	0
Pyrene	129-00-0	5	2.7E+06	4	3.4E+06	3	1.6E+06	0
Phenanthrene, 2,3,5-trimethyl-	3674-73-5	0	N/A	4	4.4E+05	2	2.1E+05	0
Docosane	629-97-0	6	1.3E+06	4	5.5E+05	4	9.3E+05	0
Acetic acid n-octadecyl ester	822-23-1	6	3.3E+05	2	4.1E+05	2	2.6E+05	0
7,8-Epoxylanostan-11-ol, 3-acetoxy-	1000187-60-9	2	2.5E+05	2	9.1E+04	9	4.3E+04	0
Octadecane, 3-ethyl-5-(2-ethylbutyl)-	55282-12-7	2	1.5E+05	2	2.0E+05	10	1.8E+05	0
4H-Cyclopropa[5',6']benz[1',2':7,8]azuleno[5,6-b]oxiren-4-one, 8-(acetyloxy)-1,1a,1b,1c,2a,3,3a,6a,6b,7,8,8a-dodecahydro-3a,6b,8a-trihydroxy-2a-(hydroxymethyl)-1,1,5,7-tetramethyl-, (1a.alpha.,1b.beta.,1c.beta.,2a.beta.,3a.beta.,6a.alpha.,6b.alpha.,7.alpha.,8.beta.,8a.alpha.)-	77646-23-2	0	N/A	1	2.0E+05	3	5.6E+04	0
Pentacosane	629-99-2	9	2.2E+06	7	1.4E+06	7	1.6E+06	0
Tetracosane	646-31-1	6	2.3E+06	6	1.5E+06	5	1.7E+06	0
Triacontane	638-68-6	0	N/A	3	2.7E+05	4	5.5E+05	0
Methyl dehydroabietate	1235-74-1	1	N/A	3	3.1E+05	3	2.2E+05	0
1,4-Benzenediamine, N-(1,3-dimethylbutyl)-N'-phenyl *(Alternate name: 6PPD)*	793-24-8	6	3.9E+07	4	1.2E+07	2	3.4E+06	0
Hexanedioic acid, bis(2-ethylhexyl) ester	103-23-1	3	5.0E+05	0	N/A	2	6.1E+05	0
Nonacosane	630-03-5	20	1.6E+06	12	9.5E+05	11	1.3E+06	0
Hexa(methoxymethyl)melamine	68002-20-0	3	6.6E+05	1	3.9E+05	0		0
Bis(2-ethylhexyl) phthalate	117-81-7	1	1.4E+06	4	3.4E+06	3	3.3E+06	0
7,11-Dioxapentacyclo[15.3.0.0(4,16).0(5,13).0(5,10)]eicos-13-en-20-ol-8-one, 1.beta.,12,12-trimethyl-	1000195-82-2	3	4.6E+05	3	3.4E+05	3	4.4E+05	0
Hexacosane	630-01-3	6	2.5E+06	3	9.8E+05	4	2.0E+06	0
Octacosane	630-02-4	5	2.0E+06	6	9.8E+05	8	2.1E+06	0
2,7-Dipropoxy-fluoren-9-one	303735-73-1	1	2.7E+05	1	3.1E+05	3	4.1E+05	0
4,4'-((p-Phenylene)diisopropylidene)diphenol *(Alternate name: Bisphenol P)*	2167-51-3	6	1.6E+07	4	1.1E+07	4	5.7E+06	0
1,4-Benzenediamine, N,N'-diphenyl- *(Alternate name: DPPD)*	74-31-7	4	1.8E+06	2	2.1E+06	1	5.0E+05	0
N-(2,4-Dinitrophenyl)-m-phenylenediamine	101927-38-2	6	4.9E+06	2	5.2E+06	2	2.0E+06	0

Table R-1 Continued

Tentative Chemical Identification • Match Factor >50% • Minimum Frequency = 3 • In Order of Retention Time	CAS Number	Recycling Plants Frequency	Recycling Plants Mean Area Counts	Indoor Fields Frequency	Indoor Fields Mean Area Counts	Outdoor Fields Frequency	Outdoor Fields Mean Area Counts	Reagent Blanks Mean Area Counts
5-Phenyl-2,4-pyrimidinediamine di tms	1000332-62-1	4	5.9E+05	3	3.9E+05	2	5.6E+05	0
N(1)-(2,4-Dinitrophenyl)-4-methyl-m-phenylenediamine	130498-34-9	5	2.7E+06	2	3.1E+06	2	1.6E+06	0
17.alfa.,21.beta.-28,30-Bisnorhopane	1000360-26-1	4	2.7E+05	7	2.7E+05	9	2.1E+05	0
Hexatriacontane	630-06-8	13	1.1E+06	4	6.2E+05	16	7.6E+05	0
.gamma.-Sitosterol	83-47-6	1	5.4E+04	1	6.9E+04	3	1.1E+05	0

[a] SVOC = semivolatile organic compound; GC/MS= gas chromatography/mass spectrometry; N/A = not applicable

[b] Recycling Plants (n=6); Indoor Fields (n=5); Outdoor Fields (n=4); Reagent Blanks (n=3)

[c] Total compounds tentatively identified = 60; Compounds identified by source: Recycling Plants – 49 compounds (Sum of Frequency = 205), Indoor Fields – 54 compounds (Sum of Frequency = 166), Outdoor Fields – 53 compounds (Sum of Frequency = 195)

[d] Unique numerical identifier assigned by the Chemical Abstracts Services (CAS)

Table R-2. Non-Targeted Analysis SVOC Results for Tire Crumb Rubber Extracts by LC/TOFMS Positive Mode – Highly Tentative Screening Results[a,b]

Tentative Chemical Identification[c]	CAS Number[d]	Chemical Formula	Score	Number of Chemicals Same Formula	Recycling Plants – Frequency	Recycling Plants – Mean Area Counts	Indoor Fields – Frequency	Indoor Fields – Mean Area Counts	Outdoor Fields – Frequency	Outdoor Fields – Mean Area Counts	Blanks – Frequency	Blanks – Mean Area Counts
3-(2-Fluoro-4,5-dihydroxyphenyl)-2-methylalanine	6482-05-9	C10H12FNO4	97.73	3	18	7.32E+05	6	1.48E+05	3	6.66E+04	0	N/A
Ethanol, 2,2'-(hexylimino)bis-	6752-33-6	C10H23NO2	87.06	5	18	2.52E+05	15	1.53E+05	6	7.66E+04	0	N/A
N-tert-Butyl-2-benzothiazolesulfenamide	95-31-8	C11H14N2S2	98.72	14	12	3.49E+05	15	5.88E+04	9	4.45E+04	0	N/A
Tamitinol	59429-50-4	C11H18N2OS	92.41	16	12	9.71E+04	3	7.82E+04	9	9.24E+04	0	N/A
1,3-Propanediamine, N,N-diethyl-N'-(2-nitro-3-thienyl)-, monohydrochloride	122777-89-3	C11H19N3O2S	82.43	13	0	N/A	3	2.32E+05	3	3.53E+05	0	N/A
Diphenylamine	122-39-4	C12H11N	87.72	68	6	6.87E+05	0	N/A	0	N/A	0	N/A
1,2-Dihydro-2,2,4-trimethylquinoline	147-47-7	C12H15N	87.16	1984	12	4.32E+06	9	6.12E+05	12	5.84E+05	0	N/A
Piperidine, 4-(phenylmethyl)-	31252-42-3	C12H17N	86.91	197	18	1.30E+06	6	3.20E+05	3	1.22E+05	0	N/A
2,6-Diisopropylaniline	24544-04-5	C12H19N	98.63	137	18	1.37E+06	6	2.93E+05	0	N/A	0	N/A

Table R-2 Continued

Tentative Chemical Identification[c]	CAS Number[d]	Chemical Formula	Score	Number of Chemicals Same Formula	Recycling Plants – Frequency	Recycling Plants – Mean Area Counts	Indoor Fields – Frequency	Indoor Fields – Mean Area Counts	Outdoor Fields – Frequency	Outdoor Fields – Mean Area Counts	Blanks – Frequency	Blanks – Mean Area Counts
4-(4-Ethoxybutyl)-2,2-dimethyl-5-(trifluoromethyl) -1,3-dioxolane	189019-72-5	C12H21F3O3	80.86	4	12	1.44E+06	6	7.89E+05	0	N/A	0	N/A
4-(4-Ethoxybutyl)-2,2-dimethyl-5-(trifluoromethyl) -1,3-dioxolane	189019-72-5	C12H21F3O3	95.51	4	18	3.43E+05	6	2.16E+05	0	N/A	0	N/A
1,8-Diazacyclotetradecane-2,9-dione	56403-09-9	C12H22N2O2	93.7	192	15	5.74E+05	0	N/A	3	1.14E+05	0	N/A
4-tert-Butylcyclohexyl acetate	32210-23-4	C12H22O2	86.95	272	3	5.27E+04	15	1.26E+05	0	N/A	0	N/A
Undecyl isothiocyanate	19010-96-9	C12H23NS	86.48	7	6	1.06E+06	6	6.94E+05	12	1.42E+06	0	N/A
N6-D-Gluconoyl-L-lysine	94071-01-9	C12H24N2O8	81.85	2	18	5.87E+04	15	4.82E+04	3	5.15E+04	0	N/A
1,17-Diazido-3,6,9,12,15-pentaoxaheptadecane	356046-26-9	C12H24N6O5	98.93	2	12	3.47E+05	6	1.64E+05	0	N/A	0	N/A
Dodecamethylcyclohexasiloxane	540-97-6	C12H36O6Si6	84.44	2	0	N/A	6	3.10E+05	9	1.99E+05	0	N/A
Naphtho[1,2-d]thiazole-2(1H)-thione, 1-ethyl-3a,4, 5,9b-tetrahydro-9b-hydroxy-	63123-24-0	C13H15NOS2	96.91	8	12	9.37E+04	6	5.49E+04	0	N/A	0	N/A
Hydroxyprocaine [INN:BAN:DCF]	487-53-6	C13H20N2O3	90.66	122	6	4.46E+05	15	1.17E+05	6	3.48E+04	0	N/A
Hydroxyprocaine [INN:BAN:DCF]	487-53-6	C13H20N2O3	99.45	122	18	5.34E+05	6	1.49E+05	3	4.15E+04	0	N/A
Ethanethiol, 2-(5-(4-methyl-2-pyridyloxy)pentyl) amino-, hydrochloride	41287-58-5	C13H22N2OS	84.11	5	3	3.88E+05	12	2.99E+05	0	N/A	0	N/A
Ethyl 3-ethyl-2-methyl-3-[(trimethylsilyl)oxy] pentanoate	112611-66-2	C13H28O3Si	85.98	2	18	3.99E+05	6	3.38E+05	3	1.61E+05	0	N/A
1,3-bis[3-(propan-2-ylamino)propyl] thiourea	6962-26-1	C13H30N4S	88.11	1	15	1.93E+05	6	1.78E+05	0	N/A	0	N/A
Benzo(f)quinoline	85-02-9	C13H9N	81.8	34	3	1.04E+05	3	2.47E+05	0		0	N/A
2-[(2,3-Dimethoxybenzoyl)sulfanyl]-N,N,N-trimethylethan-1-aminium iodide	110386-96-4	C14H22NO3S	80.38	1	18	1.27E+05	9	2.50E+05	9	3.59E+05	0	N/A
1H-Imidazolium, 1-(2-carboxyethyl)-2-hexyl-4,5-dihydro-3-(2-hydroxyethyl)-, inner salt	68991-92-4	C14H26N2O3	80.22	10	9	9.10E+04	0	N/A	0	N/A	0	N/A
Ethanol, 2-(dicyclohexylamino)-	4500-31-6	C14H27NO	85.75	42	6	2.88E+05	9	2.15E+05	0	N/A	0	N/A
Phenyl bis[(trimethylsilyl)methyl] phosphate	61357-04-8	C14H27O4PSi2	95.07	1	9	4.56E+04	0	N/A	12	1.30E+05	0	N/A

Table R-2 Continued

Tentative Chemical Identification[c]	CAS Number[d]	Chemical Formula	Score	Number of Chemicals Same Formula	Recycling Plants – Frequency	Recycling Plants – Mean Area Counts	Indoor Fields – Frequency	Indoor Fields – Mean Area Counts	Outdoor Fields – Frequency	Outdoor Fields – Mean Area Counts	Blanks – Frequency	Blanks – Mean Area Counts
1-Ethenyl-N,N,N',N',N",N"-hexaethylsilanetriamine	61423-53-8	C14H33N3Si	89.32	1	18	3.34E+05	12	1.89E+05	6	7.77E+04	0	N/A
1,1'-sulfanediylbis(2-isothiocyanatobenzene)	40939-90-0	C14H8N2S3	95.46	8	36	8.84E+04	30	1.39E+05	30	1.21E+05	0	N/A
1,1'-sulfanediylbis(2-isothiocyanatobenzene)	40939-90-0	C14H8N2S3	97.82	8	36	2.80E+05	30	4.10E+05	30	4.61E+05	0	N/A
N-Isopropyl-N'-phenyl-p-phenylenediamine	101-72-4	C15H18N2	87.26	102	9	7.29E+05	12	6.69E+05	0	N/A	0	N/A
Benzonitrile, 4-(trans-4-ethylcyclohexyl)-	72928-54-2	C15H19N	81.8	84	18	9.10E+04	12	8.67E+04	9	5.26E+04	0	N/A
Benzonitrile, 4-(trans-4-ethylcyclohexyl)-	72928-54-2	C15H19N	84.29	84	18	1.16E+05	6	1.12E+05	0	N/A	0	N/A
tert-Butyl 3-[(4-fluoroanilino)methyl] azetidine-1-carboxylate	887590-04-7	C15H21FN2O2	98.06	12	18	6.11E+06	6	8.00E+05	3	4.68E+05	0	N/A
Pyridine, 1-butyl-1,2,3,6-tetrahydro-4-phenyl-	102003-99-6	C15H21N	99.1	67	18	3.78E+05	12	2.14E+05	9	9.62E+04	0	N/A
alpha-pyrrolidinovalerophenone	14530-33-7	C15H21NO	96.82	137	18	1.85E+06	15	8.20E+05	3	5.17E+04	0	N/A
Nootkatone	4674-50-4	C15H22O	98.97	142	0	N/A	9	3.57E+05	12	2.73E+05	0	N/A
1-[3-(4-Fluorophenoxy)propyl]-3-methoxypiperidin-4-amine	104860-26-6	C15H23FN2O2	98	1	18	3.09E+06	12	6.25E+05	9	3.41E+05	0	N/A
Alprenolol	13655-52-2	C15H23NO2	92.96	141	18	2.64E+06	9	1.02E+06	12	8.84E+05	0	N/A
2,6-Di-tert-butyl-4-hydroperoxy-4-methyl-2,5-cyclohexadienone	6485-57-0	C15H24O3	87.14	216	36	9.79E+05	12	1.03E+06	0	N/A	0	N/A
Tris(dimethylamino)(2,4,6-trimethylphenoxy) phosphanium azide	73014-63-8	C15H29N3OP	95.86	1	15	1.88E+06	9	7.22E+05	0	N/A	0	N/A
Succinyl-leucyl-agmatine	126673-18-5	C15H29N5O4	95.67	2	18	1.99E+05	15	5.13E+05	9	2.29E+05	0	N/A
Succinyl-leucyl-agmatine	126673-18-5	C15H29N5O4	86.93	2	12	1.20E+05	15	2.09E+05	6	9.19E+04	0	N/A
Hexa(methoxymethyl)melamine	3089-11-0	C15H30N6O6	89.83	2	18	2.59E+07	15	1.24E+07	6	5.81E+05	0	N/A
Ezogabine	150812-12-7	C16H18FN3O2	84.13	6	12	3.21E+05	15	1.76E+05	6	4.94E+04	0	N/A
(3S)-N-Cyclopentyl-N-[(2,4-difluorophenyl) methyl]pyrrolidin-3-amine	820980-07-2	C16H22F2N2	84.62	2	12	1.81E+05	6	1.01E+05	0	N/A	0	N/A

Table R-2 Continued

Tentative Chemical Identification[c]	CAS Number[d]	Chemical Formula	Score	Number of Chemicals Same Formula	Recycling Plants – Frequency	Recycling Plants – Mean Area Counts	Indoor Fields – Frequency	Indoor Fields – Mean Area Counts	Outdoor Fields – Frequency	Outdoor Fields – Mean Area Counts	Blanks – Frequency	Blanks – Mean Area Counts
Allyxycarb	6392-46-7	C16H22N2O2	85.07	93	18	9.37E+05	15	7.06E+05	9	3.28E+05	0	N/A
Ethyl (2-cyclohexyloxiran-2-yl) phenylphosphinate	87989-28-4	C16H23O3P	81.42	2	6	2.43E+04	15	4.29E+04	12	4.19E+04	0	N/A
1-(2-fluoroethyl)-3-(3,5,7-trimethyl tricyclo[3.3.1. 13,7]dec-1-yl) urea	33044-13-2	C16H27FN2O	98.5	1	18	3.27E+06	6	1.19E+06	3	5.50E+05	0	N/A
16-Azidohexadecanoic acid	112668-54-9	C16H32N3O2	86.85	1	3	6.29E+05	0	N/A	3	8.79E+05	0	N/A
2,3-Bis(((2-((2-aminoethyl)amino)ethyl) amino) methyl)phenol	93940-98-8	C16H32N6O	87.08	2	18	6.27E+05	6	4.31E+05	0	N/A	0	N/A
4-Dodecylmorpholine	1541-81-7	C16H33NO	82.72	116	18	1.03E+05	15	1.49E+05	9	7.03E+04	0	N/A
4-Dodecylmorpholine	1541-81-7	C16H33NO	92.78	116	18	1.46E+06	15	2.95E+05	9	2.11E+05	0	N/A
Bis-2-ethylhexylamine	106-20-7	C16H35N	97.9	41	12	1.47E+05	3	1.88E+05	0	N/A	0	N/A
MC1568	852475-26-4	C17H15FN2O3	82.01	7	6	6.22E+04	3	4.04E+04	12	6.35E+04	0	N/A
Diphenhydramine	58-73-1	C17H21NO	97.95	140	6	4.80E+05	12	5.17E+05	12	5.66E+05	0	N/A
Phosphine oxide, (diethoxymethyl) diphenyl-	20570-20-1	C17H21O3P	82.67	16	6	9.65E+04	9	1.21E+05	15	1.90E+05	0	N/A
Eperisone hydrochloride	56839-43-1	C17H25NO	86.7	61	18	1.42E+05	6	7.47E+04	0	N/A	0	N/A
Cedr-8-en-15-yl acetate	1405-92-1	C17H26O2	87.25	92	0	N/A	3	1.74E+05	9	2.67E+05	0	N/A
1,1,1-Trifluoroheptadec-12-en-2-one	878997-67-2	C17H29F3O	85.81	1	9	1.32E+05	0	N/A	6	2.85E+05	0	N/A
tert-Butyl (2S,4S)-2-[(cyclohexylmethoxy) carbamoyl]-4-fluoropyrrolidine-1-carboxylate	1204334-30-4	C17H29FN2O4	97.72	1	18	1.14E+06	9	2.64E+05	6	1.15E+05	0	N/A
1-[(Decylsulfanyl)methyl]-3-methylpyridin-1-ium chloride	76652-33-0	C17H30NS	92.61	1	18	4.24E+05	6	1.32E+05	6	5.76E+04	0	N/A
1,3,5-Triazine-2,4-diamine, 6-tetradecyl-	191486-18-7	C17H33N5	91.98	1	15	3.21E+05	6	5.36E+05	0	N/A	0	N/A
L-Valyl-L-alanyl-L-alanyl-L-lysine	798540-45-1	C17H33N5O5	96.22	4	15	2.37E+05	15	4.53E+05	9	1.62E+05	0	N/A
L-Valyl-L-alanyl-L-alanyl-L-lysine	798540-45-1	C17H33N5O5	95.31	4	6	1.36E+05	15	2.11E+05	3	1.21E+05	0	N/A
N-(13-Methyltetradecyl)acetamide	64317-66-4	C17H35NO	96.43	120	18	1.72E+05	30	1.73E+05	6	1.10E+05	0	N/A
N-(13-Methyltetradecyl)acetamide	64317-66-4	C17H35NO	98.95	120	36	4.28E+05	30	2.58E+05	18	1.74E+05	0	N/A

Table R-2 Continued

Tentative Chemical Identification[c]	CAS Number[d]	Chemical Formula	Score	Number of Chemicals Same Formula	Recycling Plants – Frequency	Recycling Plants – Mean Area Counts	Indoor Fields – Frequency	Indoor Fields – Mean Area Counts	Outdoor Fields – Frequency	Outdoor Fields – Mean Area Counts	Blanks – Frequency	Blanks – Mean Area Counts
N,N'-Diphenyl-p-phenylenediamine	74-31-7	C18H16N2	98	74	18	1.48E+06	3	4.91E+05	0	N/A	0	N/A
Benzenediazonium, 2,5-diethoxy-4-[(4-methyl benzoyl)amino]-, (T-4)-tetrachlorozincate(2-) (2:1)	38656-58-5	C18H20N3O3	90.13	1	6	7.47E+04	9	1.54E+05	6	1.51E+05	0	N/A
N-(3-Phenyl-n-propyl)-1-phenyl-2-aminopropane	131903-56-5	C18H23N	96.98	38	9	1.29E+06	9	3.54E+05	12	3.12E+05	0	N/A
Pyridinium, 4-[2-[4-(diethylamino) phenyl]ethenyl]-1-methyl-	133338-40-6	C18H23N2	96.11	3	3	1.35E+06	12	1.24E+06	15	1.12E+06	0	N/A
N-(1,3-Dimethylbutyl)-N'-phenyl-p-phenylenediamine *(Alternate name: 6PPD)*	793-24-8	C18H24N2	83.12	52	6	4.55E+07	12	2.18E+07	6	6.26E+06	2	2.64E+05
Dextromethorphan	125-71-3	C18H25NO	86.26	132	18	2.13E+05	12	1.59E+05	3	1.14E+05	0	N/A
Dextromethorphan	125-71-3	C18H25NO	92.36	132	18	2.42E+05	9	1.32E+05	6	7.64E+04	0	N/A
tert-Butyl 3-({[(4-fluorophenyl)methyl] amino} methyl)piperidine-1-carboxylate	887587-55-5	C18H27FN2O2	80.3	6	15	2.23E+05	12	3.41E+05	6	5.21E+05	0	N/A
3-Carbamoyl-1-[2-(decylamino)-2-oxoethyl] pyridine-1-ium chloride	110177-28-1	C18H30N3O2	84.65	1	3	2.53E+04	9	4.53E+05	15	6.02E+05	0	N/A
2-[2-[4-(1,1,3,3-Tetramethylbutyl) phenoxy]ethoxy] ethanol	2315-61-9	C18H30O3	84.57	58	12	1.61E+05	12	6.80E+05	9	2.88E+05	0	N/A
7-[(Benzyloxy)methyl]-3,6,9,12-tetraoxatetra decane-1,14-diol	91472-18-3	C18H30O7	84.17	2	18	8.31E+06	15	4.08E+06	6	1.86E+05	0	N/A
Oleic acid	112-80-1	C18H34O2	84.62	107	15	2.51E+05	9	1.84E+05	9	1.95E+05	0	N/A
1-Piperazinecarboxylic acid, 4-(2-(pentylamino) ethyl)-, cyclohexyl ester, hydrochloride	24269-89-4	C18H35N3O2	98.5	5	12	2.74E+05	6	1.25E+05	0	N/A	0	N/A
5-Tetradecylpyrimidine-2,4,6-triamine	94087-77-1	C18H35N5	84.35	3	12	3.03E+05	3	6.25E+05	0	N/A	0	N/A
Spiroxamine	118134-30-8	C18H35NO2	86.77	66	15	2.74E+05	6	2.41E+05	12	1.93E+05	0	N/A
1-Piperazinecarboxylic acid, 4-(2-(dibutylamino) ethyl)-, isopropyl ester, hydrochloride	24269-60-1	C18H37N3O2	94.14	6	12	1.50E+05	3	4.76E+04	0	N/A	0	N/A
Octadecanamide	124-26-5	C18H37NO	93.72	372	45	5.23E+05	27	1.51E+05	18	8.27E+04	0	N/A

Table R-2 Continued

Tentative Chemical Identification[c]	CAS Number[d]	Chemical Formula	Score	Number of Chemicals Same Formula	Recycling Plants – Frequency	Recycling Plants – Mean Area Counts	Indoor Fields – Frequency	Indoor Fields – Mean Area Counts	Outdoor Fields – Frequency	Outdoor Fields – Mean Area Counts	Blanks – Frequency	Blanks – Mean Area Counts
Octadecanamide	124-26-5	C18H37NO	86.19	372	36	1.75E+05	45	1.16E+05	18	1.75E+05	0	N/A
Octadecanamide	124-26-5	C18H37NO	92.65	372	54	2.84E+05	45	2.22E+05	36	1.99E+05	0	N/A
Octadecanamide	124-26-5	C18H37NO	90.82	372	54	1.39E+06	45	1.33E+06	36	7.38E+05	0	N/A
Palmitoylethanolamide	544-31-0	C18H37NO2	87.34	468	18	1.64E+05	6	1.02E+05	15	1.46E+05	0	N/A
Palmitoylethanolamide	544-31-0	C18H37NO2	96.07	468	18	7.35E+05	15	2.82E+05	9	1.07E+05	0	N/A
Mega 11	119772-49-5	C18H37NO6	91.32	1	0	N/A	6	4.79E+05	0	N/A	0	N/A
1,9,10-Octadecanetriol	7023-01-0	C18H38O3	89.34	6	18	4.03E+06	9	1.65E+06	6	2.10E+06	0	N/A
Tris(2-butoxyethyl) phosphate	78-51-3	C18H39O7P	94.38	3	15	3.92E+05	15	5.29E+05	3	2.10E+05	0	N/A
Disiloxane, hexapropyl-	17841-51-9	C18H42OSi2	81.68	2	3	1.26E+05	3	3.23E+05	0	N/A	0	N/A
1,1,1-Tri(propan-2-yl)-N-[tri(propan-2-yl)silyl] silanamine	923027-92-3	C18H43NSi2	88.4	2	18	4.81E+05	12	3.36E+05	3	3.59E+05	3	1.04E+05
9-Anilinoacridine	3340-22-5	C19H14N2	85.86	31	18	2.71E+05	15	2.92E+05	9	2.56E+05	0	N/A
Naftoxate	28820-28-2	C19H14N2OS2	94.26	3	18	1.66E+05	6	5.19E+04	0		0	N/A
Thiazole, 2-(1H-imidazol-1-yldiphenylmethyl)-	49620-36-2	C19H15N3S	91.75	4	18	1.40E+05	9	1.35E+05	12	1.47E+05	0	N/A
Benzenemethanol, 4-amino-.alpha.,.alpha.-bis(4-aminophenyl)-	467-62-9	C19H19N3O	83.67	37	15	3.06E+05	6	2.07E+05	0	N/A	0	N/A
Triprolidine	486-12-4	C19H22N2	86.42	53	9	8.26E+05	3	1.46E+05	12	1.14E+05	0	N/A
Cinchonine	118-10-5	C19H22N2O	95.76	88	18	6.60E+05	15	5.13E+05	9	2.74E+05	0	N/A
Amitraz	33089-61-1	C19H23N3	99.38	23	12	5.43E+05	3	2.77E+05	0	N/A	0	N/A
Labetalol	36894-69-6	C19H24N2O3	93.27	39	18	1.37E+06	3	4.10E+05	3	1.53E+05	0	N/A
Propanedinitrile, (((2-(((5-((bis(1-methylethyl) amino)methyl)-2-furanyl)methyl)amino)ethyl) amino)(methylamino)methylene)-	135017-15-1	C19H30N6O	84.18	1	0	N/A	3	4.13E+05	15	3.66E+05	0	N/A
Bencyclane	2179-37-5	C19H31NO	97.63	22	18	8.82E+05	3	1.49E+05	0	N/A	0	N/A
1-(Piperidin-1-yl)tetradeca-2,4-dien-1-one	52657-12-2	C19H33NO	91.52	20	18	1.11E+06	15	5.21E+05	6	1.09E+05	0	N/A
1,9-di(piperidin-1-yl)nonane-1,9-dione	66759-29-3	C19H34N2O2	89.33	7	12	9.52E+04	12	1.74E+05	6	2.80E+05	0	N/A
PUBCHEM_54607300	67606-56-8	C19H37N5	80.97	2	18	2.85E+05	15	3.05E+05	6	1.35E+05	0	N/A

Table R-2 Continued

Tentative Chemical Identification[c]	CAS Number[d]	Chemical Formula	Score	Number of Chemicals Same Formula	Recycling Plants – Frequency	Recycling Plants – Mean Area Counts	Indoor Fields – Frequency	Indoor Fields – Mean Area Counts	Outdoor Fields – Frequency	Outdoor Fields – Mean Area Counts	Blanks – Frequency	Blanks – Mean Area Counts
N',2-Bis(2,2,6,6-tetramethylpiperidin-4-ylidene) hydrazine-1-carbohydrazonamide	64636-27-7	C19H37N7	86.4	1	9	1.14E+05	3	9.37E+04	0	N/A	0	N/A
Tridemorph	24602-86-6	C19H39NO	80.81	14	18	1.54E+05	12	1.30E+05	9	1.42E+05	0	N/A
NSC297111	63595-54-0	C19H40N8S2	93.44	1	18	1.05E+06	6	6.34E+05	12	3.33E+05	0	N/A
AGN-PC-00DGDP	47363-93-9	C20H15N4	83.95	3	18	1.91E+05	12	2.51E+05	6	1.41E+05	0	N/A
{2,2-Bis[(benzyloxy)methyl]-3,3-difluorocyclo propyl}methanol	220825-78-5	C20H22F2O3	83.08	1	15	2.78E+05	3	4.05E+05	3	3.52E+04	0	N/A
1,3-Propanediamine, N'-benzo(g)quinolin-4-yl-N,N-diethyl-	56297-68-8	C20H25N3	92.65	16	18	7.51E+05	15	9.49E+05	6	2.97E+05	0	N/A
1,3-Propanediamine, N'-benzo(g)quinolin-4-yl-N,N-diethyl-	56297-68-8	C20H25N3	96.46	16	15	3.75E+05	15	6.78E+05	6	2.73E+05	0	N/A
Estradiol acetate	4245-41-4	C20H26O3	81.77	32	6	2.21E+05	15	2.45E+05	6	5.16E+05	0	N/A
Aspidospermidine, 17-methoxy-	2447-50-9	C20H28N2O	83.64	24	9	1.31E+06	6	3.93E+05	0	N/A	0	N/A
Oxyphencyclimine	125-53-1	C20H28N2O3	93.19	18	9	6.79E+05	0		0	N/A	0	N/A
Oxyphencyclimine	125-53-1	C20H28N2O3	97.77	18	18	9.24E+05	3	4.34E+05	3	1.42E+05	0	N/A
all-trans-Retinoic acid	302-79-4	C20H28O2	89.66	62	9	4.34E+05	12	5.28E+05	9	4.79E+05	0	N/A
3,4-Piperidinediol, 4-(3-(diethylamino)-1-propynyl)-1,3-dimethyl-6-(4-fluorophenyl)-, (3-alpha,4-beta,6-beta)-	120768-88-9	C20H29FN2O2	80.26	1	9	3.40E+05	6	3.09E+05	0	N/A	0	N/A
Retinol	68-26-8	C20H30O	97.4	31	0	N/A	3	4.90E+05	9	5.65E+05	0	N/A
17-Methyltestosterone	58-18-4	C20H30O2	83.78	132	18	1.35E+05	6	5.57E+04	0	N/A	0	N/A
Lubiprostone	136790-76-6	C20H32F2O5	81.37	1	18	1.01E+05	3	6.53E+04	0	N/A	0	N/A
Arachidonic acid	506-32-1	C20H32O2	84.16	120	0	N/A	6	7.16E+05	9	1.33E+06	0	N/A
Dimethyl[(9Z)-octadec-9-en-1-yl]amine oxide	14351-50-9	C20H41NO	90.93	360	36	1.16E+05	45	9.06E+04	27	1.51E+05	0	N/A
Dimethyl[(9Z)-octadec-9-en-1-yl]amine oxide	14351-50-9	C20H41NO	88.57	360	45	3.09E+05	45	2.26E+05	36	1.19E+06	0	N/A
Dimethyl[(9Z)-octadec-9-en-1-yl]amine oxide	14351-50-9	C20H41NO	95.64	360	54	4.75E+05	45	4.45E+05	18	2.32E+05	0	N/A

Table R-2 Continued

Tentative Chemical Identification[c]	CAS Number[d]	Chemical Formula	Score	Number of Chemicals Same Formula	Recycling Plants – Frequency	Recycling Plants – Mean Area Counts	Indoor Fields – Frequency	Indoor Fields – Mean Area Counts	Outdoor Fields – Frequency	Outdoor Fields – Mean Area Counts	Blanks – Frequency	Blanks – Mean Area Counts
Dimethyl[(9Z)-octadec-9-en-1-yl]amine oxide	14351-50-9	C20H41NO	91.69	360	54	1.18E+06	45	8.20E+05	36	1.30E+06	0	N/A
N-(2-Hydroxyethyl)octadecanamide	111-57-9	C20H41NO2	83.94	19	12	3.54E+05	12	2.29E+05	6	1.72E+05	0	N/A
2-{2-[(2-Hexyldecyl)oxy]ethoxy}ethan-1-ol	113181-09-2	C20H42O3	80.76	12	9	6.44E+05	6	2.05E+05	6	5.04E+05	0	N/A
N,N-Dimethyl-1-octadecanamine	124-28-7	C20H43N	92.77	33	18	4.33E+06	15	1.55E+06	9	4.58E+05	0	N/A
Bromonickel--1,4,16,19-tetraoxa-7,10,13,22,25,28-hexaazacyclotriacontane--water (1/1/4)	7238-17-7	C20H46N6O4	87.03	2	12	1.42E+06	12	1.06E+06	6	5.81E+05	0	N/A
ST029102	5193-48-6	C21H20N4O2S2	86.87	1	18	1.91E+05	15	1.26E+05	6	4.35E+04	0	N/A
PF-622	898235-65-9	C21H22N4O	93.22	12	15	4.74E+05	3	4.28E+05	6	3.28E+05	0	N/A
T5244034	5521-48-2	C21H24F3N3O4	87.68	1	18	1.16E+05	6	1.11E+05	3	8.37E+04	0	N/A
Acetamide, N-(1-(10,11-dihydro-5H-dibenzo(a,d) cyclohepten-5-yl)-3-azetidinyl)-N-methyl-	61450-45-1	C21H24N2O	81.56	34	18	1.07E+05	12	1.20E+05	9	9.31E+04	0	N/A
3~4~-Fluoro-1~4~-propyl-1~1~,1~2~,1~3~,1~4~, 1~5~,1~6~-hexahydro-1~1~,2~1~:2~4~,3~1~-terphenyl	87260-24-0	C21H25F	84.63	1	6	2.06E+05	0	N/A	3	2.99E+05	0	N/A
Benzenamine, 4,4'-methylenebis[N-butylidene-	72089-11-3	C21H26N2	83.82	36	18	4.97E+05	3	3.41E+05	6	2.21E+05	0	N/A
Benzenamine, 4,4'-methylenebis[N-butylidene-	72089-11-3	C21H26N2	95.69	36	18	1.60E+06	15	1.22E+06	9	9.40E+05	0	N/A
STK108220	5669-53-4	C21H26N2O5S	85.21	5	9	2.82E+05	9	1.29E+05	9	1.14E+05	0	N/A
ETH-LAD	65527-62-0	C21H27N3O	98.21	50	15	3.68E+05	15	6.06E+05	9	1.55E+05	0	N/A
ETH-LAD	65527-62-0	C21H27N3O	93.96	50	18	1.25E+06	15	1.28E+06	9	3.94E+05	0	N/A
MLS000579055	5637-46-7	C21H27N3O5S	89.51	3	18	8.11E+05	6	3.84E+05	3	1.28E+05	0	N/A
N(1),N(8)-Bis(2,3-dihydroxybenzoyl)spermidine	54135-84-1	C21H27N3O6	88.48	4	18	1.36E+06	12	8.08E+05	6	7.02E+05	0	N/A
Amorolfine	78613-35-1	C21H35NO	92.06	14	18	6.84E+05	9	3.87E+05	0	N/A	0	N/A
4-Amino-1-hexadecylpyridin-1-ium bromide	13554-67-1	C21H39N2	81.53	1	18	4.97E+05	6	2.66E+05	3	4.17E+05	0	N/A

Table R-2 Continued

Tentative Chemical Identification[c]	CAS Number[d]	Chemical Formula	Score	Number of Chemicals Same Formula	Recycling Plants – Frequency	Recycling Plants – Mean Area Counts	Indoor Fields – Frequency	Indoor Fields – Mean Area Counts	Outdoor Fields – Frequency	Outdoor Fields – Mean Area Counts	Blanks – Frequency	Blanks – Mean Area Counts
1-Hexyl-4-({2-[hexyl(dimethyl) azaniumyl]ethyl} sulfanyl)pyridin-1-ium diiodide	878547-58-1	C21H40N2S	92.6	1	18	3.32E+06	6	3.93E+06	3	2.56E+06	0	N/A
Netilmicin sulfate	56391-57-2	C21H41N5O7	96.24	2	15	1.31E+05	15	2.18E+05	6	1.21E+05	0	N/A
2,2-Dibutyl-N~1~,N~3~-bis(4-methylpiperazin-1-yl)propanediamide	88172-29-6	C21H42N6O2	97.86	1	3	2.55E+05	0	N/A	3	1.83E+05	0	N/A
1-Hexadecylpyridine N-oxide	53669-72-0	C21H43NO	81.85	8	18	1.79E+05	12	1.71E+05	9	1.85E+05	0	N/A
6-Azidoketanserin	97930-92-2	C22H21FN6O3	86.19	2	18	1.49E+05	6	1.08E+05	3	9.95E+04	0	N/A
C.I. 50030	3562-46-7	C22H24N6	83.37	2	18	2.02E+05	9	8.44E+04	6	6.82E+04	0	N/A
4-(9-Acridinylamino)-2,2,6,6-tetramethyl-1-piperidinyloxy	58814-40-7	C22H27N3O	96.53	34	18	6.28E+05	12	3.69E+05	9	1.83E+05	0	N/A
4-(9-Acridinylamino)-2,2,6,6-tetramethyl-1-piperidinyloxy	58814-40-7	C22H27N3O	88.3	34	18	5.51E+05	3	1.70E+05	3	9.57E+04	0	N/A
Mafoprazine	80428-29-1	C22H28FN3O3	99.39	1	18	8.47E+05	6	2.69E+05	0	N/A	0	N/A
Fentanyl	437-38-7	C22H28N2O	97.1	32	15	3.12E+05	12	3.21E+05	9	2.18E+05	0	N/A
2-(2H-Benzotriazol-2-yl)-4,6-bis(1,1-dimethyl propyl)phenol	25973-55-1	C22H29N3O	81.78	20	6	2.01E+05	3	7.13E+04	0	N/A	0	N/A
AFP-07 free acid	788799-13-3	C22H30F2O5	87.31	3	18	1.36E+06	15	7.38E+05	3	7.94E+04	0	N/A
SCHEMBL9702839	51549-37-2	C22H31N3O5Si	80.11	2	9	2.20E+05	0	N/A	0	N/A	0	N/A
Benzquinamide	63-12-7	C22H32N2O5	94.61	6	18	3.25E+05	6	1.20E+05	3	6.29E+04	0	N/A
1-Octadecyl-1H-pyrrole-2,5-dione	17450-30-5	C22H39NO2	96.44	7	6	9.38E+04	9	3.73E+05	15	3.90E+05	0	N/A
7224-39-7	7224-39-7	C22H40N4	91.87	2	18	2.49E+06	6	1.43E+06	6	2.03E+06	0	N/A
Ethanol, 2,2'-(1,4-piperazinylene)di-, diheptanoate, dihydrochloride	54468-75-6	C22H42N2O4	83.21	1	6	9.20E+04	9	1.00E+05	0	N/A	0	N/A
5-Octadecylpyrimidine-2,4,6-triamine	94087-81-7	C22H43N5	93.58	2	18	1.35E+06	6	7.67E+05	6	1.10E+06	0	N/A
[(6-Heptadecyl-1,3,5-triazine-2,4-diyl) diazanediyl] dimethanol	51604-73-0	C22H43N5O2	93.98	1	18	1.96E+05	9	3.25E+05	0	N/A	0	N/A
Docosanamide	3061-75-4	C22H45NO	95.22	52	30	4.08E+05	30	2.08E+05	24	4.38E+05	0	N/A
Docosanamide	3061-75-4	C22H45NO	94.37	52	36	6.64E+05	30	4.48E+05	30	8.11E+05	0	N/A
1-Docosanamine	14130-06-4	C22H47N	88.92	9	6	1.63E+05	12	4.04E+06	0	N/A	0	N/A

Table R-2 Continued

Tentative Chemical Identification[c]	CAS Number[d]	Chemical Formula	Score	Number of Chemicals Same Formula	Recycling Plants – Frequency	Recycling Plants – Mean Area Counts	Indoor Fields – Frequency	Indoor Fields – Mean Area Counts	Outdoor Fields – Frequency	Outdoor Fields – Mean Area Counts	Blanks – Frequency	Blanks – Mean Area Counts
3H-Indolium, 1,3,3-trimethyl-2-[[2-methyl-2-(2-naphthalenyl) hydrazinylidene]methyl]-, chloride (1:1)	38936-33-3	C23H24N3	83.2	2	18	3.59E+05	3	1.08E+05	0	N/A	0	N/A
Isoreserpiline, citrate	6270-51-5	C23H28N2O5	87.78	12	18	3.31E+05	3	9.61E+04	0	N/A	0	N/A
Urea, 1,3-bis(2,6-xylyl)-1-(2-(diethylamino)ethyl)-, hydrochloride	78371-87-6	C23H33N3O	81.66	3	18	5.36E+05	6	3.26E+05	0	N/A	0	N/A
1-Fluoro-4-{4-[2-(4-propylcyclohexyl) ethyl] cyclohexyl}benzene	91162-04-8	C23H35F	83.14	1	18	1.74E+06	12	1.69E+06	6	1.78E+06	0	N/A
N-[4-(5-Sulfanylidene-2,5-dihydro-1H-tetrazol-1-yl)phenyl]hexadecanamide	97916-68-2	C23H37N5OS	80.27	1	18	1.72E+05	15	3.46E+05	9	1.23E+05	0	N/A
(Cyclotetradeca-1,2-dien-9-yne-1,3,8-triyl)tris (trimethylsilane)	61173-64-6	C23H44Si3	82.2	1	6	1.77E+05	0	N/A	0	N/A	0	N/A
Triethylsilyl 11-(triethoxysilyl)undecanoate	194343-84-5	C23H50O5Si2	89.26	1	9	1.34E+05	9	1.46E+05	6	1.84E+05	0	N/A
(1)Benzopyrano(2,3-b)(1,5) benzodiazepin-13(6H)-one, 6-benzoyl-2-methyl-	77436-67-0	C24H16N2O3	97.73	14	18	9.94E+04	15	9.17E+04	9	5.49E+04	0	N/A
5-Methoxy-3-methyl-2-(2-((3-(3-sulphonatopropyl) -3H-benzothiazol-2-ylidene)methyl)but-1-enyl) benzoxazolium	55811-26-2	C24H27N2O5S2	92.77	4	36	2.34E+05	30	1.94E+05	30	1.59E+05	0	N/A
5-Methoxy-3-methyl-2-(2-((3-(3-sulphonatopropyl) -3H-benzothiazol-2-ylidene)methyl)but-1-enyl) benzoxazolium	55811-26-2	C24H27N2O5S2	90.72	4	36	1.50E+05	30	1.29E+05	30	1.40E+05	0	N/A
Phenol, 2-(2H-naphtho[1,2-d]triazol-2-yl)-4-(1,1,3,3-tetramethylbutyl)-	27876-55-7	C24H27N3O	95.95	72	36	8.20E+05	30	6.98E+05	30	8.02E+05	0	N/A
Phenol, 2-(2H-naphtho[1,2-d]triazol-2-yl)-4-(1,1,3,3-tetramethylbutyl)-	27876-55-7	C24H27N3O	92.16	72	36	8.66E+05	12	3.87E+05	0	N/A	0	N/A
1,3,8-Triazaspiro(4.5)decane-2,4-dione, 8-(2-phenylethyl)-3-(3-phenylpropyl)-	124312-80-7	C24H29N3O2	83.56	10	9	2.38E+05	3	1.82E+05	12	2.03E+05	0	N/A
4-Butyl-N-[4-(2,4,4-trimethylpentan-2-yl)phenyl] aniline	142944-36-3	C24H35N	82.64	5	12	3.18E+05	12	3.24E+05	3	1.17E+05	0	N/A

Table R-2 Continued

Tentative Chemical Identification[c]	CAS Number[d]	Chemical Formula	Score	Number of Chemicals Same Formula	Recycling Plants – Frequency	Recycling Plants – Mean Area Counts	Indoor Fields – Frequency	Indoor Fields – Mean Area Counts	Outdoor Fields – Frequency	Outdoor Fields – Mean Area Counts	Blanks – Frequency	Blanks – Mean Area Counts
N~1~-[1-(2,2-Diphenylethyl)piperidin-4-yl]-N~3~-ethylpropane-1,3-diamine	827045-76-1	C24H35N3	93.58	1	12	1.92E+05	3	5.75E+04	0	N/A	0	N/A
2-naphthalen-1-yl-6-piperidin-1-yl-2-propan-2-ylhexan-1-amine	27566-49-0	C24H36N2	90.04	11	18	1.21E+06	6	1.04E+06	6	4.45E+05	0	N/A
Lovastatin ammonium salt	77550-67-5	C24H38O6	90.5	11	15	1.85E+05	12	2.46E+05	3	5.52E+04	0	N/A
1,1'-(Decane-1,10-diyl)bis[4-(dimethylamino) pyridin-1-ium] dibromide	99082-26-5	C24H40N4	92.45	2	12	9.51E+04	9	8.85E+04	6	1.08E+05	0	N/A
Octadecanamide, N-phenyl-	637-54-7	C24H41NO	83.53	8	3	6.22E+05	0	N/A	6	7.64E+05	0	N/A
N~2~-Butyl-6-heptadecyl-1,3,5-triazine-2,4-diamine	66709-66-8	C24H47N5	80.1	1	12	2.64E+05	9	1.05E+05	9	1.93E+05	0	N/A
1-(3,7,11,15-Tetramethylhexadecanoyl) pyrrolidine	56630-63-8	C24H47NO	87.67	6	12	1.62E+05	12	1.17E+05	9	1.83E+05	0	N/A
3-[2-Hydroxy-3-(octadecyloxy) propoxy]propane-1,2-diol	121637-23-8	C24H50O5	95.87	2	18	5.66E+05	6	3.38E+05	6	4.66E+05	0	N/A
Trioctylamine	1116-76-3	C24H51N	94.89	18	12	1.24E+05	12	8.79E+04	3	6.35E+04	0	N/A
Phosphine, trioctyl-	4731-53-7	C24H51P	91	4	12	4.54E+05	6	2.32E+05	6	4.43E+05	0	N/A
9,9'-Spirobi[fluorene]-2,2'-diamine	67665-45-6	C25H18N2	81.68	5	0	N/A	9	1.09E+05	3	4.07E+04	0	N/A
4-amino-N,N-dibenzyl-2-benzylsulfanyl-1,3-thiazole-5-carboxamide	63238-10-8	C25H23N3OS2	82.28	4	18	8.82E+05	6	6.97E+04	0	N/A	0	N/A
4-amino-N,N-dibenzyl-2-benzylsulfanyl-1,3-thiazole-5-carboxamide	63238-10-8	C25H23N3OS2	88.83	4	18	1.43E+06	6	1.16E+05	0	N/A	0	N/A
Phenothiazine, 10-(2-(4-benzyl-1-piperazinyl) ethyl)-	103168-78-1	C25H27N3S	92.13	1	18	1.89E+05	3	1.84E+05	12	3.88E+05	0	N/A
Benzene-1,4-diamine, N-(benzo(g)quinolin-4-yl)-N'-(2-(diethylamino)ethyl)-	127136-27-0	C25H28N4	90.87	3	9	6.16E+05	9	2.86E+05	3	1.44E+05	0	N/A
Nufenoxole	57726-65-5	C25H29N3O	96.79	9	18	7.62E+05	15	4.55E+05	6	1.77E+05	0	N/A
Metergoline	17692-51-2	C25H29N3O2	96.05	6	18	3.29E+05	6	1.42E+05	0	N/A	0	N/A

Table R-2 Continued

Tentative Chemical Identification[c]	CAS Number[d]	Chemical Formula	Score	Number of Chemicals Same Formula	Recycling Plants – Frequency	Recycling Plants – Mean Area Counts	Indoor Fields – Frequency	Indoor Fields – Mean Area Counts	Outdoor Fields – Frequency	Outdoor Fields – Mean Area Counts	Blanks – Frequency	Blanks – Mean Area Counts
3-(2-Aminoethyl)-8-(3-(4-fluorobenzoyl)propyl)-4-oxo-1-phenyl-1,3,8-triazaspiro(4.5)decan-4-one	125094-03-3	C25H31FN4O2	97.33	1	6	1.86E+05	3	2.02E+05	9	1.76E+05	0	N/A
A 55453	89687-06-9	C25H32N6O3	81.24	2	9	1.76E+05	6	8.18E+04	9	6.50E+04	0	N/A
N-[1-({2-[(1-Hydroxy-3-phenylpropan-2-yl)amino] -2-oxoethyl}amino)-4-(methanesulfinyl)-1-oxobutan-2-yl]tyrosinamide	82598-04-7	C25H34N4O6S	87.76	1	18	1.79E+05	6	1.18E+05	0	N/A	0	N/A
1-Butyl-1-{2-[(diphenylacetyl)oxy] ethyl}piperidin-1-ium iodide	62088-57-7	C25H34NO2	86.85	1	9	2.38E+05	3	2.10E+05	6	2.28E+05	0	N/A
Propylamine, N-(4-tert-butylcyclohexyl) -3,3-diphenyl-, hydrochloride, cis-	61925-70-0	C25H35N	86.81	3	6	2.54E+05	3	9.31E+04	0	N/A	0	N/A
5H-Dibenz(b,f)azepine-5-propanamine, 10,11-dihydro-N,N-dimethyl-2-(1-piperidinylmethyl)-	64097-63-8	C25H35N3	90.06	2	18	7.94E+05	15	7.31E+05	9	1.92E+05	0	N/A
Amesergide	121588-75-8	C25H35N3O	80.36	16	18	2.39E+05	12	2.05E+05	9	1.17E+05	0	N/A
Bis{3-[2-(diethylamino)ethoxy]phenyl} methanone	67588-09-4	C25H36N2O3	84.31	3	18	2.40E+05	9	1.29E+05	0	N/A	0	N/A
Diamocaine	27112-37-4	C25H37N3O	83.98	5	18	5.61E+05	12	4.40E+05	6	3.16E+05	0	N/A
1-Hexadecyl-5-hydroxyquinolin-1-ium	113451-64-2	C25H40NO	89.51	1	18	1.84E+06	12	8.26E+05	6	2.50E+06	1	1.93E+04
(1",2"-Dimethyl-5"-ethyl)-delta6-tetrahydro cannabinol	343770-62-7	C25H40O2	91.14	5	0	N/A	9	6.65E+05	15	1.96E+06	0	N/A
Butanamide, 2-(3-pentadecylphenoxy)-	62609-89-6	C25H43NO2	86.82	22	6	2.69E+05	3	1.91E+05	0	N/A	0	N/A
Butanamide, 2-(3-pentadecylphenoxy)-	62609-89-6	C25H43NO2	92.25	22	0		9	9.33E+05	15	2.46E+06	0	N/A
N-[1-(Octadecyloxy)-4-(2H-tetrazol-5-yl)butan-2-yl]acetamide	192563-92-1	C25H49N5O2	87.67	1	18	1.71E+05	15	2.32E+05	6	5.42E+04	0	N/A
1-Dodecanamine, N-dodecyl-N-methyl-	2915-90-4	C25H53N	94.59	3	12	1.06E+06	12	1.37E+06	3	2.21E+06	0	N/A
1H-Indole, 1,1'-(3,7-dimethyl-6-octen-1-ylidene) bis-	67801-16-5	C26H30N2	92.7	12	18	5.47E+05	6	4.88E+05	3	2.88E+05	0	N/A

Table R-2 Continued

Tentative Chemical Identification[c]	CAS Number[d]	Chemical Formula	Score	Number of Chemicals Same Formula	Recycling Plants – Frequency	Recycling Plants – Mean Area Counts	Indoor Fields – Frequency	Indoor Fields – Mean Area Counts	Outdoor Fields – Frequency	Outdoor Fields – Mean Area Counts	Blanks – Frequency	Blanks – Mean Area Counts
2-({4-[(2-Amino-4-oxo-4,5-dihydro-1,3-thiazol-5-yl)methyl]phenoxy} methyl)-2,5,7,8-tetramethyl-3,4-dihydro-2H-1-benzopyran-6-yl acetate	171485-87-3	C26H30N2O5S	91.6	1	18	1.51E+05	12	9.03E+04	9	7.55E+04	0	N/A
9,10-Anthracenedione, 1,4-bis[(1,3-dimethylbutyl) amino]-	19720-42-4	C26H34N2O2	93.32	15	0	N/A	0	N/A	6	2.83E+05	0	N/A
2,3-dimethoxy-5-octadecylsulfanyl cyclohexa-2,5-diene-1,4-dione	53092-24-3	C26H44O4S	80.5	2	15	2.24E+05	3	1.55E+05	0	N/A	0	N/A
{[18-(4-Methylpiperidin-1-yl)-18-oxooctadecan-9-yl]sulfanyl}acetic acid	65768-88-9	C26H49NO3S	87.66	1	15	9.53E+04	3	2.02E+04	3	2.76E+04	0	N/A
Bis(2-ethylhexyl) decanedioate	122-62-3	C26H50O4	88.19	14	18	1.12E+06	6	7.75E+05	6	1.84E+06	0	N/A
1-Tridecanamine, N-tridecyl-	5910-75-8	C26H55N	96.96	6	12	2.57E+05	12	1.71E+05	3	1.35E+05	0	N/A
3,6,9,12-Tetraazatriacontane-1-sulfonic acid	29401-55-6	C26H58N4O3S	80.16	1	15	3.13E+05	3	2.04E+05	12	2.64E+05	0	N/A
Carbamic acid, (5,6,7,9-tetrahydro-1,2,3-trimethoxy-10-(methylthio)-9-oxobenzo(a) heptalene-7-yl)-, phenyl ester, (S)-	96737-27-8	C27H27NO6S	84.34	1	18	1.09E+06	15	5.71E+05	6	8.21E+04	0	N/A
N-[2-(Cyclohexylamino)-1-(2-methylphenyl)-2-oxoethyl]-N-(3-fluorophenyl)-2-(2-methyl-1H-imidazol-1-yl)acetamide	1355326-35-0	C27H31FN4O2	93.52	8	36	4.33E+05	30	5.58E+05	30	6.13E+05	0	N/A
N-[2-(Cyclohexylamino)-1-(2-methylphenyl)-2-oxoethyl]-N-(3-fluorophenyl)-2-(2-methyl-1H-imidazol-1-yl)acetamide	1355326-35-0	C27H31FN4O2	92.79	8	0	N/A	6	3.29E+05	24	6.69E+05	0	N/A
AC1NSNAY	5784-09-8	C27H31N3O3	85.29	2	3	8.26E+04	3	2.12E+05	3	2.05E+05	0	N/A
Rolitetracycline	751-97-3	C27H33N3O8	81.97	2	12	4.91E+04	9	5.38E+04	12	1.05E+05	0	N/A
Duokvin	120509-24-2	C27H34N2	85.01	36	0	N/A	9	8.16E+05	3	1.15E+06	0	N/A
Duokvin	120509-24-2	C27H34N2	82.02	36	18	5.85E+05	3	4.90E+05	3	2.11E+05	0	N/A
Duokvin	120509-24-2	C27H34N2	91.67	36	18	7.37E+05	9	5.47E+05	12	6.88E+05	0	N/A

Table R-2 Continued

Tentative Chemical Identification[c]	CAS Number[d]	Chemical Formula	Score	Number of Chemicals Same Formula	Recycling Plants – Frequency	Recycling Plants – Mean Area Counts	Indoor Fields – Frequency	Indoor Fields – Mean Area Counts	Outdoor Fields – Frequency	Outdoor Fields – Mean Area Counts	Blanks – Frequency	Blanks – Mean Area Counts
2-[2-Fluoro-4-(octyloxy)phenyl]-5-(nonyloxy) pyrimidine	143625-23-4	C27H41FN2O2	97.89	1	18	2.21E+06	9	1.32E+06	6	6.15E+05	0	N/A
2,2',2"-Phosphanetriyltris(4,5-dipropyl-1H-imidazole)	89210-52-6	C27H45N6P	82.33	2	18	2.36E+05	3	2.01E+05	0	N/A	0	N/A
3-Pentadecyl-4-(piperidin-1-ylmethyl) benzene-1,2-diol hydrochloride	66495-64-5	C27H47NO2	87.99	4	6	6.70E+04	12	3.17E+05	15	6.17E+05	0	N/A
1-Octanamine, 7-methyl-N,N-bis(7-methyloctyl)-	18198-40-8	C27H57N	93.39	2	12	1.88E+06	12	2.45E+06	3	4.21E+06	0	N/A
4-Quinolinecarboxylic acid, 2-(10-(2-(dimethylamino)ethyl)-10H-phenothiazin-2-yl)-, ethyl ester, monohydrochloride	72170-44-6	C28H27N3O2S	86.06	1	18	2.78E+05	15	2.33E+05	9	1.09E+05	0	N/A
N-Propyl-1-(triphenylmethyl)-L-histidinamide	171176-63-9	C28H30N4O	90.93	1	15	5.80E+05	6	3.80E+05	9	1.69E+05	0	N/A
GBR 12935	76778-22-8	C28H34N2O	83.16	7	3	1.68E+05	3	1.42E+05	9	1.02E+05	0	N/A
2-Naphthalenol, 1-[(4-dodecylphenyl) azo]-	68310-09-8	C28H36N2O	95.09	5	12	2.53E+05	9	5.44E+05	3	3.35E+05	0	N/A
N-[1-[4-(4-methylphenyl)-5-[(3-methylphenyl) methylsulfanyl]-1,2,4-triazol-3-yl]ethyl] nonanamide	5977-63-9	C28H38N4OS	80.83	1	18	4.48E+05	6	4.58E+05	6	1.24E+05	0	N/A
(2S)-1-[(2S,3S)-3-Hexyl-4-oxooxetan-2-yl]tridecan -2-yl N-formyl-L-methioninate	1356354-38-5	C28H51NO5S	80.1	1	3	9.67E+04	12	1.54E+05	0	N/A	0	N/A
Impacarzine	41340-39-0	C28H55N5O2	85.92	1	18	9.65E+05	12	4.04E+05	6	7.82E+05	0	N/A
1-(Tetradecylperoxy)tetradecane	2130-45-2	C28H58O2	86.93	2	12	2.62E+05	9	1.01E+05	6	3.56E+05	0	N/A
Dimyristylamine	17361-44-3	C28H59N	90.89	3	12	1.51E+05	9	1.08E+05	3	6.71E+04	0	N/A
1-(2-(2-(Diphenyl)methoxy)ethyl)-4-(3-phenyl propyl)homopiperazine	150151-14-7	C29H36N2O	86.98	4	18	1.70E+05	6	1.90E+05	0	N/A	0	N/A
Onapristone	96346-61-1	C29H39NO3	89.69	5	18	4.97E+05	3	5.30E+05	0	N/A	0	N/A
Nonyl 4-[(E)-{[4-(hexyloxy)phenyl] imino}methyl] benzoate	793724-55-7	C29H41NO3	88.9	1	18	2.22E+05	6	2.60E+05	0	N/A	0	N/A
PUBCHEM_71314385	83274-68-4	C29H50O6Si	92.47	1	18	6.48E+05	15	3.79E+05	9	3.27E+05	0	N/A

Table R-2 Continued

Tentative Chemical Identification[c]	CAS Number[d]	Chemical Formula	Score	Number of Chemicals Same Formula	Recycling Plants – Frequency	Recycling Plants – Mean Area Counts	Indoor Fields – Frequency	Indoor Fields – Mean Area Counts	Outdoor Fields – Frequency	Outdoor Fields – Mean Area Counts	Blanks – Frequency	Blanks – Mean Area Counts
2,2-Bis(((1-oxoheptyl)oxy)methyl)butyl nonan-1-oate	84788-10-3	C29H54O6	84.69	1	18	2.64E+05	6	1.85E+05	3	2.83E+05	0	N/A
1,3,5,6-Tetraphenyl-5,6-dihydro-4H-thieno[3,4-c]pyrrole-4-thione	61505-64-4	C30H21NS2	82.5	1	18	1.21E+05	6	7.69E+04	0	N/A	0	N/A
N-[3-(1,3-benzothiazol-2-yl)-5,5,7,7-tetramethyl-4,6-dihydrothieno[2,3-c]pyridin-2-yl]-3-methoxy naphthalene-2-carboxamide	6268-77-5	C30H29N3O2S2	81.79	1	6	5.19E+04	12	9.73E+04	15	1.61E+05	0	N/A
4-(2-Phenylpropan-2-yl)-N-[4-(2-phenylpropan-2-yl)phenyl]aniline	10081-67-1	C30H31N	91.88	3	15	1.01E+05	6	1.25E+05	6	1.49E+05	0	N/A
T0503-2801	6544-75-8	C30H31N2OP	97.92	1	15	1.32E+05	6	3.36E+04	9	8.76E+04	0	N/A
Pyrimidine, 4-methoxy-2-(4-(3,3,3-triphenyl propyl)-1-piperazinyl)-	20980-13-6	C30H32N4O	95.48	3	18	2.73E+06	12	1.23E+06	9	1.03E+06	0	N/A
Triphenyl{[(tricyclo[3.3.1.1~3,7~]decane-1-carbonyl)amino]methyl} phosphanium chloride	142414-38-8	C30H33NOP	81.6	1	3	1.03E+05	0	N/A	6	2.62E+05	0	N/A
N-[1-(3,3-Diphenylpropyl)piperidin-4-yl]-N'-phenyl-N-prop-2-en-1-ylurea	821008-04-2	C30H35N3O	83.16	2	18	4.09E+05	3	3.14E+05	0	N/A	0	N/A
Benzo(g)quinolin-4-ol, 3-((3,5-bis((diethylamino) methyl)-4-hydroxyphenyl)methyl)-	127136-58-7	C30H37N3O2	86.05	2	15	1.82E+05	9	1.52E+05	3	1.76E+05	0	N/A
PUBCHEM_24184170	6275-38-3	C30H38N2	89.74	3	18	6.24E+05	6	4.16E+05	9	1.96E+05	0	N/A
N-Decyl-N-ethyl-4-[(E)-{4-[(E)-phenyldiazenyl] phenyl}diazenyl] aniline	89132-17-2	C30H39N5	88.43	1	15	3.26E+05	6	1.22E+05	0	N/A	0	N/A
1-Nonyl-4-[(Z)-(4-nonylphenyl)-NNO-azoxy] benzene	37592-91-9	C30H46N2O	93.38	1	3	8.82E+04	0	N/A	3	9.03E+04	0	N/A
2-(4-{4-[(2-Fluorooctyl)oxy]butoxy} phenyl)-5-octylpyrimidine	118642-49-2	C30H47FN2O2	96.29	1	18	3.66E+05	3	1.38E+05	0	N/A	0	N/A
Bis(2-nonylphenoxy)phosphanolate	53197-99-2	C30H47O3P	85.66	3	18	3.55E+05	6	2.72E+05	6	5.44E+04	0	N/A
4-[2-(Benzylsulfanyl)-3-(hexadecyloxy)propoxy] butan-1-amine	89449-40-1	C30H55NO2S	88.05	1	9	1.22E+05	6	1.02E+05	0	N/A	0	N/A

Table R-2 Continued

Tentative Chemical Identification[c]	CAS Number[d]	Chemical Formula	Score	Number of Chemicals Same Formula	Recycling Plants – Frequency	Recycling Plants – Mean Area Counts	Indoor Fields – Frequency	Indoor Fields – Mean Area Counts	Outdoor Fields – Frequency	Outdoor Fields – Mean Area Counts	Blanks – Frequency	Blanks – Mean Area Counts
15-Decyl-3,6,9,12,18,21,24,27-octaoxa-15-azanonacosane-1,29-diol	61480-62-4	C30H63NO10	97.47	1	0	N/A	9	3.90E+05	0	N/A	0	N/A
2,5-dibenzyl-1-methyl-3,4-diphenyl-1h-pyrrole	31396-94-8	C31H27N	83.33	2	9	5.87E+04	3	1.41E+05	6	1.13E+05	0	N/A
Di-tert-butyl[3,6-dimethoxy-2',4',6'-tri(propan-2-yl)[1,1'-biphenyl]-2-yl]phosphane	1160861-53-9	C31H49O2P	97.85	1	18	2.99E+05	15	4.26E+05	6	5.37E+05	0	N/A
(2S,2'S,2"S)-2,2',2"-{(2S,5S,8S,11S)-2,5,8,11-Tetramethyl-10-[(2S)-1-oxo-1-({2-[(pyridin-2-yl)disulfanyl]ethyl} amino)propan-2-yl]-1,4,7,10-tetraazacyclododecane-1,4,7-triyl}tripropanoic acid	1192364-56-9	C31H52N6O7S2	81.6	1	18	3.60E+05	15	1.61E+05	9	1.77E+05	0	N/A
PUBCHEM_46780403	125175-64-6	C31H52O6Si	89.43	1	18	5.51E+05	6	2.72E+05	3	1.21E+05	0	N/A
4-{(E)-[4-(2,2-Diphenylethenyl)phenyl] diazenyl}-N,N-dipropylaniline	726180-87-6	C32H33N3	96.64	1	6	3.55E+05	0	N/A	3	1.04E+05	0	N/A
(2R,10R)-2-(Acetyloxy)nonadecan-10-yl naphthalene-2-carboxylate	825623-09-4	C32H48O4	83.28	2	9	3.00E+05	3	1.63E+05	0	N/A	0	N/A
(2R,10R)-2-(Acetyloxy)nonadecan-10-yl naphthalene-2-carboxylate	825623-09-4	C32H48O4	88.43	2	12	3.30E+05	3	1.94E+05	0	N/A	0	N/A
(3beta,5alpha,22S)-3-[(Oxan-2-yl)oxy] cholestane-20,22-diol	61893-31-0	C32H56O4	80.95	2	12	8.39E+04	6	1.21E+05	0	N/A	0	N/A
L-Arginine, L-glutaminyl-L-seryl-L-seryl-L-asparaginyl-L-leucyl-L-valyl-	265099-06-7	C32H58N12O12	88.37	1	15	1.44E+05	6	7.24E+04	0	N/A	0	N/A
(5,5-Diphenyl-4,5-dihydro-1H-pyrazol-3-yl) (triphenyl)phosphanium bromide	32251-65-3	C33H28N2P	81.05	2	18	1.43E+05	15	1.15E+05	9	6.04E+04	0	N/A
1-[2,4-Dimethyl-1-(3-phenylpropanoyl) - 1H-pyrrol-3-yl]octadecan-1-one	185696-43-9	C33H51NO2	91.06	2	18	1.36E+06	0	N/A	3	3.09E+05	0	N/A
3-(Dodecyloxy)-6-{[4-(octyloxy) anilino] methylidene}cyclohexa-2,4-dien-1-one	643755-26-4	C33H51NO3	87.95	3	18	5.67E+05	15	2.91E+05	6	3.04E+05	0	N/A
2-{4-[(6-Methyldecyl)oxy]phenyl}-5-undecyl pyridine	111336-38-0	C33H53NO	88.73	1	18	5.42E+05	9	3.40E+05	9	2.50E+05	0	N/A

Table R-2 Continued

Tentative Chemical Identification[c]	CAS Number[d]	Chemical Formula	Score	Number of Chemicals Same Formula	Recycling Plants – Frequency	Recycling Plants – Mean Area Counts	Indoor Fields – Frequency	Indoor Fields – Mean Area Counts	Outdoor Fields – Frequency	Outdoor Fields – Mean Area Counts	Blanks – Frequency	Blanks – Mean Area Counts
Akt inhibitor VIII	612847-09-3	C34H29N7O	80.85	1	18	2.50E+05	9	1.29E+05	9	9.13E+04	0	N/A
Urea, N-(2,6-bis(1-methylethyl)phenyl)-N'-((1-(1-methyl-2-phenyl-1H-indol-3-yl)cyclopentyl) methyl)-	145131-60-8	C34H41N3O	82.85	2	18	3.62E+05	6	3.22E+05	6	5.26E+04	0	N/A
Butanediamide, N1-((1S,2R)-3-((2S)-2-(((1,1-dimethylethyl)amino)carbonyl)-1-piperidinyl)-2-hydroxy-1-(phenylmethyl)propyl)-2-((2-quinolinylcarbonyl)amino)-, (2S)-	127749-99-9	C34H44N6O5	80	2	18	3.33E+05	9	8.67E+04	0	N/A	0	N/A
N-[(3beta,5alpha,6beta)-3,5-Dihydroxycholestan-6-yl]benzamide	62684-27-9	C34H53NO3	89.29	2	15	1.21E+06	15	4.29E+05	6	1.91E+05	0	N/A
2,3-Dibenzyl-1-[(naphthalen-1-yl)methyl]-5-phenyl -1H-pyrrole	824421-64-9	C35H29N	84.03	2	18	7.63E+05	15	8.21E+05	9	2.72E+05	0	N/A
1-[10-(9H-Carbazol-9-yl)decyl]-1'-propyl-4,4'-bipyridin-1-ium dibromide	141484-71-1	C35H43N3	85.62	1	15	1.35E+05	6	6.60E+04	0	N/A	0	N/A
N-{2-[Benzyl({1-[(4-fluorophenyl) methyl]-1H-pyrrol-2-yl}methyl)amino]-2-oxoethyl}-4-tert-butyl-N-(3-methoxypropyl)benzamide	5951-50-8	C36H42FN3O3	80.29	1	15	1.19E+05	9	1.29E+05	6	1.43E+05	0	N/A
N-{4-[2-(Quinolin-2-yl)ethenyl]phenyl} nonadec-2-enamide	143252-47-5	C36H48N2O	81.87	1	18	3.96E+05	9	2.28E+05	3	1.41E+05	0	N/A
1,8-Octanediamine, N,N'-bis(3,5-dimethoxy-9-acridinyl)-	64955-58-4	C38H42N4O4	92.48	3	18	8.92E+04	6	5.52E+04	9	7.51E+04	0	N/A
Azithromycin B	307974-61-4	C38H72N2O11	87.68	1	18	1.67E+06	15	5.00E+05	9	5.16E+05	0	N/A
1,6-Hexanediamine, N,N'-bis(4-butoxy-9-acridinyl)-	64955-53-9	C40H46N4O2	84.55	4	18	1.15E+05	9	2.30E+05	6	3.43E+05	0	N/A
AGN-PC-0LOLQU	6115-58-8	C41H57NO4	87.02	1	12	7.26E+05	15	6.57E+05	9	3.58E+05	0	N/A
Propane-1,2,3-triyl (9Z,9'Z,9"Z)tri-tetradec-9-enoate	99483-10-0	C45H80O6	80.73	1	18	3.11E+05	3	1.92E+05	6	7.67E+04	0	N/A
Dimepranol	108-16-7	C5H13NO	87.32	74	18	1.77E+05	15	1.24E+05	3	3.98E+04	0	N/A
Dacarbazine	4342-03-4	C6H10N6O	85.91	12	12	2.51E+05	9	2.26E+05	0	N/A	0	N/A
Dacarbazine	4342-03-4	C6H10N6O	87.35	12	18	3.17E+05	15	2.46E+05	9	8.61E+04	0	N/A
Ethane, 1,1-diethoxy-2,2,2-trifluoro-	31224-45-0	C6H11F3O2	87.79	1	12	5.07E+04	15	1.75E+05	9	1.66E+05	2	4.78E+04

Table R-2 Continued

Tentative Chemical Identification[c]	CAS Number[d]	Chemical Formula	Score	Number of Chemicals Same Formula	Recycling Plants – Frequency	Recycling Plants – Mean Area Counts	Indoor Fields – Frequency	Indoor Fields – Mean Area Counts	Outdoor Fields – Frequency	Outdoor Fields – Mean Area Counts	Blanks – Frequency	Blanks – Mean Area Counts
Methanol, (1,3,5-triazine-2,4,6-triyltriimino)tris-	1017-56-7	C6H12N6O3	87.29	4	6	5.70E+04	6	2.43E+05	6	1.60E+05	0	N/A
1-(diaminomethylidene)-2-pyrazin-2-ylguanidine	51531-75-0	C6H9N7	84.33	6	12	1.41E+05	9	7.61E+04	0	N/A	0	N/A
3-(4(5)-Imidazolyl)propylguanidine	46129-28-6	C7H13N5	83.97	17	18	1.31E+05	15	3.36E+05	9	4.49E+05	2	1.16E+05
N~2~,N~2~-Diethyl-N~4~,N~6~-dihydroxy-1,3,5-triazine-2,4,6-triamine	33901-81-4	C7H14N6O2	87.38	6	18	3.04E+05	6	2.35E+05	0	N/A	0	N/A
N~2~,N~2~-Diethyl-N~4~,N~6~-dihydroxy-1,3,5-triazine-2,4,6-triamine	33901-81-4	C7H14N6O2	86.84	6	18	1.97E+05	6	2.01E+05	0	N/A	0	N/A
1-Phenylurea	64-10-8	C7H8N2O	87.12	157	12	2.12E+05	3	2.08E+05	0	N/A	0	N/A
N,N-Dimethylcyclohexylamine	98-94-2	C8H17N	87.26	125	18	3.56E+05	12	9.29E+04	6	6.16E+04	0	N/A
Valpromide	2430-27-5	C8H17NO	82.39	398	18	2.48E+05	6	1.29E+05	6	7.93E+04	0	N/A
Valpromide	2430-27-5	C8H17NO	98.49	398	18	1.22E+06	9	7.72E+04	3	1.14E+05	0	N/A
alpha-Methylstyrene	98-83-9	C9H10	87.75	47	6	9.73E+04	6	2.21E+05	9	2.17E+05	0	N/A
3-Phenyl-2-propen-1-ol	104-54-1	C9H10O	87.48	109	3	1.62E+05	6	2.23E+05	9	2.28E+05	0	N/A
gamma-Nonanolactone	104-61-0	C9H16O2	86.67	373	6	2.99E+04	3	5.30E+04	9	2.21E+05	0	N/A
Triisopropanolamine	122-20-3	C9H21NO3	99.54	16	18	8.08E+05	15	5.99E+05	9	1.57E+05	0	N/A
2,2-Dihydroxy-5-nitroindene-1,3-dione	106483-66-3	C9H5NO6	82.24	9	18	3.78E+05	6	9.68E+04	6	7.02E+04	0	N/A
Hippuric acid	495-69-2	C9H9NO3	85.23	374	18	3.28E+05	9	3.52E+05	0	N/A	0	N/A
Hippuric acid	495-69-2	C9H9NO3	97.69	374	18	2.68E+05	9	2.19E+05	0	N/A	0	N/A

[a] SVOC = semivolatile organic compound; LC/TOFMS = liquid chromatography/time-of-flight mass spectrometry; N/A = not applicable

[b] Recycling Plants (n=6); Indoor Fields (n=5); Outdoor Fields (n=5); Blanks (n=3)

[c] Some pharmaceutical chemicals have been highly tentatively identified; while these chemicals are sometimes found in the environment, these results may also reflect a bias in chemical assignment that is partly based on frequency of appearance in literature data sources.

[d] Unique numerical identifier assigned by the Chemical Abstracts Services (CAS)

Table R-3. Non-Targeted Analysis SVOC Results for Tire Crumb Rubber Extracts by LC/TOFMS Negative Mode – Highly Tentative Screening Results[a,b]

Tentative Chemical Identification	CAS Number[c]	Chemical Formula	Score	Number of Chemicals Same Formula	Recycling Plants – Frequency	Recycling Plants – Mean Area Counts	Indoor Fields – Frequency	Indoor Fields – Mean Area Counts	Outdoor Fields – Frequency	Outdoor Fields – Mean Area Counts	Blanks – Frequency	Blanks – Mean Area Counts
Cyclooct-4-en-1-yl methyl carbonate	87731-18-8	C10H16O3	87.48	256	0	N/A	9	7.14E+04	9	5.58E+04	0	N/A
1-[1-(tert-Butoxycarbonyl)pyrrolidin-2-yl]-2-diazonioethen-1-olate	28094-74-8	C11H18N3O3	86.47	1	18	9.58E+04	6	7.19E+04	0	N/A	0	N/A
2-Fluoro-1-[4-(3-methylbut-2-en-1-yl) piperazin-1-yl]ethan-1-one	76825-94-0	C11H19FN2O	97.63	1	18	5.31E+05	15	3.28E+05	6	1.60E+05	0	N/A
Methyl decanoate	110-42-9	C11H22O2	86.8	209	18	2.07E+05	15	1.17E+05	3	6.32E+04	0	N/A
Guanidine, (4-phenyl-1-piperidinyl)-, sulfate (2:1)	59083-99-7	C12H18N4	86.5	32	18	1.06E+05	3	9.47E+04	0	N/A	0	N/A
Dodec-11-ene-1-sulfonyl fluoride	623114-66-9	C12H23FO2S	96.3	1	18	2.78E+05	15	1.63E+05	3	4.16E+04	0	N/A
Dodecanoic acid	143-07-7	C12H24O2	84.7	229	18	1.75E+05	15	1.45E+05	9	8.63E+04	0	N/A
Sodium dodecyl sulfate	151-21-3	C12H26O4S	98.43	34	3	3.13E+04	12	6.23E+04	0	N/A	0	N/A
S-(4-Methylphenyl) 4-(hydroxy(oxido) amino) benzenesulfonothioate	94583-15-0	C13H11NO4S2	93.74	3	15	6.03E+04	3	5.68E+04	0	N/A	0	N/A
Diphenylurea	102-07-8	C13H12N2O	80.91	177	15	1.04E+05	9	1.73E+05	3	9.19E+04	0	N/A
Bis(4-hydroxyphenyl)methane	620-92-8	C13H12O2	85.55	155	12	1.09E+05	6	8.84E+04	0	N/A	0	N/A
Acetanilide, 2-(diethylamino)-5'-ethyl-2'-fluoro-	787-99-5	C14H21FN2O	83.62	1	18	1.00E+05	12	5.37E+04	3	4.95E+04	0	N/A
2,6-Di-tert-butyl-4-nitrophenol	728-40-5	C14H21NO3	85.47	140	6	4.49E+04	15	6.81E+04	0	N/A	0	N/A
4-(1,1,3,3-Tetramethylbutyl)phenol	140-66-9	C14H22O	85.32	214	6	5.66E+04	3	3.17E+04	0	N/A	0	N/A
Sodium myristyl sulfate	1191-50-0	C14H30O4S	87.13	11	0	N/A	3	8.33E+04	0	N/A	0	N/A
2,6-Di-tert-butyl-4-hydroperoxy-4-methyl-2,5-cyclohexadienone	6485-57-0	C15H24O3	84.68	54	0	N/A	9	1.31E+05	12	6.92E+04	0	N/A
6-Fluoro-3,7,11-trimethyldodeca-1,6,10-trien-3-ol	116058-31-2	C15H25FO	83.31	8	36	1.44E+05	30	1.79E+05	30	9.01E+04	0	N/A
6-Fluoro-3,7,11-trimethyldodeca-1,6,10-trien-3-ol	116058-31-2	C15H25FO	96.27	8	36	2.65E+06	30	3.10E+06	30	1.32E+06	0	N/A
2,6-Diphenylpyridine	3558-69-8	C17H13N	85.03	38	3	9.19E+04	3	9.49E+04	0	N/A	0	N/A
Linalyl benzoate	126-64-7	C17H22O2	95.97	68	18	1.29E+05	15	1.10E+05	9	6.22E+04	0	N/A
Alkylbenzenesulfonate, linear	42615-29-2	C17H28O3S	89.17	15	18	9.97E+04	6	4.18E+04	0	N/A	0	N/A
Triphenylamine	603-34-9	C18H15N	85.41	48	18	9.59E+04	15	1.15E+05	6	5.50E+04	0	N/A

Table R-3 Continued

Tentative Chemical Identification	CAS Number[c]	Chemical Formula	Score	Number of Chemicals Same Formula	Recycling Plants – Frequency	Recycling Plants – Mean Area Counts	Indoor Fields – Frequency	Indoor Fields – Mean Area Counts	Outdoor Fields – Frequency	Outdoor Fields – Mean Area Counts	Blanks – Frequency	Blanks – Mean Area Counts
4(1H)-Pyrimidinone, 2-((2,2-dimethoxyethyl) thio)-5-(1-methylethyl)-6-(phenylmethyl)-	199852-00-1	C18H24N2O3S	93.65	7	18	1.35E+05	6	1.25E+05	0	N/A	0	N/A
Linolenic acid	463-40-1	C18H30O2	84.04	76	15	1.83E+05	9	1.85E+05	6	1.22E+05	0	N/A
2-[2-[4-(1,1,3,3-Tetramethylbutyl) phenoxy] ethoxy]ethanol	2315-61-9	C18H30O3	84.74	58	18	1.07E+05	15	1.85E+05	9	9.35E+04	0	N/A
Dodecylbenzenesulfonic acid	27176-87-0	C18H30O3S	92.26	75	12	8.68E+04	9	6.08E+04	0	N/A	0	N/A
Cyclopropanecarboxylic acid, 2-[1-(3,3-dimethylcyclohexyl)ethoxy]-2-methylpropyl ester	477218-42-1	C18H32O3	84.92	28	18	3.31E+05	15	3.72E+05	9	1.27E+05	0	N/A
Tritylamine	5824-40-8	C19H17N	83.37	148	30	8.27E+04	30	1.12E+05	24	6.05E+04	0	N/A
Tritylamine	5824-40-8	C19H17N	84.64	148	30	1.21E+05	30	1.80E+05	24	7.71E+04	0	N/A
2alpha-Fluorodihydrotestosterone	1649-46-3	C19H29FO2	98.18	3	15	1.91E+05	6	3.72E+04	6	4.68E+04	0	N/A
1-(Dodecyloxy)-4-fluoro-2-methylbenzene	451-98-9	C19H31FO	99.08	1	15	1.29E+06	9	1.40E+05	6	1.77E+05	0	N/A
[Bis(2-hydroxyethyl)amino]methyl tetra decanoate	88519-61-3	C19H39NO4	94.88	3	15	1.82E+05	9	1.07E+05	0	N/A	0	N/A
Ethyl [bis(octyloxy)phosphanyl] carbamate	61670-40-4	C19H40NO4P	89.62	2	18	3.17E+05	6	1.91E+05	0	N/A	0	N/A
Estradiol acetate	4245-41-4	C20H26O3	83.87	32	12	5.11E+04	12	5.58E+04	9	6.62E+04	0	N/A
1-(3,7,11-Trimethyldodeca-2,6,10-trien-1-yl) pyridin-1-ium	927670-34-6	C20H30N	82.21	2	0		6	4.87E+04	0		0	N/A
17-Methyltestosterone	58-18-4	C20H30O2	97.51	760	9	2.60E+05	15	1.97E+05	9	9.38E+04	0	N/A
Eicosanoic acid	506-30-9	C20H40O2	82.32	308	36	4.78E+04	30	4.90E+04	24	4.11E+04	0	N/A
Eicosanoic acid	506-30-9	C20H40O2	98.84	308	36	6.98E+04	30	9.86E+04	30	1.71E+05	0	N/A
2-Hexadecanol, 1-[bis(2-hydroxyethyl) oxido amino]-	28865-36-3	C20H43NO4	83.72	2	0	N/A	3	7.19E+04	0	N/A	0	N/A
1-(4-Methoxy-3,5-dimethylbenzyl)-4-(3-(ethylamino)-2-pyridyl)piperazine hydrochloride	136818-99-0	C21H30N4O	83.65	4	18	1.14E+05	9	8.23E+04	0	N/A	0	N/A
[Bis(2-hydroxyethyl)amino]methyl hexadecanoate	88519-62-4	C21H43NO4	98.59	1	18	1.28E+05	15	7.97E+04	6	3.54E+04	0	N/A

Table R-3 Continued

Tentative Chemical Identification	CAS Number[c]	Chemical Formula	Score	Number of Chemicals Same Formula	Recycling Plants – Frequency	Recycling Plants – Mean Area Counts	Indoor Fields – Frequency	Indoor Fields – Mean Area Counts	Outdoor Fields – Frequency	Outdoor Fields – Mean Area Counts	Blanks – Frequency	Blanks – Mean Area Counts
Ethanol, 2,2'-(heptadecylimino)bis-	7517-26-2	C21H45NO2	82.86	1	0	N/A	3	1.27E+05	0	N/A	0	N/A
Phenol, 2,4-bis(1-phenylethyl)-	2769-94-0	C22H22O	96.2	19	12	1.73E+05	15	1.19E+05	3	4.75E+04	0	N/A
Norethindrone acetate	51-98-9	C22H28O3	90.22	54	18	6.88E+04	6	5.80E+04	0	N/A	0	N/A
Norethindrone acetate	51-98-9	C22H28O3	82.86	54	6	6.66E+04	12	7.27E+04	12	1.00E+05	0	N/A
Promegestone	34184-77-5	C22H30O2	82.37	57	15	7.85E+04	6	1.06E+05	0	N/A	0	N/A
Ahr 12234	125651-31-2	C22H40N4O3S	86.09	1	9	4.42E+04	3	3.15E+04	0	N/A	0	N/A
Hexadecyl glucoside	75319-63-0	C22H44O6	93.78	5	9	3.62E+04	3	1.34E+05	0	N/A	0	N/A
Megestrol acetate	595-33-5	C24H32O4	96.79	21	3	2.53E+05	0	N/A	0	N/A	0	N/A
3-Oxochola-4,6-dien-24-oic Acid	88179-71-9	C24H34O3	92	10	3	8.53E+04	0	N/A	3	5.29E+04	0	N/A
2,2'-Methylenebis(ethyl-6-tert-butylphenol)	88-24-4	C25H36O2	82.35	57	18	5.15E+04	6	7.73E+04	6	1.32E+05	0	N/A
2,2'-Methylenebis(ethyl-6-tert-butylphenol)	88-24-4	C25H36O2	99.13	57	18	3.30E+05	15	1.22E+05	6	1.68E+05	0	N/A
CB-25	869376-63-6	C25H41NO3	97.38	7	18	8.80E+04	15	4.89E+04	6	4.23E+04	0	N/A
Pyridinium, 1,1'-[1,4-phenylenebis (methylene)]bis[4-(1-pyrrolidinyl)-	807314-59-6	C26H32N4	98.5	6	3	3.68E+05	0	N/A	0	N/A	0	N/A
Estradiol cypionate	313-06-4	C26H36O3	96.99	10	9	6.48E+04	12	9.80E+04	15	4.90E+04	0	N/A
Resocortol butyrate	76738-96-0	C26H38O5	99.45	5	3	3.00E+05	0		0	N/A	0	N/A
NSC103655	27702-16-5	C26H42N6	87.09	1	18	3.52E+04	15	4.97E+04	6	4.26E+04	0	N/A
Hydrocortisone 21-hexanoate	3593-96-2	C27H40O6	96.38	5	18	1.68E+05	15	1.68E+05	6	2.22E+05	0	N/A
[2,2-Bis[(3,7-dimethyl-2,6-octadienyl) oxy] ethyl]benzene	67634-02-0	C28H42O2	93.61	19	18	7.69E+04	15	8.68E+04	9	4.20E+04	0	N/A
5-benzyl-6-hydroxy-1,2,3-triphenyl pyrimidin-1-ium-4-one	56409-80-4	C29H23N2O2	99.1	1	18	1.26E+05	15	5.30E+04	3	5.44E+04	0	N/A
ethyl 2,5-dimethyl-3,4,6-triphenyl benzoate	76331-32-3	C29H26O2	94	2	12	7.51E+04	15	1.12E+05	6	1.03E+05	0	N/A
1H,3H,5H-Oxazolo[3,4-c]oxazole, dihydro-3,5-bis[1-methyl-2-[4-(1-methylethyl)phenyl] ethyl]-	1001164-15-3	C29H41NO2	98.32	2	18	1.17E+05	6	9.96E+04	0	N/A	0	N/A

Table R-3 Continued

Tentative Chemical Identification	CAS Number[c]	Chemical Formula	Score	Number of Chemicals Same Formula	Recycling Plants – Frequency	Recycling Plants – Mean Area Counts	Indoor Fields – Frequency	Indoor Fields – Mean Area Counts	Outdoor Fields – Frequency	Outdoor Fields – Mean Area Counts	Blanks – Frequency	Blanks – Mean Area Counts
Nonyl 4-[(E)-{[4-(hexyloxy)phenyl] imino} methyl]benzoate	793724-55-7	C29H41NO3	97.15	1	18	2.50E+05	6	3.24E+05	0	N/A	0	N/A
2-{3-[Dimethyl(octadecyl)silyl] propoxy} propane-1,2,3-tricarboxylic acid	923273-68-1	C29H56O7Si	84.89	1	3	1.63E+05	0	N/A	0	N/A	0	N/A
1H-Indole-3-tetradecanol, 5-methoxy-1-[(4-methoxyphenyl)sulfonyl]-	651331-73-6	C30H43NO5S	82.27	2	18	4.67E+04	12	3.88E+04	6	2.77E+04	0	N/A
RH 292	119738-64-6	C30H46N3	96.78	1	6	5.15E+04	12	1.39E+05	15	1.13E+05	0	N/A
Tetrabutyl ethylidenebisphenol	35958-30-6	C30H46O2	96.74	11	15	1.26E+05	9	1.35E+05	6	5.52E+04	0	N/A
Abieslactone	38577-26-3	C31H48O3	97.37	3	18	4.94E+04	6	5.68E+04	0	N/A	0	N/A
[1,1'-Biphenyl]-4-carboxylic acid, 4'-octyl-, 4-(2-methylbutyl)phenyl ester	93798-26-6	C32H40O2	98.21	4	6	4.82E+04	3	6.48E+04	12	6.62E+04	0	N/A
1-{4-[(4'-Pentyl[1,1'-biphenyl]-4-yl)methoxy] phenyl}octane-1,3-diol	915316-39-1	C32H42O3	95.71	2	12	8.59E+04	9	8.47E+04	0	N/A	0	N/A
1H-Indole-3-hexadecanol, 5-methoxy-1-[(4-methoxyphenyl)sulfonyl]-	651331-74-7	C32H47NO5S	86.56	2	15	5.93E+04	3	5.05E+04	0	N/A	0	N/A
4-(4-Hydroxy-3,5-bis(2-methylbutan-2-yl) phenyl)-2,6-bis(2-methylbutan-2-yl)phenol	65901-03-3	C32H50O2	94.99	6	18	5.99E+04	15	7.08E+04	9	2.91E+04	0	N/A
Phenol, 2,2'-methylenebis[4-methyl-6-nonyl-	7786-17-6	C33H52O2	97.98	36	36	1.13E+05	30	9.61E+04	30	2.15E+05	0	N/A
Phenol, 2,2'-methylenebis[4-methyl-6-nonyl-	7786-17-6	C33H52O2	97.89	36	36	2.33E+06	30	1.76E+06	30	4.61E+05	0	N/A
2-{4-[Ethoxy(diphenyl)methyl]phenyl}-3-hydroxy-1H-phenalen-1-one	113337-70-5	C34H26O3	86.99	1	12	8.82E+04	9	4.88E+04	0	N/A	0	N/A
Phenol, 4,4',4"-(1-methyl-1-propanyl-3-ylidene)tris[2-(1,1-dimethylethyl)-	25211-93-2	C34H46O3	95.41	2	15	4.64E+04	3	3.81E+04	0	N/A	0	N/A
N-[(3beta,5alpha,6beta)-3,5-Dihydroxy cholestan-6-yl]benzamide	62684-27-9	C34H53NO3	99.53	2	18	1.86E+05	9	1.82E+05	6	4.95E+04	0	N/A
1-[(Octadecyloxy)methyl]pyrene	134217-20-2	C35H48O	95.27	9	45	7.35E+04	45	7.85E+04	45	4.08E+04	0	N/A
1-[(Octadecyloxy)methyl]pyrene	134217-20-2	C35H48O	97.5	9	54	6.70E+05	45	2.88E+05	36	1.07E+05	0	N/A
1-[(Octadecyloxy)methyl]pyrene	134217-20-2	C35H48O	98.65	9	54	1.12E+05	45	9.87E+04	45	4.49E+04	0	N/A

Table R-3 Continued

Tentative Chemical Identification	CAS Number[c]	Chemical Formula	Score	Number of Chemicals Same Formula	Recycling Plants – Frequency	Recycling Plants – Mean Area Counts	Indoor Fields – Frequency	Indoor Fields – Mean Area Counts	Outdoor Fields – Frequency	Outdoor Fields – Mean Area Counts	Blanks – Frequency	Blanks – Mean Area Counts
3-[(Oxan-2-yl)oxy]lup-20(29)-en-28-al	59741-99-0	C35H56O3	99.34	1	0	N/A	6	1.00E+05	15	1.34E+05	0	N/A
2-Propenoic acid, 3-(4-hydroxyphenyl)-, hexacosyl ester	71660-26-9	C35H60O3	98.26	3	12	1.45E+05	3	1.38E+05	9	2.61E+05	1	8.39E+04
1,1,12-Triphenyloctadec-9-ene-1,12-diol	91533-11-8	C36H48O2	92.13	1	12	5.51E+04	6	5.94E+04	0	N/A	0	N/A
4'-(Nonyloxy)[1,1'-biphenyl]-4-yl 4-[(octan-2-yl)oxy]benzoate	104586-47-2	C36H48O4	89.46	2	18	8.00E+04	15	7.55E+04	6	2.62E+04	0	N/A
1,1'-[1,4-Phenylenebis(methyleneoxy)] bis(4-nonylbenzene)	88457-40-3	C38H54O2	92.68	2	0	N/A	12	1.06E+05	3	3.01E+04	0	N/A
1,3-Bis(4-dodecylphenyl)propan-2-one	189139-40-0	C39H62O	94.93	1	0	N/A	0	N/A	6	1.08E+05	0	N/A
Lutein	127-40-2	C40H56O2	88.76	4	9	6.18E+04	12	7.05E+04	12	4.62E+04	0	N/A
(3beta)-Cholest-5-en-3-yl anthracene-9-carboxylate	2641-40-9	C42H54O2	96.78	1	18	2.68E+05	12	2.45E+05	3	4.83E+04	0	N/A
L-Lysyl-L-lysyl-L-leucyl-L-methionyl-L-phenylalanyl-L-lysyl-L-threonine	189813-01-2	C42H74N10O9S	87.22	1	6	5.76E+04	6	1.02E+05	0		0	N/A
6-Fluoropurine	1480-89-3	C5H3FN4	85.24	6	6	7.86E+04	0	N/A	0	N/A	0	N/A
2-Hydroxyethyl acrylate	818-61-1	C5H8O3	81.73	111	0	N/A	6	5.15E+04	6	8.55E+04	0	N/A
1,5-Trisiloxanediol, 1,1,3,3,5,5-hexamethyl-	3663-50-1	C6H20O4Si3	97.87	40	0	N/A	24	1.95E+05	48	1.09E+05	0	N/A
1,5-Trisiloxanediol, 1,1,3,3,5,5-hexamethyl-	3663-50-1	C6H20O4Si3	96.04	40	24	1.33E+05	36	2.99E+05	48	2.59E+05	4	8.34E+04
1,7-Tetrasiloxanediol, 1,1,3,3,5,5,7,7-octamethyl-	3081-07-0	C8H26O5Si4	93.14	75	0	N/A	45	2.40E+05	60	2.61E+05	0	N/A
1,7-Tetrasiloxanediol, 1,1,3,3,5,5,7,7-octamethyl-	3081-07-0	C8H26O5Si4	94.1	75	15	2.41E+04	45	3.11E+05	60	1.40E+05	0	N/A
1,7-Tetrasiloxanediol, 1,1,3,3,5,5,7,7-octamethyl-	3081-07-0	C8H26O5Si4	91.08	75	15	2.41E+04	45	3.75E+05	60	1.93E+05	0	N/A
1,7-Tetrasiloxanediol, 1,1,3,3,5,5,7,7-octamethyl-	3081-07-0	C8H26O5Si4	94.73	75	15	2.41E+04	45	2.83E+05	60	1.87E+05	0	N/A
1,7-Tetrasiloxanediol, 1,1,3,3,5,5,7,7-octamethyl-	3081-07-0	C8H26O5Si4	93.84	75	0	N/A	30	1.21E+05	60	5.92E+04	0	N/A

Table R-3 Continued

Tentative Chemical Identification	CAS Number[c]	Chemical Formula	Score	Number of Chemicals Same Formula	Recycling Plants – Frequency	Recycling Plants – Mean Area Counts	Indoor Fields – Frequency	Indoor Fields – Mean Area Counts	Outdoor Fields – Frequency	Outdoor Fields – Mean Area Counts	Blanks – Frequency	Blanks – Mean Area Counts
2,4(1H,3H)-Pteridinedione, 1,3-dimethyl-	13401-18-8	C8H8N4O2	80.06	54	6	9.18E+04	0	N/A	3	4.15E+04	0	N/A

[a] SVOC = semivolatile organic compound; LC/TOFMS = liquid chromatography/time-of-flight mass spectrometry; N/A = not applicable

[b] Recycling Plants (n=6); Indoor Fields (n=5); Outdoor Fields (n=5); Blanks (n=3)

[c] Unique numerical identifier assigned by the Chemical Abstracts Services (CAS)

Table R-4. Non-Targeted Analysis for VOC 60 °C Chamber Emission Samples by GC/TOFMS – Highly Tentative Screening Results[a,b,c]

Tentative Chemical Identifications • Match Factor > 75% Forward and Reverse • Listed in Order of Retention Time	Recycling Plants – Frequency	Recycling Plants – Mean Area Counts	Indoor Fields – Frequency	Indoor Fields – Mean Area Counts	Outdoor Fields – Frequency	Outdoor Fields – Mean Area Counts	Chamber Backgrounds – Frequency	Chamber Backgrounds – Mean Area Counts	Tube Blanks – Frequency	Tube Blanks – Mean Area Counts
Sulfur dioxide	5	2.99E+05	2	2.00E+05	3	2.95E+04	0	N/A	0	N/A
Ethanol	6	3.69E+06	6	1.24E+06	5	6.20E+05	3	8.41E+05	3	3.39E+05
Acetaldehyde	5	4.50E+06	4	2.27E+07	5	5.38E+06	3	3.83E+06	3	2.94E+06
Ethylenimine	4	3.82E+06	2	1.24E+07	2	1.77E+06	0	N/A	1	8.75E+05
1-Propene, 2-methyl-	1	1.73E+08	5	5.95E+07	5	2.70E+07	3	1.70E+07	2	1.32E+06
2-Butene	6	2.16E+08	1	9.70E+05	3	6.94E+05	2	1.07E+06	0	N/A
Nitrous Oxide	5	2.01E+06	7	3.15E+05	4	7.94E+04	3	5.51E+04	3	5.38E+04
Methanethiol	5	4.56E+05	3	2.84E+05	3	1.70E+05	0	N/A	2	1.41E+05
Trimethylsilyl fluoride	4	6.52E+05	3	2.79E+05	3	3.02E+05	1	2.61E+04	0	N/A
Acetonitrile	6	1.79E+07	5	4.03E+07	5	7.28E+06	3	1.15E+06	3	4.71E+06
2-Propenenitrile	5	6.84E+05	3	2.72E+06	4	1.16E+06	3	7.82E+05	3	3.60E+05
Argon	3	5.39E+04	0	N/A	2	1.49E+04	0	N/A	0	N/A
Methane, isocyanato-	1	1.19E+04	3	3.09E+05	2	5.56E+04	0	N/A	1	2.12E+04
Acetone	6	2.62E+07	4	3.85E+07	5	1.85E+07	3	7.94E+06	3	4.66E+06
2-Butanone	9	4.65E+05	4	7.13E+06	5	2.75E+06	3	2.32E+06	4	6.16E+05

Table R-4 Continued

Tentative Chemical Identifications • Match Factor > 75% Forward and Reverse • Listed in Order of Retention Time	Recycling Plants – Frequency	Recycling Plants – Mean Area Counts	Indoor Fields – Frequency	Indoor Fields – Mean Area Counts	Outdoor Fields – Frequency	Outdoor Fields – Mean Area Counts	Chamber Backgrounds – Frequency	Chamber Backgrounds – Mean Area Counts	Tube Blanks – Frequency	Tube Blanks – Mean Area Counts
2-Propanamine, 2-methyl-	9	4.26E+08	7	1.76E+07	3	2.66E+06	0	N/A	0	N/A
1,3-Pentadiene, (E)-	0	N/A	1	1.35E+05	4	2.42E+05	0	N/A	0	N/A
Formamide, N-methyl-	3	4.34E+05	1	4.77E+05	1	1.53E+05	0	N/A	0	N/A
Propane, 2-methyl-1-nitro-	6	2.15E+06	1	1.63E+05	0	N/A	0	N/A	0	N/A
N,1-Dimethylhexylamine	4	3.71E+06	1	1.92E+06	0	N/A	0	N/A	0	N/A
Carbon disulfide	6	1.70E+06	4	1.16E+06	4	6.93E+05	0	N/A	1	2.76E+04
1,3-Cyclopentadiene	6	7.62E+06	4	2.27E+06	5	1.73E+06	3	1.58E+06	1	6.60E+04
Carbon tetrafluoride	2	7.30E+04	4	2.20E+04	3	2.53E+04	0	N/A	2	2.00E+04
Propanal, 2-methyl-	3	1.82E+06	2	7.94E+06	2	7.41E+05	0	N/A	0	N/A
Propanenitrile	6	1.15E+06	2	1.42E+06	3	1.65E+05	1	3.40E+04	1	2.94E+05
1-Pentene, 4-methyl-	6	5.27E+06	4	2.46E+06	4	6.99E+05	0	N/A	0	N/A
Silanol, trimethyl-	6	6.85E+06	4	1.37E+07	4	2.89E+06	2	6.65E+05	3	4.32E+05
Methyl vinyl ketone	6	5.39E+06	4	1.36E+07	5	1.73E+07	0	N/A	0	N/A
Acetic acid ethenyl ester	8	7.09E+05	3	1.58E+06	5	2.41E+06	4	3.34E+05	3	4.79E+05
2-Butanone, 3-methyl-	3	8.64E+05	2	2.26E+05	2	2.42E+05	1	7.41E+04	0	N/A
2-Pentene, 4-methyl-	8	4.06E+06	5	2.56E+06	6	1.18E+06	0	N/A	0	N/A
1-Butene, 3,3-dimethyl-	3	1.43E+06	0	N/A	0	N/A	0	N/A	0	N/A
1,2-Ethanediamine, N,N'-diethyl-N,N'-dimethyl-	4	2.22E+05	1	1.37E+05	0	N/A	0	N/A	0	N/A
Acetic acid	6	8.22E+07	3	7.45E+07	5	2.33E+07	3	4.09E+06	1	1.59E+05
Propane, 2-isocyano-2-methyl-	6	4.82E+06	3	1.06E+06	0	N/A	0	N/A	0	N/A
Furan, 2-methyl-	12	3.01E+06	7	9.78E+06	7	1.09E+07	6	2.01E+05	3	2.02E+05
Furan, 3-methyl-	1	8.71E+05	2	1.52E+06	6	3.56E+06	0	N/A	2	3.66E+04
Methane, bromochloro-	6	6.89E+05	4	2.04E+06	5	1.78E+06	3	5.66E+05	3	1.69E+06
2-Hexene	4	2.80E+06	3	1.76E+05	5	1.56E+05	3	1.49E+05	0	N/A
Butanenitrile, 3-methyl-	7	2.65E+06	1	2.65E+06	0	N/A	0	N/A	0	N/A
Propanenitrile, 2,2-dimethyl-	6	1.06E+06	0	N/A	0	N/A	0	N/A	0	N/A

Table R-4 Continued

Tentative Chemical Identifications • Match Factor > 75% Forward and Reverse • Listed in Order of Retention Time	Recycling Plants – Frequency	Recycling Plants – Mean Area Counts	Indoor Fields – Frequency	Indoor Fields – Mean Area Counts	Outdoor Fields – Frequency	Outdoor Fields – Mean Area Counts	Chamber Backgrounds – Frequency	Chamber Backgrounds – Mean Area Counts	Tube Blanks – Frequency	Tube Blanks – Mean Area Counts
Propane, 2-isocyanato-2-methyl-	6	3.87E+07	4	1.00E+07	5	1.59E+06	2	1.95E+05	0	N/A
2-Propanone, 1-hydroxy-	1	3.58E+06	3	3.64E+05	2	1.20E+06	0	N/A	2	1.55E+05
4-Methyl-1,3-pentadiene	6	3.32E+05	1	1.31E+05	1	1.80E+05	0	N/A	0	N/A
1,3-Cyclohexadiene	6	9.72E+05	9	5.12E+05	9	4.82E+05	4	2.53E+05	0	N/A
1,3-Cyclopentadiene, 5-methyl-	8	2.88E+06	2	1.55E+06	0	N/A	0	N/A	0	N/A
Disiloxane, pentamethyl-	4	2.29E+05	1	2.65E+06	0	N/A	0	N/A	0	N/A
N-Ethylidene t-butylamine	6	3.43E+07	1	5.76E+05	0	N/A	0	N/A	0	N/A
1-Butanol	1	4.25E+06	2	3.24E+06	5	5.45E+06	2	1.81E+06	2	4.91E+05
Ethanone, 1-cyclopropyl-	1	6.53E+05	2	5.27E+05	3	4.15E+05	2	5.38E+04	0	N/A
3-Buten-2-one, 3-methyl-	0	N/A	1	3.52E+05	3	4.78E+05	1	1.08E+05	0	N/A
Furan, 2,3-dihydro-5-methyl-	0	N/A	2	8.26E+05	3	1.82E+06	0	N/A	0	N/A
Diisopropylamine	5	2.83E+06	1	1.18E+06	0	N/A	0	N/A	0	N/A
Propanoic acid	7	2.37E+07	2	1.07E+07	1	3.07E+05	1	1.34E+05	0	N/A
Cyclohexene	6	2.03E+07	4	5.40E+06	5	1.96E+06	2	2.78E+05	0	N/A
Trichloroethylene	4	1.10E+06	1	4.92E+04	0	N/A	0	N/A	0	N/A
3-Heptene	3	6.35E+05	2	1.75E+06	4	4.94E+05	0	N/A	0	N/A
(Z)-3-Heptene	5	1.93E+06	1	3.18E+06	0	N/A	2	2.68E+05	0	N/A
2-Cyclopenten-1-one, 3-methyl-	7	9.33E+05	3	4.81E+05	5	6.11E+05	0	N/A	0	N/A
2-Butenal, 2-ethenyl-	0	N/A	0	N/A	3	1.14E+06	1	3.53E+05	0	N/A
Pyrazine	0	N/A	1	6.53E+05	3	5.93E+04	1	1.96E+04	0	N/A
1-Pentene, 2,4,4-trimethyl-	5	1.15E+06	4	2.01E+06	5	1.12E+06	3	1.54E+05	0	N/A
1H-Pyrrole, 2-methyl-	5	2.30E+05	5	1.69E+07	6	6.48E+05	2	3.66E+04	3	6.88E+04
Acetamide	3	1.38E+06	2	5.20E+06	0	N/A	0	N/A	0	N/A
Metyl isobutyl ketone	7	1.14E+08	4	8.81E+07	5	3.40E+07	1	8.26E+05	0	N/A
Pyridine	6	5.70E+05	4	4.52E+05	2	2.96E+05	0	N/A	0	N/A
2-Pentene, 2,4,4-trimethyl-	0	N/A	2	4.15E+05	5	3.18E+05	0	N/A	0	N/A

Table R-4 Continued

Tentative Chemical Identifications • Match Factor > 75% Forward and Reverse • Listed in Order of Retention Time	Recycling Plants – Frequency	Recycling Plants – Mean Area Counts	Indoor Fields – Frequency	Indoor Fields – Mean Area Counts	Outdoor Fields – Frequency	Outdoor Fields – Mean Area Counts	Chamber Backgrounds – Frequency	Chamber Backgrounds – Mean Area Counts	Tube Blanks – Frequency	Tube Blanks – Mean Area Counts
3-Cyclohexene-1-carboxaldehyde	2	1.39E+06	4	5.91E+06	5	7.36E+06	0	N/A	0	N/A
2-Pentanamine, 4-methyl-	4	2.61E+07	0	N/A	0	N/A	0	N/A	0	N/A
2,3-Dimethyl-1-hexene	12	1.05E+07	12	8.75E+06	7	7.00E+06	0	N/A	0	N/A
Formamide, N,N-dimethyl-	4	4.39E+06	4	7.62E+05	2	3.78E+05	0	N/A	0	N/A
1,3,5-Cycloheptatriene	3	4.96E+06	1	1.10E+07	2	1.92E+06	0	N/A	0	N/A
Toluene	3	9.28E+06	3	3.38E+06	5	2.41E+06	3	2.38E+06	3	4.95E+05
1,4-Cyclohexadiene, 1-methyl-	3	7.86E+05	0	N/A	0	N/A	0	N/A	0	N/A
1,3-Cyclopentadiene, 5,5-dimethyl-	3	3.73E+05	0	N/A	1	2.64E+05	0	N/A	0	N/A
Thiophene, 3-methyl-	4	2.08E+05	4	1.30E+05	5	1.53E+05	0	N/A	0	N/A
Heptane, 3-methylene-	6	8.05E+06	2	3.15E+06	5	1.38E+06	8	1.50E+06	0	N/A
Morpholine, 4-methyl-	6	2.79E+06	0	N/A	0	N/A	0	N/A	0	N/A
3-Pentanone, 2,4-dimethyl-	4	2.85E+06	3	2.53E+07	2	6.02E+05	2	3.30E+05	0	N/A
Propanoic acid, 2,2-dimethyl-	5	7.28E+06	0	N/A	0	N/A	0	N/A	0	N/A
Furfural	1	6.16E+07	1	1.76E+06	6	3.44E+06	3	7.65E+05	3	6.80E+05
Pyridine, 2-methyl-	5	5.00E+05	2	1.12E+06	1	3.36E+05	0	N/A	0	N/A
1-Hexene, 2,5,5-trimethyl-	3	3.47E+06	3	1.70E+06	1	2.80E+06	0	N/A	0	N/A
Propanamide	4	2.45E+06	0	N/A	0	N/A	0	N/A	0	N/A
Butanoic acid, 3-methyl-	4	5.02E+06	1	6.85E+06	0	N/A	0	N/A	0	N/A
2-Cyclopentene-1,4-dione	0	N/A	0	N/A	5	1.19E+06	0	N/A	0	N/A
3,5-Dimethyl-3-heptene	5	2.73E+06	3	2.89E+06	2	4.50E+06	0	N/A	0	N/A
Cyclopentanone, 2,4,4-trimethyl-	4	1.45E+07	3	1.22E+06	1	1.34E+06	0	N/A	0	N/A
Propane, 2-isothiocyanato-2-methyl-	5	6.57E+05	2	4.79E+05	1	2.15E+05	0	N/A	0	N/A
1-Heptene, 2,6-dimethyl-	3	1.57E+07	3	1.89E+07	1	2.04E+06	0	N/A	0	N/A
Pyridine, 3-methyl-	5	1.53E+06	1	1.03E+06	0	N/A	0	N/A	0	N/A
2,4-Dimethyl-1-heptene	4	1.31E+07	5	1.20E+07	2	1.10E+07	0	N/A	0	N/A
3-Nonene, (E)-	5	1.86E+07	5	1.24E+07	1	7.85E+06	0	N/A	0	N/A

Table R-4 Continued

Tentative Chemical Identifications • Match Factor > 75% Forward and Reverse • Listed in Order of Retention Time	Recycling Plants – Frequency	Recycling Plants – Mean Area Counts	Indoor Fields – Frequency	Indoor Fields – Mean Area Counts	Outdoor Fields – Frequency	Outdoor Fields – Mean Area Counts	Chamber Backgrounds – Frequency	Chamber Backgrounds – Mean Area Counts	Tube Blanks – Frequency	Tube Blanks – Mean Area Counts
1H-Pyrrole, 2,4-dimethyl-	3	1.31E+06	1	4.52E+05	1	3.44E+05	0	N/A	1	1.33E+05
Formamide, N-(1,1-dimethylethyl)-	4	1.00E+08	1	2.46E+07	0	N/A	0	N/A	0	N/A
2,3,3-Trimethyl-1-hexene	6	7.13E+06	4	7.15E+06	2	5.80E+06	0	N/A	0	N/A
Cyclopentanone, 2-methyl-	3	8.45E+06	1	1.31E+06	0	N/A	0	N/A	1	3.80E+05
N-tert-Butylacetamide	6	1.45E+07	4	8.34E+06	0	N/A	0	N/A	0	N/A
2-Furancarboxaldehyde, 5-methyl-	1	2.70E+06	2	4.24E+05	8	4.12E+05	0	N/A	0	N/A
2,3-Dimethyl-2-heptene	6	5.07E+06	4	5.57E+06	2	4.40E+06	0	N/A	0	N/A
Benzonitrile	2	1.30E+07	1	5.64E+06	3	2.68E+06	1	2.38E+06	2	3.89E+05
N-t-Butylpyrrole	6	2.46E+06	2	1.74E+06	1	1.30E+06	0	N/A	0	N/A
Phenol, 3,5-dimethyl-	0	N/A	3	2.18E+06	2	1.61E+06	0	N/A	0	N/A
Benzene, 1-methoxy-4-methyl-	0	N/A	0	N/A	3	2.28E+06	0	N/A	0	N/A
Hexanoic acid	0	N/A	3	6.11E+06	0	N/A	0	N/A	0	N/A
Benzoxazole	3	1.11E+06	1	6.85E+05	2	2.49E+05	0	N/A	0	N/A
Phenol	3	3.85E+07	3	9.39E+06	3	2.60E+06	3	5.62E+06	2	8.58E+05
Aniline	6	2.02E+08	4	4.42E+07	3	1.44E+07	0	N/A	0	N/A
Benzene, 1,3,5-trimethyl-	1	1.34E+06	0	N/A	3	7.95E+05	1	2.83E+05	0	N/A
5-Hepten-2-one, 6-methyl-	1	2.10E+06	3	2.49E+06	2	1.47E+06	0	N/A	0	N/A
Cyclohexane, isocyanato-	6	2.37E+07	3	9.99E+06	1	1.66E+06	0	N/A	0	N/A
2(3H)-Furanone, 5-ethenyldihydro-5-methyl-	0	N/A	3	1.40E+07	4	1.61E+07	0	N/A	0	N/A
2-Pyrrolidinone	4	8.06E+06	0	N/A	0	N/A	0	N/A	0	N/A
4,7-Methano-1H-indene, 3a,4,7,7a-tetrahydro-	3	4.02E+06	1	4.67E+06	1	7.28E+05	0	N/A	0	N/A
2-Propanamine, N,N'-1,2-ethanediylidenebis[2-methyl-	6	5.50E+06	3	4.92E+06	1	1.16E+06	0	N/A	0	N/A
Benzaldehyde, 3-methyl-	0	N/A	0	N/A	3	2.76E+06	0	N/A	1	1.58E+05
p-Aminotoluene	6	2.64E+07	4	1.32E+07	3	8.12E+06	0	N/A	0	N/A
2-Pentanamine, N-ethyl-4-methyl-	4	7.20E+07	1	1.54E+07	0	N/A	0	N/A	0	N/A

Table R-4 Continued

Tentative Chemical Identifications • Match Factor > 75% Forward and Reverse • Listed in Order of Retention Time	Recycling Plants – Frequency	Recycling Plants – Mean Area Counts	Indoor Fields – Frequency	Indoor Fields – Mean Area Counts	Outdoor Fields – Frequency	Outdoor Fields – Mean Area Counts	Chamber Backgrounds – Frequency	Chamber Backgrounds – Mean Area Counts	Tube Blanks – Frequency	Tube Blanks – Mean Area Counts
N-Formylmorpholine	6	1.66E+07	1	9.64E+06	0	N/A	0	N/A	0	N/A
Hexanoic acid, 2-ethyl-	4	1.80E+07	3	2.15E+07	0	N/A	0	N/A	0	N/A
2-Piperidinone	3	1.01E+07	1	5.57E+06	0	N/A	0	N/A	0	N/A
Pentadecane, 2,6,10,14-tetramethyl-	3	2.48E+07	0	N/A	1	9.40E+05	0	N/A	1	3.38E+06
1H-Indene, 2,3-dihydro-5-methyl-	5	5.30E+06	0	N/A	0	N/A	0	N/A	0	N/A
1H-Indene, 2,3-dihydro-4-methyl-	3	6.21E+06	0	N/A	0	N/A	0	N/A	0	N/A
Benzenamine, 4-butoxy-	5	1.05E+07	4	1.03E+07	1	2.32E+06	0	N/A	0	N/A
Benzene, 1-methyl-4-(1-methylpropyl)-	6	6.38E+06	0	N/A	0	N/A	0	N/A	0	N/A
Benzene, pentamethyl-	15	2.45E+07	0	N/A	0	N/A	0	N/A	0	N/A
Naphthalene	4	6.91E+07	3	2.54E+06	5	8.26E+05	3	1.69E+06	2	5.79E+05
Benzene, 1-(1-methylethenyl)-4-(1-methylethyl)-	3	6.92E+06	0	N/A	0	N/A	0	N/A	0	N/A
Benzothiazole	6	2.74E+08	4	3.29E+08	5	1.01E+08	1	9.22E+05	0	N/A
Formamide, N-cyclohexyl-	3	1.14E+07	4	2.79E+07	0	N/A	0	N/A	0	N/A
Benzene, 2-ethenyl-1,3,5-trimethyl-	3	1.58E+07	0	N/A	0	N/A	0	N/A	0	N/A
Acetamide, N-cyclohexyl-	6	5.07E+07	2	5.39E+07	2	2.61E+06	0	N/A	0	N/A
Phenol, p-tert-butyl-	6	9.56E+07	2	7.42E+07	2	2.88E+06	0	N/A	0	N/A
Formamide, N-phenyl-	1	2.16E+07	4	1.04E+07	0	N/A	0	N/A	0	N/A
1H-Indene, 2,3-dihydro-4,7-dimethyl-	5	1.32E+07	0	N/A	0	N/A	0	N/A	0	N/A
Naphthalene, 1,2,3,4-tetrahydro-6-methyl-	3	1.55E+07	0	N/A	0	N/A	0	N/A	0	N/A
Phthalic anhydride	0	N/A	0	N/A	3	2.84E+05	0	N/A	0	N/A
Pentadecane	7	7.14E+07	4	6.62E+07	3	8.41E+06	1	5.24E+06	1	6.11E+05
Naphthalene, 2-methyl-	3	9.20E+07	2	4.00E+06	0	N/A	2	5.38E+05	0	N/A
Naphthalene, 1-methyl-	9	9.11E+07	6	5.38E+06	3	1.51E+06	1	1.22E+06	0	N/A
Benzene, 1,3,5-tris(1-methylethyl)-	3	1.12E+07	0	N/A	0	N/A	0	N/A	0	N/A
Phenol, 2-(1,1-dimethylethyl)-4-methyl-	3	3.87E+07	1	1.75E+06	0	N/A	0	N/A	0	N/A
Naphthalene, 1,2,3,4-tetrahydro-2,6-dimethyl-	3	2.13E+07	1	3.47E+06	1	5.58E+05	0	N/A	0	N/A
Hexadecane	7	7.65E+07	4	1.11E+08	4	1.26E+07	2	1.14E+07	1	9.23E+05
Tetradecane	6	6.54E+07	4	3.84E+07	2	7.41E+06	1	4.72E+06	1	5.13E+05
Diphenyl ether	6	3.56E+07	1	2.51E+07	2	3.28E+06	0	N/A	0	N/A
Naphthalene, 2-ethyl-	4	1.39E+07	2	1.82E+06	0		0	N/A	0	N/A

Table R-4 Continued

Tentative Chemical Identifications • Match Factor > 75% Forward and Reverse • Listed in Order of Retention Time	Recycling Plants – Frequency	Recycling Plants – Mean Area Counts	Indoor Fields – Frequency	Indoor Fields – Mean Area Counts	Outdoor Fields – Frequency	Outdoor Fields – Mean Area Counts	Chamber Backgrounds – Frequency	Chamber Backgrounds – Mean Area Counts	Tube Blanks – Frequency	Tube Blanks – Mean Area Counts
1,4-Methanoazulene, decahydro-4,8,8-trimethyl-9-methylene-, [1S-(1α,3aβ,4α, 8aβ)]-	8	9.43E+07	4	3.85E+07	2	6.53E+06	0	N/A	0	N/A
1,2,4-Methenoazulene, decahydro-1,5,5,8a-tetramethyl-, [1S-(1α,2α,3aβ,4α, 8aβ,9R*)]-	4	1.17E+07	0	N/A	0	N/A	0	N/A	0	N/A
Naphthalene, 1,5-dimethyl-	9	2.03E+07	3	7.98E+06	3	9.88E+05	0	N/A	0	N/A
Phthalimide	5	5.05E+07	3	1.79E+07	0		0	N/A	0	N/A
Naphthalene, 1,3-dimethyl-	6	1.73E+07	5	7.18E+06	1	1.80E+06	1	4.54E+05	0	N/A
Quinoline, 2,4-dimethyl-	6	1.32E+08	4	2.70E+07	3	7.00E+06	1	7.39E+05	0	N/A
1,4-Methano-1H-indene, octahydro-1,7a-dimethyl-4-(1-methylethenyl)-, [1S-(1α, 3aβ,4α,7aβ)]-	3	1.70E+07	0	N/A	0	N/A	0	N/A	0	N/A
Butylated Hydroxytoluene	7	2.11E+08	4	1.16E+08	1	2.15E+07	0	N/A	0	N/A
2,5-Cyclohexadiene-1,4-dione, 2,6-bis (1,1-dimethylethyl)-	3	2.77E+07	3	1.93E+07	2	2.85E+06	3	4.35E+06	0	N/A
1,1'-Biphenyl, 3-methyl-	8	4.99E+06	4	4.71E+06	2	7.05E+05	1	5.24E+05	0	N/A
Naphthalene, 1,6,7-trimethyl-	10	8.37E+06	9	4.64E+06	5	6.96E+05	0	N/A	0	N/A
Naphthalene, 2,3,6-trimethyl-	3	6.40E+06	1	3.14E+06	0	N/A	0	N/A	0	N/A
Pentadecane, 2-methyl-	1	2.66E+06	3	5.26E+06	0	N/A	0	N/A	0	N/A
Phenol, 4-(1,1,3,3-tetramethylbutyl)-	5	1.27E+08	4	5.77E+07	2	4.42E+06	0	N/A	0	N/A
Diphenylamine	6	3.44E+07	4	3.94E+07	3	6.74E+06	1	1.36E+06	0	N/A
Benzothiazole, 2-(methylthio)-	3	1.46E+07	4	3.29E+07	1	8.88E+06	1	7.96E+05	0	N/A

[a] VOC = volatile organic compound; °C = degrees Celsius; GC/TOFMS = gas chromatography/time-of-flight mass spectrometry; N/A = not applicable

[b] Recycling Plants (n=6); Indoor Fields (n=4); Outdoor Fields (n=5); Chamber Backgrounds (n=3); Tube Blanks (n=3)

[c] Total compounds tentatively identified = 164; Compounds identified by source: Recycling Plants – 151 compounds (Sum of Frequencies = 725; Sum of Frequencies per n = 121), Indoor Fields – 136 compounds (Sum of Frequencies = 136; Sum of Frequencies per n = 103), Outdoor Fields – 115 compounds (Sum of Frequencies = 186, Sum of Frequencies per n = 74), Chamber Backgrounds – 52 compounds (Sum of Frequencies = 117, Sum of Frequencies per n = 39), Tube Blanks – 36 compounds (Sum of Frequencies = 74, Sum of Frequencies per n = 25)

Table R-5. Non-Targeted Analysis for SVOC 60 °C Chamber Emission Samples by GC/MS – Highly Tentative Screening Results[a,b,c]

Tentative Compound Identification • Match Factor >50% • Minimum Frequency = 3 • In Order of Retention Time	CAS Number[d]	Recycling Plants – Frequency	Recycling Plants – Mean Area Counts	Indoor Fields – Frequency	Indoor Fields – Mean Area Counts	Outdoor Fields – Frequency	Outdoor Fields – Mean Area Counts	Chamber Backgrounds – Mean Area Counts
Thiopivalic acid	55561-02-9	1	1.4E+05	0	N/A	7	1.8E+06	0
Pentanal, 2,2-dimethyl-	14250-88-5	4	8.1E+06	5	4.8E+05	8	6.3E+06	0
2,5-Hexanedione	110-13-4	0	N/A	0	N/A	3	3.0E+05	0
Hydroperoxide, 1-ethylbutyl	24254-56-6	3	5.8E+06	4	6.1E+05	3	1.4E+06	0
Hexane, 2-nitro-	14255-44-8	0	N/A	0	N/A	4	5.3E+06	0
Hydroperoxide, 1-methylpentyl	24254-55-5	3	5.8E+06	3	1.1E+06	2	2.1E+06	0
2H-Pyran-2-methanol, tetrahydro-	100-72-1	0	N/A	0	N/A	3	5.2E+06	0
1,5-Heptadien-4-one, 3,3,6-trimethyl-	546-49-6	3	4.9E+07	2	5.3E+06	3	3.5E+06	0
Oxalic acid, cyclohexyl nonyl ester	1000309-31-1	0	N/A	4	8.7E+06	2	2.4E+07	0
Cyclopropane, 2-bromo-1,1,3-trimethyl-	36617-00-2	3	1.9E+07	0	N/A	8	2.8E+07	0
Cyclohexane, nitro-	1122-60-7	0	N/A	1	2.6E+06	4	1.4E+06	0
Oxalic acid, cyclohexyl isobutyl ester	1000309-30-4	3	1.4E+06	3	2.8E+05	1	7.9E+05	0
Sulfurous acid, dicyclohexyl ester	6214-17-1	1	3.0E+05	3	1.1E+05	3	2.6E+05	0
1-Butene, 2,3,3-trimethyl-	594-56-9	3	3.8E+06	1	4.8E+05	1	5.0E+05	0
Cyclobutanecarboxylic acid, 2-propenyl ester	1000282-60-3	0	N/A	0	N/A	6	8.7E+05	0
Cyclohexanol, 1-methyl-	590-67-0	0	N/A	0	N/A	3	2.8E+05	0
Benzothiazole	95-16-9	4	7.2E+06	2	6.0E+05	0	N/A	0
4-Oxopentanethioic acid	1000193-80-6	1	3.5E+05	0	N/A	3	7.9E+05	0
7-Methoxy-2,2,4,8-tetramethyltricyclo[5.3.1.0(4,11)]undecane	1000140-32-8	3	5.2E+05	0	N/A	0	N/A	0
Cyclooctasiloxane, hexadecamethyl-	556-68-3	3	2.6E+05	3	5.2E+04	2	1.1E+05	0
cis-13-Eicosenoic acid	17735-94-3	2	5.5E+05	0	N/A	0	N/A	0
Cyclononasiloxane, octadecamethyl-	556-71-8	5	1.5E+05	4	1.7E+04	1	6.7E+04	0
Tetracosamethyl-cyclododecasiloxane	18919-94-3	3	1.4E+05	1	1.0E+04	0	N/A	0
Cyclodecasiloxane, eicosamethyl-	18772-36-6	14	3.5E+05	0	N/A	0	N/A	0
Squalene	111-02-4	3	1.8E+06	0	N/A	1	3.9E+05	0

[a] SVOC = semivolatile organic compound; °C = degrees Celsius; GC/MS = gas chromatography/mass spectrometry; N/A = not applicable

[b] Recycling Plants (n=6); Indoor Fields (n=5); Outdoor Fields (n=5); Chamber Backgrounds (n=3)

[c] Total compounds tentatively identified = 25; Compounds identified by source: Recycling Plants – 18 compounds (Sum of Frequencies = 62), Indoor Fields – 13 compounds (Sum of Frequencies = 36), Outdoor Fields – 20 compounds (Sum of Frequencies = 68)

[d] Unique numerical identifier assigned by the Chemical Abstracts Services (CAS)

Table R-6. Non-Targeted Analysis for SVOC 60 °C Chamber Emission Samples by LC/TOFMS Positive Mode – Highly Tentative Screening Results[a,b]

Tentative Chemical Identification	CAS Number[c]	Chemical Formula	Score	Number of Chemicals Same Formula	Recycling Plants – Frequency	Recycling Plants – Mean Area Counts	Indoor Fields – Frequency	Indoor Fields – Mean Area Counts	Outdoor Fields – Frequency	Outdoor Fields – Mean Area Counts	Chamber Backgrounds – Frequency	Chamber Backgrounds – Mean Area Counts
Decamethylcyclopentasiloxane	541-02-6	C10H30O5Si5	91.15	1	3	1.58E+05	1	4.22E+05	0	N/A	0	N/A
Dicyclohexylamine	101-83-7	C12H23N	99.31	198	6	1.49E+06	5	6.09E+05	0	N/A	0	N/A
1-Piperazineethanol, 4-[2-[(2-hydroxypropyl)amino]ethyl]-.alpha.-methyl-	68310-64-5	C12H27N3O2	98.44	3	2	4.28E+05	2	4.61E+05	4	4.03E+05	0	N/A
N'',N'''-Ethane-1,2-diylbis(N,N'-diethylguanidine)	13561-03-0	C12H28N6	99.13	1	5	1.27E+06	5	1.34E+06	4	1.16E+06	0	N/A
CTK3H8080	918313-44-7	C13H16N7	89.78	2	3	1.61E+05	1	1.17E+05	1	1.08E+05	0	N/A
1,1-Dimethyl-2-phenylethyl butanoate	10094-34-5	C14H20O2	97.7	225	4	1.41E+05	3	2.07E+05	2	1.07E+05	0	N/A
N,N-Diethyl-4-[2-(1-oxido-4-pyridinyl) diazenyl]benzenamine	7347-49-1	C15H18N4O	86.27	22	3	1.43E+05	1	6.93E+04	2	4.21E+05	0	N/A
alpha-pyrrolidinovalerophenone	14530-33-7	C15H21NO	81.71	137	4	1.74E+05	3	6.13E+04	0	N/A	0	N/A
2,6-Di-tert-butyl-4-hydroperoxy-4-methyl -2,5-cyclohexadienone	6485-57-0	C15H24O3	92.34	54	2	5.72E+05	3	2.40E+05	0	N/A	0	N/A
1,3-bis(cyclohexylmethyl)urea	5472-16-2	C15H28N2O	82.8	10	4	1.39E+05	1	1.02E+05	0	N/A	0	N/A
Dodecanoic acid, 5-hydroxy-, 2,3-dihydroxypropyl ester	93762-24-4	C15H30O5	82.99	12	5	7.79E+04	4	7.81E+04	4	1.06E+05	0	N/A
Hexahydro-1,3,5-tris(3-methoxypropyl)-s-triazine	3960-05-2	C15H33N3O3	96.84	2	4	2.43E+05	4	1.08E+05	3	4.73E+05	4	1.34E+05
N,N-Dimethyl-1,2-diphenylethanamine	6319-84-2	C16H19N	81.7	82	3	9.98E+04	2	8.58E+04	1	1.94E+05	1	3.50E+04
13-Hexyl-1,4,7,10-tetraoxa-13-azacyclopentadecane	75006-53-0	C16H33NO4	98.27	16	8	1.10E+05	8	2.00E+05	6	8.11E+04	6	6.51E+04
Benzenamine, N,N-diethyl-4-[(2-methoxy-4-nitrophenyl)azo]-	6373-95-1	C17H20N4O3	94.55	17	4	1.46E+05	3	1.39E+05	4	9.70E+04	1	4.12E+04
(9Z)-Octadec-9-enamide	301-02-0	C18H35NO	94.77	108	5	4.56E+05	4	3.76E+05	4	2.35E+06	4	4.23E+05
(9Z)-Octadec-9-enamide	301-02-0	C18H35NO	94.77	108	6	1.03E+06	5	7.54E+05	5	2.41E+06	5	6.64E+05
1-Phenyl-N-(2-phenylaziridin-1-yl)-3-(trimethylsilyl)propan-1-imine	144487-92-3	C20H26N2Si	80.01	2	2	1.13E+05	2	1.05E+05	3	1.35E+05	0	N/A
10-[(3,7-Dimethylocta-2,6-dien-1-yl)oxy]decyl thiocyanate	586966-65-6	C21H37NOS	83.81	3	2	1.16E+05	3	1.77E+05	1	9.51E+04	2	5.02E+04

Table R-6 Continued

Tentative Chemical Identification	CAS Number[c]	Chemical Formula	Score	Number of Chemicals Same Formula	Recycling Plants – Frequency	Recycling Plants – Mean Area Counts	Indoor Fields – Frequency	Indoor Fields – Mean Area Counts	Outdoor Fields – Frequency	Outdoor Fields – Mean Area Counts	Chamber Backgrounds – Frequency	Chamber Backgrounds – Mean Area Counts
Decanedioic acid, methyl 1,2,2,6,6-pentamethyl-4-piperidinyl ester	82919-37-7	C21H39NO4	98.47	5	4	1.04E+05	3	1.12E+05	4	6.38E+05	3	9.80E+04
1H-Pyrido(3,4-b)indole-1,3(2H)-dione, 4,9-dihydro-2-(4-(4-(2-pyrimidinyl)-1-piperazinyl)butyl)-	184691-49-4	C23H26N6O2	98.82	6	5	4.15E+06	5	4.39E+06	4	2.30E+06	2	1.36E+06
1H-Pyrido(3,4-b)indole-1,3(2H)-dione, 4,9-dihydro-2-(4-(4-(2-pyrimidinyl)-1-piperazinyl)butyl)-	184691-49-4	C23H26N6O2	98.2	6	6	4.03E+06	5	3.35E+06	5	7.82E+06	4	8.76E+05
L-Glutamic acid, N-(1-oxooctadecyl)-, sodium salt (1:2)	38079-62-8	C23H43NO5	99.07	9	3	1.14E+05	2	1.08E+05	2	8.09E+05	3	8.87E+04
Bis-ferulamidobutane	91000-13-4	C24H28N2O6	95.19	32	5	1.62E+06	3	5.14E+05	4	1.29E+06	2	2.93E+05
Diisodecyl phthalate	26761-40-0	C28H46O4	96.66	24	5	2.75E+05	4	6.59E+05	4	1.81E+05	5	1.53E+05
6-Deoxocathasterone	NOCAS_40952	C28H50O2	83.94	10	3	1.55E+05	4	2.11E+05	2	8.77E+04	1	5.78E+04
1,1'-(9H-Fluorene-2,7-diyl)di(octan-1-one)	61314-10-1	C29H38O2	89.29	3	4	8.14E+05	4	1.44E+06	3	9.77E+05	1	3.72E+05
(17beta)-3-Hydroxyestra-1,3,5(10)-trien-17-yl methyl 2,3,4-tri-O-acetyl-beta-D-glucopyranosiduronate	14364-66-0	C31H40O11	81.36	2	4	2.51E+05	4	2.70E+05	3	2.32E+05	0	N/A
1-Acetyl-L-prolyl-L-alanyl-L-prolyl-L-phenylalanyl-L-phenylalaninamide	60240-22-4	C33H42N6O6	92.03	2	6	3.81E+05	5	3.15E+05	4	6.15E+05	3	1.52E+05
L-Phenylalanyl-L-valyl-L-alanyl-L-prolyl-L-phenylalanyl-L-proline	161258-30-6	C36H48N6O7	91.81	2	6	5.49E+05	5	4.34E+05	4	8.69E+05	3	2.64E+05
Triethylamine	121-44-8	C6H15N	87.73	279	5	8.36E+05	2	2.46E+05	0	N/A	0	N/A
Ethanamine, 2,2'-[oxybis(2,1-ethanediyloxy)]bis-	929-75-9	C8H20N2O3	98.92	3	4	1.95E+06	3	1.84E+06	4	1.06E+06	0	N/A

[a] SVOC = semivolatile organic compound; °C = degrees Celsius; LC/TOFMS = liquid chromatography/time-of-flight mass spectrometry; N/A = not applicable

[b] Recycling Plants (n=6); Indoor Fields (n=5); Outdoor Fields (n=5); Chamber Backgrounds (n=3)

[c] Unique numerical identifier assigned by the Chemical Abstracts Services (CAS)

Table R-7. Non-Targeted Analysis for SVOC 60 °C Chamber Emission Samples by LC/TOFMS Negative Mode – Highly Tentative Screening Results[a,b]

Tentative Chemical Identification	CAS Number[c]	Chemical Formula	Score	Number of Chemicals Same Formula	Recycling Plants – Frequency	Recycling Plants – Mean Area Counts	Indoor Fields – Frequency	Indoor Fields – Mean Area Counts	Outdoor Fields – Frequency	Outdoor Fields – Mean Area Counts	Chamber Backgrounds – Frequency	Chamber Backgrounds – Mean Area Counts
Oleic acid	112-80-1	C18H34O2	99.19	107	4	5.41E+05	4	2.81E+05	2	1.89E+05	1	1.79E+05
1H-Pyrido(3,4-b)indole-1,3(2H)-dione, 4,9-dihydro-2-(4-(4-(2-pyrimidinyl)-1-piperazinyl)butyl)-	184691-49-4	C23H26N6O2	98.1	8	5	1.35E+05	3	1.38E+05	3	4.50E+05	1	8.30E+04
1H-Pyrido(3,4-b)indole-1,3(2H)-dione, 4,9-dihydro-2-(4-(4-(2-pyrimidinyl)-1-piperazinyl)butyl)-	184691-49-4	C23H26N6O2	99.48	8	6	6.50E+05	4	3.24E+05	4	2.81E+06	3	1.37E+05
1,5-Trisiloxanediol, 1,1,3,3,5,5-hexamethyl-	3663-50-1	C6H20O4Si3	98.35	4	3	3.42E+05	2	2.49E+05	1	1.27E+06	2	2.14E+05

[a] SVOC = semivolatile organic compound; °C = degrees Celsius; LC/TOFMS = liquid chromatography/time-of-flight mass spectrometry

[b] Recycling Plants (n=6); Indoor Fields (n=5); Outdoor Fields (n=5); Chamber Backgrounds (n=3)

[c] Unique numerical identifier assigned by the Chemical Abstracts Services (CAS)

Appendix S

Targeted Microbiological Analysis Results for Tire Crumb Rubber Infill Samples Collected at Synthetic Turf Fields

Table S-1. Variability in Targeted Microbial Gene Quantities of 16S rRNA Within Each Field[a]

Field ID	Individual Field Location Samples – Mean	Individual Field Location Samples – Standard Deviation	Individual Field Location Samples – % Relative Standard Deviation	Individual Field Sample Location 1 Results (molecules/g TCR)	Individual Field Sample Location 2 Results (molecules/g TCR)	Individual Field Sample Location 3 Results (molecules/g TCR)	Individual Field Sample Location 4 Results (molecules/g TCR)	Individual Field Sample Location 5 Results (molecules/g TCR)	Individual Field Sample Location 6 Results (molecules/g TCR)	Individual Field Sample Location 7 Results (molecules/g TCR)
1	2.73E+07	9.92E+06	36.3	1.55E+07	2.40E+07	2.09E+07	4.37E+07	3.70E+07	2.13E+07	2.87E+07
2	1.29E+07	8.43E+06	65.1	7.33E+06	1.44E+07	7.26E+06	3.01E+07	1.13E+07	5.21E+06	1.51E+07
3	4.77E+07	1.28E+07	26.9	5.14E+07	2.59E+07	5.34E+07	3.54E+07	4.78E+07	5.74E+07	6.24E+07
4	2.99E+05	2.83E+05	94.8	8.01E+05	3.81E+05	3.17E+05	4.53E+05	3.59E+03	2.96E+04	1.04E+05
5	9.26E+06	7.56E+06	81.6	4.51E+06	2.91E+06	4.12E+05	2.24E+07	1.01E+07	1.46E+07	9.94E+06
6	5.72E+05	4.13E+05	72.2	2.18E+05	3.49E+05	1.40E+06	3.63E+05	7.88E+05	5.98E+05	2.93E+05
7	3.55E+05	1.89E+05	53.1	3.26E+05	3.45E+05	7.57E+05	2.35E+05	1.73E+05	2.98E+05	3.53E+05
8	2.97E+06	1.85E+06	62.1	3.63E+06	1.21E+06	9.20E+05	2.97E+06	1.91E+06	3.92E+06	6.24E+06
9	1.65E+07	1.26E+07	76.3	1.02E+07	1.95E+07	3.84E+07	1.85E+07	QCF	1.06E+07	1.63E+06
10	2.02E+06	1.18E+06	58.5	8.60E+05	1.38E+06	2.06E+06	3.33E+06	7.88E+05	1.86E+06	3.84E+06
11	2.25E+05	1.77E+05	78.4	1.10E+04	1.56E+05	5.88E+05	2.17E+05	1.71E+05	1.91E+05	2.41E+05
12	2.10E+07	2.28E+07	109	2.74E+07	1.44E+07	7.02E+07	9.74E+06	6.31E+06	7.15E+06	1.19E+07
13	3.35E+06	2.51E+06	74.9	4.27E+06	3.07E+06	QCF	3.21E+06	4.25E+05	1.49E+06	7.65E+06
14	4.67E+06	2.72E+06	58.3	3.70E+06	9.29E+05	3.35E+06	6.58E+06	4.69E+06	8.75E+06	QCF
15	7.38E+06	3.66E+06	49.6	7.85E+06	2.79E+06	3.05E+06	7.65E+06	7.63E+06	1.35E+07	9.24E+06
16	7.09E+06	4.73E+06	66.7	2.13E+06	1.18E+06	8.89E+06	9.96E+06	1.06E+07	1.33E+07	3.59E+06
17	2.32E+07	7.31E+06	31.5	2.01E+07	1.66E+07	1.62E+07	1.85E+07	3.47E+07	2.57E+07	3.09E+07
18	5.05E+07	2.44E+07	48.2	2.64E+07	2.32E+07	3.99E+07	6.32E+07	7.35E+07	8.70E+07	4.03E+07
19	2.60E+06	9.80E+05	37.6	2.59E+06	1.54E+06	3.38E+06	1.49E+06	4.14E+06	3.00E+06	2.08E+06
20	1.85E+06	1.88E+06	102	3.37E+06	1.39E+06	5.45E+06	8.71E+05	5.79E+05	4.27E+05	8.26E+05
21	2.35E+06	1.32E+06	56.3	5.01E+06	1.47E+06	2.54E+06	1.55E+06	1.37E+06	1.55E+06	2.94E+06
22	1.67E+06	8.74E+05	52.3	1.78E+06	1.35E+06	3.38E+06	1.83E+06	1.46E+06	1.43E+06	4.84E+05
23	1.38E+07	5.42E+06	39.3	5.52E+06	1.15E+07	1.37E+07	2.26E+07	1.75E+07	1.06E+07	1.51E+07
24	1.50E+06	1.12E+06	74.3	3.85E+06	1.62E+06	1.71E+06	6.40E+05	8.82E+05	1.10E+06	7.19E+05

Table S-1 Continued

Field ID	Individual Field Location Samples – Mean	Individual Field Location Samples – Standard Deviation	Individual Field Location Samples – % Relative Standard Deviation	Individual Field Sample Location 1 Results (molecules/g TCR)	Individual Field Sample Location 2 Results (molecules/g TCR)	Individual Field Sample Location 3 Results (molecules/g TCR)	Individual Field Sample Location 4 Results (molecules/g TCR)	Individual Field Sample Location 5 Results (molecules/g TCR)	Individual Field Sample Location 6 Results (molecules/g TCR)	Individual Field Sample Location 7 Results (molecules/g TCR)
25	1.25E+06	1.78E+06	143	9.53E+05	6.32E+05	5.25E+06	4.04E+05	6.43E+05	3.49E+05	4.92E+05
26	2.56E+07	1.28E+07	50.1	2.08E+07	2.21E+07	3.81E+07	1.88E+07	1.31E+07	1.75E+07	4.85E+07
27	1.73E+06	4.96E+05	28.6	2.54E+06	2.08E+06	1.71E+06	9.82E+05	1.75E+06	1.38E+06	1.67E+06
28	2.37E+05	1.47E+05	61.9	9.94E+04	QCF	2.76E+05	1.86E+05	1.52E+05	5.12E+05	1.95E+05
29	8.27E+05	5.10E+05	61.7	1.58E+06	4.30E+04	1.15E+06	7.79E+05	1.08E+06	7.99E+05	3.65E+05
30	1.45E+06	5.44E+05	37.6	1.32E+06	1.99E+06	6.90E+05	2.12E+06	1.80E+06	9.19E+05	1.28E+06
31	1.59E+07	5.11E+06	32.1	1.35E+07	2.26E+07	1.32E+07	1.47E+07	1.23E+07	2.38E+07	1.13E+07
32	2.40E+07	1.19E+07	49.5	2.26E+07	1.11E+07	1.08E+07	4.23E+07	2.41E+07	3.65E+07	2.05E+07
33	8.20E+06	3.29E+06	40.1	6.80E+06	1.16E+07	1.37E+07	7.57E+06	7.57E+06	4.09E+06	6.16E+06
34	1.81E+07	5.00E+06	27.6	1.76E+07	1.38E+07	2.80E+07	1.56E+07	1.64E+07	1.43E+07	2.11E+07
35	2.01E+07	9.51E+06	47.2	6.00E+06	2.29E+07	3.43E+07	1.59E+07	2.68E+07	1.21E+07	2.30E+07
36	2.13E+05	1.45E+05	68.4	1.54E+05	8.27E+04	3.47E+05	1.25E+05	4.66E+05	8.63E+04	2.27E+05
37	1.95E+06	2.68E+06	138	1.94E+06	1.29E+06	7.88E+06	1.08E+06	3.47E+05	6.30E+05	4.45E+05
38	7.61E+06	1.45E+07	190	1.88E+06	4.02E+07	7.23E+05	7.17E+05	6.58E+05	3.95E+06	5.10E+06
39	2.57E+07	1.13E+07	43.8	4.67E+07	1.51E+07	1.18E+07	2.60E+07	2.86E+07	2.75E+07	2.40E+07
40	1.44E+07	4.53E+06	31.5	1.71E+07	9.31E+06	2.31E+07	1.44E+07	1.30E+07	1.27E+07	1.12E+07

[a] molecules/g TCR = molecules/gram of tire crumb rubber; rRNA = ribosomal ribonucleic acid; QCF = Failed QC, Result Not Reported

Table S-2. Variability in Targeted Microbial Gene Quantities of *S. aureus* SA0140 protein Within Each Field[a]

Field ID	Individual Field Location Samples – Mean	Individual Field Location Samples – Standard Deviation	Individual Field Location Samples – % Relative Standard Deviation	Individual Field Sample Location 1 Results (molecules/g TCR)	Individual Field Sample Location 2 Results (molecules/g TCR)	Individual Field Sample Location 3 Results (molecules/g TCR)	Individual Field Sample Location 4 Results (molecules/g TCR)	Individual Field Sample Location 5 Results (molecules/g TCR)	Individual Field Sample Location 6 Results (molecules/g TCR)	Individual Field Sample Location 7 Results (molecules/g TCR)
1	0	0	N/A	0	0	0	0	0	0	0
2	0	0	N/A	0	0	0	0	0	0	0
3	0	5.70E+00	N/A	0	0	0	0	0	0	0
4	1.01E+01	1.03E+01	101	1.50E+01	0	1.86E+01	2.51E+01	0	0	1.23E+01
5	0	0	N/A	0	0	0	0	0	0	0
6	4.02E+01	5.43E+01	135	4.24E+01	2.13E+01	1.55E+02	1.12E+01	0	0	5.19E+01
7	1.43E+02	3.31E+02	232	8.90E+02	0	1.91E+01	0	6.10E+01	0	2.75E+01
8	0	0	N/A	0	0	0	0	0	0	0
9	0	0	N/A	0	0	0	0	QCF	0	0
10	1.36E+02	3.10E+02	228	0	0	1.22E+02	8.30E+02	0	0	0
11	0	0	N/A	0	0	0	0	0	0	0
12	0	0	N/A	0	0	0	0	0	0	0
13	0	0	N/A	0	0	QCF	0	0	0	0
14	0	0	N/A	0	0	0	0	0	0	QCF
15	0	0	N/A	0	0	0	0	0	0	0
16	0	0	N/A	0	0	0	0	0	0	0
17	0	0	N/A	0	0	0	0	0	0	0
18	0	0	N/A	0	0	0	0	0	0	0
19	2.10E+00	5.50E+00	265	0	0	0	1.45E+01	0	0	0
20	3.96E+01	5.36E+01	136	6.93E+01	2.88E+01	1.49E+02	1.87E+01	0	0	1.15E+01
21	0	0	N/A	0	0	0	0	0	0	0
22	6.26E+01	6.26E+01	100	4.02E+01	3.21E+01	8.84E+01	1.91E+02	3.28E+01	5.34E+01	0
23	0	0	N/A	0	0	0	0	0	0	0

Table S-2 Continued

Field ID	Individual Field Location Samples – Mean	Individual Field Location Samples – Standard Deviation	Individual Field Location Samples – % Relative Standard Deviation	Individual Field Sample Location 1 Results (molecules/g TCR)	Individual Field Sample Location 2 Results (molecules/g TCR)	Individual Field Sample Location 3 Results (molecules/g TCR)	Individual Field Sample Location 4 Results (molecules/g TCR)	Individual Field Sample Location 5 Results (molecules/g TCR)	Individual Field Sample Location 6 Results (molecules/g TCR)	Individual Field Sample Location 7 Results (molecules/g TCR)
24	3.99E+01	7.00E+01	176	1.95E+02	2.14E+01	3.04E+01	0	0	3.21E+01	0
25	3.04E+01	7.63E+01	251	0	0	0	0	2.03E+02	0	9.6
26	0	0	N/A	0	0	0	0	0	0	0
27	4.79E+01	1.94E+01	40.5	7.23E+01	4.66E+01	3.33E+01	3.37E+01	7.84E+01	3.57E+01	3.50E+01
28	6.60E+00	1.62E+01	245	0	QCF	0	0	0	39.8	0
29	1.45E+01	2.19E+01	151	4.12E+01	0	5.07E+01	0	0	9.60E+00	0
30	4.05E+01	1.74E+01	43	4.22E+01	6.89E+01	2.82E+01	1.90E+01	4.39E+01	5.46E+01	2.69E+01
31	2.10E+00	5.60E+00	265	0	1.47E+01	0	0	0	0	0
32	0	0	N/A	0	0	0	0	0	0	0
33	1.10E+02	1.01E+02	91.6	3.21E+02	1.15E+02	1.36E+02	7.48E+01	5.51E+01	4.11E+01	2.78E+01
34	0	0	N/A	0	0	0	0	0	0	0
35	0	0	N/A	0	0	0	0	0	0	0
36	0	0	N/A	0	0	0	0	0	0	0
37	3.38E+01	3.26E+01	96.3	5.18E+01	7.01E+01	7.68E+01	2.78E+01	1.02E+01	0	0
38	2.65E+01	1.78E+01	67.1	5.11E+01	4.66E+01	0	1.43E+01	2.44E+01	2.81E+01	2.10E+01
39	0	0	N/A	0	0	0	0	0	0	0
40	0	0	N/A	0	0	0	0	0	0	0

[a] molecules/g TCR = molecules/gram of tire crumb rubber; QCF = Failed QC, Result Not Reported; N/A= Not applicable

Table S-3. Variability in Targeted Microbial Gene Quantities of *mecA* methicillin resistance gene Within Each Field[a]

Field ID	Individual Field Location Samples – Mean	Individual Field Location Samples – Standard Deviation	Individual Field Location Samples – % Relative Standard Deviation	Individual Field Sample Location 1 Results (molecules/g TCR)	Individual Field Sample Location 2 Results (molecules/g TCR)	Individual Field Sample Location 3 Results (molecules/g TCR)	Individual Field Sample Location 4 Results (molecules/g TCR)	Individual Field Sample Location 5 Results (molecules/g TCR)	Individual Field Sample Location 6 Results (molecules/g TCR)	Individual Field Sample Location 7 Results (molecules/g TCR)
1	9.30E+00	1.50E+01	161	4.18E+01	0	0	6.20E+00	0	5.40E+00	1.16E+01
2	8.70E+00	7.10E+00	81.3	1.35E+01	1.48E+01	1.93E+01	4.50E+00	4.80E+00	4.10E+00	0
3	7.40E+00	9.90E+00	133	0	8.80E+00	0	5.80E+00	2.78E+01	9.70E+00	0
4	5.64E+01	5.22E+01	92.4	1.70E+02	6.54E+01	3.94E+01	2.56E+01	3.48E+01	3.81E+01	2.14E+01
5	0	0	N/A	0	0	0	0	0	0	0
6	2.05E+02	8.70E+01	42.4	2.83E+02	1.33E+02	3.63E+02	1.39E+02	1.75E+02	1.41E+02	2.00E+02
7	7.46E+01	5.57E+01	74.6	5.43E+01	2.09E+01	1.86E+02	4.57E+01	6.59E+01	1.07E+02	4.31E+01
8	0	0	N/A	0	0	0	0	0	0	0
9	0	0	N/A	0	0	0	0	QCF	0	0
10	1.02E+01	2.70E+01	265	0	0	7.16E+01	0	0	0	0
11	2.10E+00	5.60E+00	265	0	0	0	0	0	0	1.47E+01
12	0	0	N/A	0	0	0	0	0	0	0
13	0	0	N/A	0	0	QCF	0	0	0	0
14	0	0	N/A	0	0	0	0	0	0	QCF
15	0	0	N/A	0	0	0	0	0	0	0
16	0	0	N/A	0	0	0	0	0	0	0
17	5.50E+00	7.60E+00	140	0	1.95E+01	0	8.30E+00	1.06E+01	0	0
18	0	0	N/A	0	0	0	0	0	0	0
19	3.50E+00	9.30E+00	265	0	0	0	0	2.46E+01	0	0
20	3.41E+02	2.60E+02	76.2	7.02E+02	2.09E+02	7.33E+02	2.18E+02	1.88E+02	1.21E+02	2.15E+02
21	4.30E+00	5.10E+00	119	14.2	0	5.60E+00	0	4.60E+00	6.00E+00	0
22	5.65E+02	3.45E+02	61.1	7.35E+02	3.46E+02	1.28E+03	3.96E+02	2.91E+02	4.71E+02	4.37E+02
23	0	0	N/A	0	0	0	0	0	0	0
24	3.94E+02	3.80E+02	96.3	1.20E+03	4.98E+02	3.21E+02	3.27E+02	1.01E+02	2.04E+02	1.12E+02

Table S-3 Continued

Field ID	Individual Field Location Samples – Mean	Individual Field Location Samples – Standard Deviation	Individual Field Location Samples – % Relative Standard Deviation	Individual Field Sample Location 1 Results (molecules/g TCR)	Individual Field Sample Location 2 Results (molecules/g TCR)	Individual Field Sample Location 3 Results (molecules/g TCR)	Individual Field Sample Location 4 Results (molecules/g TCR)	Individual Field Sample Location 5 Results (molecules/g TCR)	Individual Field Sample Location 6 Results (molecules/g TCR)	Individual Field Sample Location 7 Results (molecules/g TCR)
25	5.03E+01	1.98E+01	39.3	5.08E+01	8.04E+01	6.51E+01	3.26E+01	4.84E+01	2.04E+01	5.46E+01
26	5.80E+00	5.50E+00	96.3	1.06E+01	0	7.30E+00	1.13E+01	0	0	1.11E+01
27	3.74E+02	2.02E+02	53.8	5.38E+02	3.72E+02	3.82E+02	2.44E+02	3.78E+02	2.95E+02	4.12E+02
28	1.20E+02	9.53E+01	79.6	4.49E+01	QCF	7.19E+01	9.79E+01	1.12E+02	3.09E+02	8.35E+01
29	2.68E+02	7.52E+01	28.1	3.65E+02	3.42E+02	3.14E+02	1.67E+02	2.66E+02	2.29E+02	1.95E+02
30	5.20E+02	2.94E+02	56.5	4.21E+02	2.56E+02	3.77E+02	5.00E+02	1.16E+03	4.51E+02	4.75E+02
31	4.23E+01	9.48E+01	224	8.10E+00	3.24E+01	2.56E+02	0	0	0	0
32	0	0	N/A	0	0	0	0	0	0	0
33	6.59E+02	1.80E+02	27.3	7.99E+02	9.30E+02	5.38E+02	7.69E+02	6.37E+02	4.29E+02	5.11E+02
34	0	0	N/A	0	0	0	0	0	0	0
35	3.70E+00	7.00E+00	187	0	0	8.10E+00	0	0	1.80E+01	0
36	3.04E+01	1.94E+01	63.7	3.71E+01	3.06E+01	6.87E+01	8.00E+00	2.73E+01	1.59E+01	2.56E+01
37	4.58E+02	3.77E+02	82.2	4.43E+02	4.89E+02	1.26E+03	2.10E+02	1.51E+02	4.20E+02	2.35E+02
38	1.03E+02	3.15E+01	30.5	6.75E+01	1.34E+02	6.36E+01	1.41E+02	9.24E+01	9.73E+01	1.27E+02
39	8.70E+00	1.29E+01	149	1.32E+01	1.31E+01	0	0	0	0	3.45E+01
40	1.30E+00	3.40E+00	265	8.90E+00	0	0	0	0	0	0

[a] molecules/g TCR = molecules/gram of tire crumb rubber; QCF = Failed QC, Result Not Reported; N/A= Not applicable

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Appendix T
Dynamic Chamber Silicone Wristband Experiments

T.1 Introduction

Silicone wristbands have seen increasing interest and use as a tool for personal and area chemical sample collection in exposure assessment research. Silicone wristbands can serve as passive samplers for many types of organic chemicals and are especially effective for chemicals present in the air. With no power requirements, ease of use, and minimal participant burden and interaction requirements make them attractive for personal sample collection. There is interest in how silicone wristbands might be used in future exposure measurement studies for synthetic field users where bulky air sampling equipment can't be worn safely during intense athletic activity. A critical question regarding their suitability for synthetic turf field personal sampling is whether, and at what rate they are able to collect chemicals of interest associated with tire crumb rubber or other field materials.

As a first step towards determining feasibility, it is important to understand how to measure the relevant chemicals in wristbands and to assess the sorption of chemicals when exposed to tire crumb rubber materials. Exploratory tests were designed to provide an initial assessment and demonstration. The results are intended to inform evaluation of the potential utility in future facility and personal monitoring and/or field air monitoring in future synthetic turf field research studies.

T.2 Methods

In an effort to investigate the future viability of using silicone wristbands as a passive sampling device, we conducted a set of screening-level experiments in controlled dynamic emission chambers. The tests were designed to measure the amount of selected tire crumb rubber SVOCs absorbed to wristbands buried in the tire crumb rubber, and suspended in the air above tire crumb rubber, under controlled conditions of temperature, humidity, and ventilation.

A total of four identical experiments were conducted using tire crumb material collected from three separate fields and one recycling plant. The synthetic field samples were selected to test tire crumb rubber infill from fields selected across a range of installation ages. (The age selection criterion was applied prior to discovering the important differences in content and emission factors for indoor and outdoor fields). The four samples were designated as follows:

Field A	New outdoor field sample (installation age group 2013-2016)
Field B	Middle age indoor field sample (installation age group 2009-2012)
Field C	Older age indoor field sample (installation age group 2004-2008)
Plant Z	New recycling plant sample (collected in 2016)

Silicone wristbands were adult-sized bands procured from 24hourwristbands.com and were pre-cleaned using a solvent extraction procedure (SOP D-EMMD-PHCB-029-SOP-01).

The experiments were conducted inside 53 L small electro-polished stainless-steel chambers at 25 °C and 45% RH which were ventilated at 1 air exchange per hour (Figure T-1). The chambers included a mixing fan suspended in the center of the chamber. For each experiment, one wristband was placed inside of an aluminum foil tray that was 90 mm in diameter and approximately 17 mm deep. A pre-determined amount of tire crumb material (60 g) was used to completely cover the wristband in the tray. Two additional wristbands were suspended separately with fine wire from the chamber's inlet and outlet manifolds (Figure T-2). The chambers were sealed and air samples from the chamber exhaust were collected onto 22-mm PUF plugs at 48- to 64-hour intervals, collecting 288 L to 384 L of air per sample (100 mL/minute sampling rate). During the 7-day exposure time, three separate PUF air samples were collected consecutively to allow measurement SVOC concentrations in the chamber air across the entire experiment duration (Figure T-3). After collection, air samples collected on PUF were stored inside their collection tubes, capped and wrapped in foil inside of a zip-lock bag, under freezer conditions (-20 °C) until analysis. Silicone wristbands were transferred to certified clean, 60 mL amber jars with polytetrafluoroethylene (PTFE)-lined lids and were also stored under freezer conditions (-20 °C) until analysis.

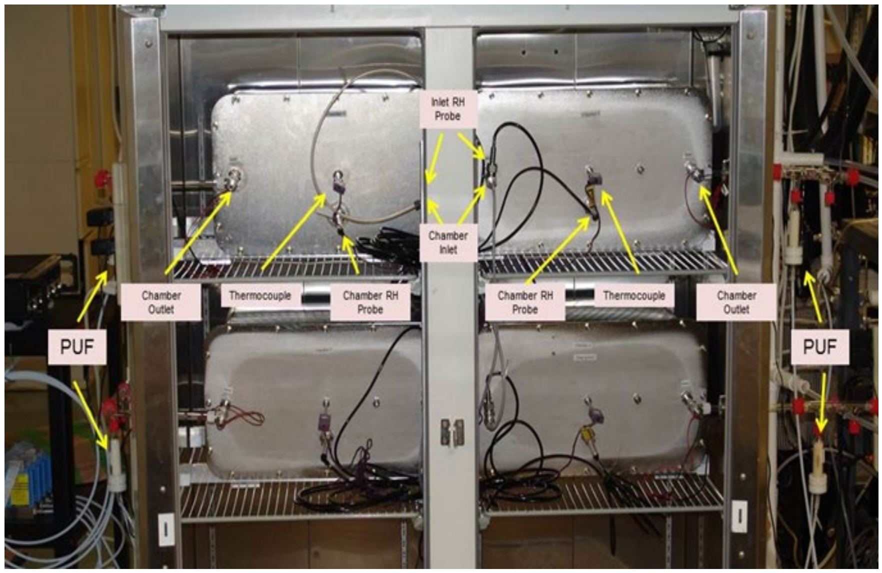

Figure T-1. 53-L test chambers 1-4 inside the incubator set up for the wristband test.

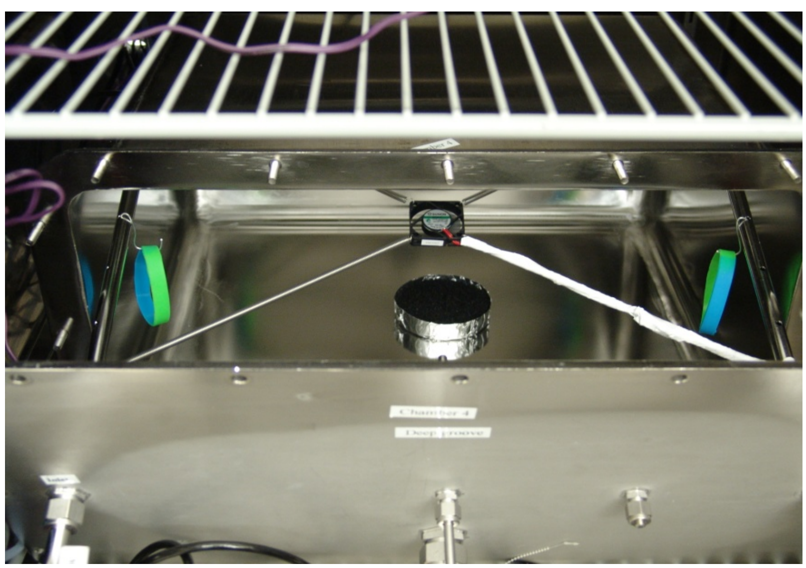

Figure T-2. Tire crumb in aluminum foil tray with 60 g of tire crumb rubber, buried wristband, and suspended wristbands in chamber prior to test start.

Figure T-3. Exhaust manifold with polyurethane foam (PUF) samplers.

Samples were extracted and analyzed using SOP D-EMMD-PHCB-036-SOP-01. Briefly, samples were extracted by sonication using 1:1 acetone:hexane. Extracts were evaporated to a final volume of 1 mL and were analyzed by GC/MS/MS in MRM mode.

T.3 Results

Measurement data from these experiments are summarized in Tables T-1 through T-4.

In order to estimate the effective sampling rates for the wristbands, the concentration found on each wristband (ng/band) was divided by the mean concentration in chamber air from the PUF samples (ng/L). The result was multiplied by 1/sampling time (hours) to give the effective sampling rate for each chemical. This was done for each experiment and results were averaged to estimate the mean effective sampling rates.

$$Effective\ Sampling\ Rate_{L/hour} = \left(\frac{Concentration_{ng/band}}{Mean\ Chamber\ Air_{ng/L}}\right) \times \left(\frac{1}{Sampling\ Time_{hours}}\right)$$

For example, the measured concentration of benzothiazole on the wristband located at the left outlet from the Field A experiment was found to be 2108 ng/band for the 161-hour sampling time. The mean air concentration from PUF samples for that experiment was found to be 1.95 ng/L.

$$Effective\ Sampling\ Rate_{L/hour} = \left(\frac{2108_{ng/band}}{1.95_{ng/L}}\right) \times \left(\frac{1}{161_{hours}}\right) = 6.72\ \text{L/hour}$$

The effective sampling rate from the right outlet was found to be 6.44 L/h, so the average for Field A was 6.58 ng/L for benzothiazole. The mean effective sampling rate was calculated using the average rates from each of the four experiments. For benzothiazole, this was calculated to be 5.1 L/h.

Once the effective sampling rate has been measured, the concentration in air per unit volume can be estimated for a wristband sample. This can be done using the following formula:

$$Estimated\ Air\ Concentration_{ng/L} = \left(\frac{Concentration_{ng/band}}{(Sampling\ Time_{hours} \times Effective\ Sampling\ Rate_{L/h})}\right)$$

As an example, using the average effective sampling rate calculated across the four experiments, the chamber air concentration of benzothiazole was estimated for the band at the left outlet in the Field A experiment:

$$Estimated\ Air\ Concentration_{ng/L} = \left(\frac{2108_{ng/band}}{(161_{hours} \times 5.1_{L/h})}\right) = 2.6_{ng/L}$$

The average air concentration found in the chamber air from the PUF samples was 1.9 ng/L, so the calculated estimate is reasonable. Estimated effective sampling rates are reported in Table T-5 for all chemicals with measurable air concentrations in at least 3 samples.

Table T-1. Wristband Testing Measurement Results for Tire Crumb Rubber Infill from Synthetic Turf Field A in Dynamic Emissions Chamber Testing[a,b]

Chemical	Tire Crumb Extract (ng/g)	Wristband Buried in Tire Crumb (ng/band)	Suspended Wristband Left Side (ng/band)	Suspended Wristband Right Side (ng/band)	Mean Wristband Blank (ng/sample)	Mean Chamber Air (ng/L)	Mean PUF Field Blank (ng/sample)
Aniline	640	640	170	150	0.3	0.3	3.3
n-Butylbenzene	0	0.80	0.3	0.3	0.4	0	0.6
Naphthalene	24	7.3	3.8	3.7	1.3	0.01	1.6
Benzothiazole	4600	3500	2100	2000	5.4	1.9	37
2-Methylnaphthalene	54	110	29	28	0.7	0.04	1.2
1-Methylnaphthalene	37	60	16	15	0.2	0.03	0.5
Dimethyl Phthalate	9.2	0.80	2.3	2.4	0.3	0	0.6
Acenaphthalene	31	42	13	13	0.4	0.01	0.4
Diethyl phthalate	26	49	64	63	14	0.07	16
Fluorene	92	150	40	38	0.1	0.01	0.4
4-tert-octylphenol	5100	3200	690	630	1.5	0.05	2.0
2-Bromomethylnaphthalene	0	140	44	39	1.4	0.01	1.5
2-Hydroxybenzothiazole	0	1600	46	40	3.8	0.03	11
Dibenzothiophene	290	210	28	28	0.2	0	0.2
Phenanthrene	2000	870	190	180	0.5	0.02	1.2
Anthracene	300	220	33	30	0	0	0
Diisobutyl phthalate	360	280	220	190	68	0.06	17
3-Methylphenanthrene	2700	770	98	93	0.9	0.01	0.9
2-Methylphenanthrene	2600	540	71	67	0	0	0
1-Methylphenanthrene	1500	480	43	39	0.9	0	0
Dibutyl phthalate	520	280	120	99	54	0.07	23
Fluoranthene	5900	540	40	35	0.2	0	0.3
Pyrene	13000	550	32	32	0.4	0	0.3
Benz(a)anthracene	2900	41	0	0.5	0	0	0

Table T-1 Continued

Chemical	Tire Crumb Extract (ng/g)	Wristband Buried in Tire Crumb (ng/band)	Suspended Wristband Left Side (ng/band)	Suspended Wristband Right Side (ng/band)	Mean Wristband Blank (ng/sample)	Mean Chamber Air (ng/L)	Mean PUF Field Blank (ng/sample)
Chrysene	2500	98	0.3	0.3	0.1	0	0.1
Di-n-octyl phthalate	45	13	4.4	0.7	1.3	0	0
Benzo(b)fluoranthene	1600	21	0.2	0.2	0.3	0	0.3
Benzo(k)fluoranthene	0	5.6	0	0	0	0	0
Benzo(e)pyrene	2000	21	0	0	0	0	0
Benzo[a]pyrene	1000	12	0.2	0.1	0.2	0	0.3
Bis(2,2,6,6-tetramethyl-4-piperidyl) sebacate	1300	32	0	0	0	0	0.1
DBA + ICDP[c]	300	4.0	0	0	0.1	0	0.3
Benzo[ghi]perylene	1600	16	0.1	0.1	0.1	0	0.3
Coronene	680	5.0	0	0	0	0	0.1

[a] ng = nanogram; PUF = polyurethane foam

[b] Wristband Blanks (n=3), Chamber Air Samples (n=3); PUF Field Blanks (n=3)

[c] DBA + ICDP = Sum of Dibenz[a,h]anthracene and Indeno(1,2,3-cd)pyrene

Table T-2. Wristband Testing Measurement Results for Tire Crumb Rubber Infill from Synthetic Turf Field B in Dynamic Emissions Chamber Testing[a,b]

Chemical	Tire Crumb Extract (ng/g)	Wristband Buried in Tire Crumb (ng/band)	Suspended Wristband Left Side (ng/band)	Suspended Wristband Right Side (ng/band)	Mean Wristband Blank (ng/sample)	Mean Chamber Air (ng/L)	Mean PUF Field Blank (ng/sample)
Aniline	1950	1900	810	860	0.3	1.7	3.3
n-Butylbenzene	0	22	0	0	0.4	0	0.6
Naphthalene	115	98	17	19	1.3	0.06	1.6
Benzothiazole	14000	3800	3400	3400	5.4	6.3	37
2-Methylnaphthalene	650	620	210	220	0.7	0.3	1.2
1-Methylnaphthalene	540	510	140	140	0.2	0.2	0.5
Dimethyl Phthalate	110	80	18	18	0.3	0	0.6
Acenaphthalene	240	200	69	69	0.4	0.04	0.4
Diethyl phthalate	180	320	93	88	14	0.06	16
Fluorene	1400	570	300	310	0.1	0.05	0.4
4-tert-octylphenol	16000	3900	2000	1700	1.5	0.1	2
2-Bromomethylnaphthalene	0	370	95	98	1.4	0.02	1.5
2-Hydroxybenzothiazole	0	3500	280	210	3.8	0.03	11
Dibenzothiophene	1500	590	83	83	0.2	0.01	0.2
Phenanthrene	8100	1500	510	510	0.5	0.04	1.2
Anthracene	2600	850	87	80	0	0.01	0
Diisobutyl phthalate	6400	760	360	330	68	0.05	17
3-Methylphenanthrene	7200	1300	230	220	0.9	0.01	0.9
2-Methylphenanthrene	10000	840	170	160	0	0.01	0
1-Methylphenanthrene	4700	790	77	71	0.9	0	0

Table T-2 Continued

Chemical	Tire Crumb Extract (ng/g)	Wristband Buried in Tire Crumb (ng/band)	Suspended Wristband Left Side (ng/band)	Suspended Wristband Right Side (ng/band)	Mean Wristband Blank (ng/sample)	Mean Chamber Air (ng/L)	Mean PUF Field Blank (ng/sample)
Dibutyl phthalate	2700	490	150	120	54	0.06	23
Fluoranthene	9900	480	50	57	0.2	0	0.3
Pyrene	26000	680	77	76	0.4	0	0.3
Benz(a)anthracene	5300	61	0.1	0.2	0	0	0
Chrysene	5400	180	0.8	0.7	0.07	0	0.1
Di-n-octyl phthalate	180	10	1.3	1.2	1.3	0	0
Benzo(b)fluoranthene	2800	34	0.2	0.2	0.3	0	0.3
Benzo(k)fluoranthene	910	14	0	0	0	0	0
Benzo(e)pyrene	3200	39	0	0	0	0	0
Benzo[a]pyrene	2100	30	0.3	0.2	0.2	0	0.3
Bis(2,2,6,6-tetramethyl-4-piperidyl) sebacate	1700	51	0	0	0	0	0.1
DBA + ICDP[c]	790	6.7	0	0.1	0.1	0	0.3
Benzo[ghi]perylene	2500	25	0.2	0.1	0.1	0	0.3
Coronene	1400	7.8	0	0	0	0	0.1

[a] ng = nanogram; PUF = polyurethane foam

[b] Wristband Blanks (n=3), Chamber Air Samples (n=3); PUF Field Blanks (n=3)

[c] DBA + ICDP = Sum of Dibenz[a,h]anthracene and Indeno(1,2,3-cd)pyrene

Table T-3. Wristband Testing Measurement Results for Tire Crumb Rubber Infill from Synthetic Turf Field C in Dynamic Emissions Chamber Testing[a,b]

Chemical	Tire Crumb Extract (ng/g)	Wristband Buried in Tire Crumb (ng/band)	Suspended Wristband Left Side (ng/band)	Suspended Wristband Right Side (ng/band)	Mean Wristband Blank (ng/sample)	Mean Chamber Air (ng/L)	Mean PUF Field Blank (ng/sample)
Aniline	1100	970	370	310	0.3	0.5	3.3
n-Butylbenzene	0	2.1	0.6	0.6	0.4	0	0.6
Naphthalene	37	17	4.9	5.2	1.3	0.02	1.6
Benzothiazole	7500	3600	2600	2300	5.4	2.1	37
Cyclohexylisothiocyanate	650	140	38	200	67	1.2	90
2-Methylnaphthalene	110	110	28	28	0.7	0.04	1.2
1-Methylnaphthalene	95	89	21	21	0.2	0.04	0.5
Dimethyl Phthalate	18	50	16	14	0.3	0	0.6
Acenaphthalene	100	69	27	27	0.4	0.01	0.4
Diethyl phthalate	170	350	120	120	14	0.06	16
Fluorene	790	420	190	180	0.1	0.03	0.4
4-tert-octylphenol	16000	3300	1100	1000	1.5	0.06	2.0
2-Bromomethylnaphthalene	0	230	72	68	1.4	0.01	1.5
2-Hydroxybenzothiazole	10000	2700	140	180	3.8	0.02	11
Dibenzothiophene	840	390	66	65	0.2	0	0.2
Phenanthrene	7000	1200	460	450	0.5	0.03	1.2

Table T-3 Continued

Chemical	Tire Crumb Extract (ng/g)	Wristband Buried in Tire Crumb (ng/band)	Suspended Wristband Left Side (ng/band)	Suspended Wristband Right Side (ng/band)	Mean Wristband Blank (ng/sample)	Mean Chamber Air (ng/L)	Mean PUF Field Blank (ng/sample)
Anthracene	1700	440	53	54	0	0	0
Diisobutyl phthalate	6200	620	300	300	68	0.05	17
3-Methylphenanthrene	4700	900	120	130	0.9	0.01	0.9
2-Methylphenanthrene	3000	610	84	86	0	0	0
1-Methylphenanthrene	2900	550	54	54	0.9	0	0
Dibutyl phthalate	8600	640	150	170	54	0.07	23
Fluoranthene	8000	420	49	58	0.2	0	0.3
Pyrene	19000	550	74	70	0.4	0	0.3
Benz(a)anthracene	2900	24	0	0.5	0	0	0
Chrysene	1800	51	0.5	0.5	0.07	0	0.1
Di-n-octyl phthalate	1200	8.5	0.3	4.9	1.3	0	0
Benzo(b)fluoranthene	1000	14	0.3	0.2	0.3	0	0.3
Benzo(k)fluoranthene	440	3.1	0	0	0	0	0
Benzo(e)pyrene	1900	14	0	0	0	0	0
Benzo[a]pyrene	460	10	0.1	0.1	0.2	0	0.3
Bis(2,2,6,6-tetramethyl-4-piperidyl) sebacate	520	5.4	0	0	0	0	0.1
DBA + ICDP[c]	570	3.7	0.1	0.1	0.1	0	0.3
Benzo[ghi]perylene	1600	13	0.1	0.1	0.1	0	0.3
Coronene	410	3	0	0	0	0	0.1

[a] ng = nanogram; PUF = polyurethane foam

[b] Wristband Blanks (n=3), Chamber Air Samples (n=3); PUF Field Blanks (n=3)

[c] DBA + ICDP = Sum of Dibenz[a,h]anthracene and Indeno(1,2,3-cd)pyrene

Table T-4. Wristband Testing Measurement Results for Tire Crumb Rubber from Recycling Plant Z in Dynamic Emissions Chamber Testing[a,b]

Chemical	Tire Crumb Extract (ng/g)	Wristband Buried in Tire Crumb (ng/band)	Suspended Wristband Left Side (ng/band)	Suspended Wristband Right Side (ng/band)	Mean Wristband Blank (ng/sample)	Mean Chamber Air (ng/L)	Mean PUF Field Blank (ng/sample)
Aniline	2160	760	880	800	0.3	1.7	3.3
n-Butylbenzene	0	52	6.6	9.0	0.4	0	0.6
Naphthalene	510	360	68	81	1.3	0.3	1.6
Benzothiazole	83000	5700	4700	4100	5.4	8.0	37
2-Methylnaphthalene	300	460	100	100	0.7	0.2	1.2
1-Methylnaphthalene	220	300	62	62	0.2	0.1	0.5
Dimethyl Phthalate	55	20	6.4	5.9	0.3	0	0.6
Acenaphthalene	600	490	170	170	0.4	0.1	0.4
Diethyl phthalate	32	79	80	69	14	0.05	16
Fluorene	240	260	61	59	0.1	0.01	0.4

Table T-4 Continued

Chemical	Tire Crumb Extract (ng/g)	Wristband Buried in Tire Crumb (ng/band)	Suspended Wristband Left Side (ng/band)	Suspended Wristband Right Side (ng/band)	Mean Wristband Blank (ng/sample)	Mean Chamber Air (ng/L)	Mean PUF Field Blank (ng/sample)
4-tert-octylphenol	26000	4200	2200	2100	1.5	0.1	2
2-Bromomethylnaphthalene	0	320	68	58	1.4	0.01	1.5
2-Hydroxybenzothiazole	28000	3600	180	140	3.8	0.02	11
Dibenzothiophene	280	120	21	20	0.2	0	0.2
Phenanthrene	2200	840	120	120	0.5	0.01	1.2
Anthracene	330	170	18	16	0	0	0
Diisobutyl phthalate	270	160	260	260	68	0.05	17
3-Methylphenanthrene	1000	400	46	44	0.9	0	0.9
2-Methylphenanthrene	940	360	29	28	0	0	0
1-Methylphenanthrene	660	260	21	20	0.9	0	0
Dibutyl phthalate	400	190	140	130	54	0.05	23
Fluoranthene	4300	350	18	18	0.2	0	0.3
Pyrene	15000	280	47	17	0.4	0	0.3
Benz(a)anthracene	510	20	0	0	0	0	0
Chrysene	2300	42	0.3	0.3	0.07	0	0.1
Di-n-octyl phthalate	180	8.4	0.6	2.6	1.3	0	0
Benzo(b)fluoranthene	670	12	0.2	0.2	0.3	0	0.3
Benzo(k)fluoranthene	340	2.1	0	0	0	0	0
Benzo(e)pyrene	860	16	0	0	0	0	0
Benzo[a]pyrene	320	9.2	0.1	0.1	0.2	0	0.3
Bis(2,2,6,6-tetramethyl-4-piperidyl) sebacate	160	84	0	0	0	0	0.1
DBA + ICDP[c]	230	2.2	0.1	0	0.1	0	0.3
Benzo[ghi]perylene	620	23	0.1	0.1	0.1	0	0.3
Coronene	220	5.7	0	0	0	0	0.1

[a] ng = nanogram; PUF = polyurethane foam

[b] Wristband Blanks (n=3), Chamber Air Samples (n=3); PUF Field Blanks (n=3)

[c] DBA + ICDP = Sum of Dibenz[a,h]anthracene and Indeno(1,2,3-cd)pyrene

Table T-5. Estimated Silicone Wristband Effective Sampling Rates (L/h) for SVOCs Emitted from Tire Crumb Rubber in Controlled Dynamic Chamber Testing[a]

Chemical	Field A (L/h)	Field B (L/h)	Field C (L/h)	Recycling Plant D (L/h)	Mean (L/h)	Standard Deviation (L/h)	% Relative Standard Deviation
Aniline	3.1	3.0	4.1	3.1	3.3	0.44	13
Naphthalene	2.3	1.9	1.6	1.7	1.9	0.28	15
Benzothiazole	6.6	3.3	7.1	3.4	5.1	1.7	34
2-Methylnaphthalene	4.4	3.6	4.3	3.6	4.0	0.39	9.8
1-Methylnaphthalene	3.2	3.3	3.3	3.2	3.2	0.03	0.9
Acenaphthalene	7.9	11	17	10	11	3.3	29
Diethyl phthalate	5.7	9.4	13	9.3	9.2	2.5	27
Fluorene	24	38	38	37	34	5.8	17
4-tert-octylphenol	82	82	110	88	91	13	14
2-Bromomethylnaphthalene	26	30	44	39	35	7.2	21
2-Hydroxybenzothiazole	8.9	51	50	50	40	18	45
Phenanthrene	58	80	95	76	77	13	17
Diisobutyl phthalate	21	43	37	32	33	7.8	23
3-Methylphenanthrene	59	140	78	ND	92	33	36
Dibutyl phthalate	9.8	14	14	17	13	2.6	19

[a] Results only reported for chemicals with measurable chamber air concentrations in at least three samples.

T.4 References

D-EMMD-PHCB-029-SOP-01, Standard Operating Procedure (SOP) for the Collection of Personal Exposure Samples Using Silicone Bands

D-EMMD-PHCB-036-SOP-01, Standard Operating Procedure for Preparation of Air Samples Collected on PUF Plugs for GC/MS Analysis

Appendix U

Toxicity Reference Information

Chemical Constituent[a]	Synonym[b]	CAS Number[c]	EPA IRIS[1] RfD (mg/kg-day)	EPA IRIS RfC (mg/m^3)	EPA IRIS Cancer Classification	EPA IRIS Oral SF ($mg/kg\text{-}day^{-1}$)	EPA IRIS Dr. Water UR (ug/L^{-1})	EPA IRIS UR ($ug/m^{3\text{-}1}$)
Aluminum	N/A	7429-90-5	N/A	N/A	N/A	N/A	N/A	N/A
Antimony	N/A	7440-36-0	4.00E-04	N/A	N/A	N/A	N/A	N/A
Arsenic	N/A	7440-38-2	3.00E-04	N/A	A	1.5	5.00E-05	4.30E-03
Barium	N/A	7440-39-3	2.00E-01	N/A	D	N/A	N/A	N/A
Beryllium	N/A	7440-41-7	2.00E-03	2.00E-05	B1	N/A	N/A	2.40E-03
Cadmium	N/A	7440-43-9	5E-4 (water) 1E-3 (food)	N/A	B1	N/A	N/A	1.80E-03
Calcium	N/A	7440-70-2	N/A	N/A	N/A	N/A	N/A	N/A
Chloride	N/A	16887-00-6	N/A	N/A	N/A	N/A	N/A	N/A
Chromium	N/A	7440-47-3; 16065-83-1 (CrIII); 18540-29-9 (CrVI)	1.5 (CrIII) 3E-3 (CrVI)	8E-6 (CrVI mists) 1E-4 (CrVI partic.)	D (CrIII) A (CrVI-inhal.) D (CrVI-oral)	N/A	N/A	1.2E-2 (CrVI)
Cobalt	N/A	7440-48-4	N/A	N/A	N/A	N/A	N/A	N/A
Copper	N/A	7440-50-8	N/A	N/A	D	N/A	N/A	N/A
Iron	N/A	7439-89-6	N/A	N/A	N/A	N/A	N/A	N/A
Lead	N/A	7439-92-1	N/A	N/A	B2	N/A	N/A	N/A
Lithium	N/A	7439-93-2	N/A	N/A	N/A	N/A	N/A	N/A
Magnesium	N/A	7439-95-4	N/A	N/A	N/A	N/A	N/A	N/A
Manganese	N/A	7439-96-5	1.40E-01	5.00E-05	D	N/A	N/A	N/A
Mercury	N/A	7439-97-6	N/A	3.00E-04	D	N/A	N/A	N/A
Molybdenum	N/A	7439-98-7	5.00E-03	N/A	N/A	N/A	N/A	N/A
Nickel	N/A	7440-02-0	2.00E-02	N/A	N/A	N/A	N/A	N/A
Phosphorous	N/A	7723-14-0	N/A	N/A	N/A	N/A	N/A	N/A
Potassium	N/A	7440-09-7	N/A	N/A	N/A	N/A	N/A	N/A
Rubidium	N/A	7440-17-7	N/A	N/A	N/A	N/A	N/A	N/A
Selenium	N/A	7782-49-2	5.00E-03	N/A	D	N/A	N/A	N/A
Silver	N/A	7440-22-4	5.00E-03	N/A	D	N/A	N/A	N/A
Sodium	N/A	7440-23-5	N/A	N/A	N/A	N/A	N/A	N/A
Strontium	N/A	7440-24-6	6.00E-01	N/A	N/A	N/A	N/A	N/A
Sulfur	N/A	7704-34-9	N/A	N/A	N/A	N/A	N/A	N/A
Thallium	N/A	7440-28-0	N/A	N/A	N/A	N/A	N/A	N/A
Tin	N/A	7440-31-5	N/A	N/A	N/A	N/A	N/A	N/A
Titanium	N/A	7440-32-6	N/A	N/A	N/A	N/A	N/A	N/A
Tungsten	N/A	7440-33-7	N/A	N/A	N/A	N/A	N/A	N/A
Vanadium	N/A	7440-62-2	N/A	N/A	N/A	N/A	N/A	N/A
Zinc	N/A	7440-66-6	3.00E-01	N/A	D	N/A	N/A	N/A
Cadmium and Zinc Soaps	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Acenaphthene	N/A	83-32-9	6.00E-02	N/A	N/A	N/A	N/A	N/A
Acenaphthylene	N/A	208-96-8	N/A	N/A	D	N/A	N/A	N/A
Acetaldehyde	Ethanone	75-07-0	N/A	9.00E-03	B2	N/A	N/A	2.20E-06

Chemical Constituent[a]	Synonym[b]	CAS Number[c]	EPA IRIS[1] RfD (mg/kg-day)	EPA IRIS RfC (mg/m^3)	EPA IRIS Cancer Classification	EPA IRIS Oral SF ($mg/kg\text{-}day^{-1}$)	EPA IRIS Dr. Water UR (ug/L^{-1})	EPA IRIS UR ($ug/m^{3\text{-}1}$)
Acetamide, N-cyclohexyl-	N/A	1124-53-4	N/A	N/A	N/A	N/A	N/A	N/A
Acetone	N/A	67-64-1	9.00E-01	N/A	N/A	N/A	N/A	N/A
Acetone-diphenylamine condensation product (ADPA)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Acetonitrile	N/A	75-05-8	N/A	6.00E-02	D	N/A	N/A	N/A
Acetophenone	N/A	98-86-2	1.00E-01	N/A	D	N/A	N/A	N/A
6-Acetoxy-2,2-dimethyl-m-dioxane	Dimethoxane	828-00-2	N/A	N/A	N/A	N/A	N/A	N/A
Acrolein	N/A	107-02-8	5.00E-04	2.00E-05	N/A	N/A	N/A	N/A
Alcohols	Ethanol	64-17-5	N/A	N/A	N/A	N/A	N/A	N/A
Aldehydes	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Alkyl benzenes	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Alkyl dithiols	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Alkyl naphthalenes	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Alkyl phenols	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Alpha pinene	alpha-Pinene	80-56-8	N/A	N/A	N/A	N/A	N/A	N/A
Amine (N-dialkyl analine derivative)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Amines	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Anathrene [c]	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Aniline	Benzeneamine; aminobenzene	62-53-3	N/A	1.00E-03	B2	5.70E-03	1.60E-07	N/A
Anthanthrene	N/A	191-26-4	N/A	N/A	N/A	N/A	N/A	N/A
Anthracene	N/A	120-12-7	3.00E-01	N/A	D	N/A	N/A	N/A
Aromatic oil	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9,10-Anthracenedione, 2-ethyl	2-Ethylanthracene-9,10-dione	84-51-5	N/A	N/A	N/A	N/A	N/A	N/A
Azobenzene	N/A	103-33-3	N/A	N/A	B2	1.10E-01	3.10E-06	3.10E-05
Benz(e)acenaphthylene	Acephenanthrylene	201-06-9	N/A	N/A	N/A	N/A	N/A	N/A
Benzaldehyde, 3-hydroxyl-4-methoxy	3-Hydroxy-4-methoxy-benzaldehyde	621-59-0	N/A	N/A	N/A	N/A	N/A	N/A
Benz(a)anthracene	N/A	56-55-3	N/A	N/A	B2	N/A	N/A	N/A
Benzene	N/A	71-43-2	4.00E-03	3.00E-02	A	1.50E-02 to 5.50E-02	4.40E-07 to 1.60E-06	2.20E-06 to 7.80E-05
Benzene, 1,3-bis(1-methylethenyl)-	1,3-bis(1-methylethenyl)benzene; 1,3-Diisopropenylbenzene	3748-13-8	N/A	N/A	N/A	N/A	N/A	N/A
Benzene, 1,4-bis(1-methylethenyl)-	1,4-Bis(1-methylethenyl)benzene	1605-18-1	N/A	N/A	N/A	N/A	N/A	N/A
1,4-Benzenediamine, N,N'-diphenyl-	N,N'-Diphenyl-p-phenylenediamine	74-31-7	N/A	N/A	N/A	N/A	N/A	N/A
1,4-Benzendiamin, N-(1-methylethyl)-N'-phenyl-, (IPPD)	N-Isopropyl-N'-phenyl-p-phenylenediamine, Isopropylaminodephenylamine (IPPD)	101-72-4	N/A	N/A	N/A	N/A	N/A	N/A
Benzene, isocyanato-	Phenyl isocyanate	103-71-9	N/A	N/A	N/A	N/A	N/A	N/A
Benzenemethanol	Benzyl alcohol	100-51-6	N/A	N/A	N/A	N/A	N/A	N/A
Benzo(def)dibenzothiophene	Phenanthro[4,5-bcd]thiophene	30796-92-0	N/A	N/A	N/A	N/A	N/A	N/A
Benzo(g)dibenzothiophene	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Benzo(b)fluoranthene	N/A	205-99-2	N/A	N/A	B2	N/A	N/A	N/A
Benzo(bjk)fluoranthene	2,11-(Metheno)benzo[a]fluorene	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Benzo(ghi)fluoranthene	Benzo[ghi]fluoranthene	203-12-3	N/A	N/A	N/A	N/A	N/A	N/A
Benzo(i)fluoranthene	Benzo(j)fluoranthene	205-82-3	N/A	N/A	N/A	N/A	N/A	N/A
Benzo(k)fluoranthene	N/A	207-08-9	N/A	N/A	B2	N/A	N/A	N/A
Benzo(mno)fluoranthene	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Benzo(a)fluorene	11H-Benzo[a]fluorene	238-84-6	N/A	N/A	N/A	N/A	N/A	N/A
Benzo(b)fluorene	2,3-Benzofluorene	243-17-4	N/A	N/A	N/A	N/A	N/A	N/A
Benzo(def)naphthobenzothiophene	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6H-Benzo[cd]pyren-6-one	6H-Benzo(cd)pyren-6-one	3074-00-8	N/A	N/A	N/A	N/A	N/A	N/A
Benzo(a)pyrene	N/A	50-32-8	N/A	N/A	B2	7.3	2.10E-04	N/A
Benzo(e)pyrene	N/A	192-97-2	N/A	N/A	N/A	N/A	N/A	N/A
Benzo(ghi)perylene	Benzo(g,h,i)perylene	191-24-2	N/A	N/A	D	N/A	N/A	N/A

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Benzoic acid	N/A	65-85-0	4	N/A	D	N/A	N/A	N/A
Benzothiazole	N/A	95-16-9	N/A	N/A	N/A	N/A	N/A	N/A
Benzothiazole, 2-(methylthio)	2-(Methylthio)benzothiazole	615-22-5	N/A	N/A	N/A	N/A	N/A	N/A
Benzothiazole, 2-phenyl	2-Phenylbenzothiazole	883-93-2	N/A	N/A	N/A	N/A	N/A	N/A
Benzothiazolone	2-Hydroxybenzothiazole, 2(3H)-Benzothiazolone, 2(3H) benzothiazolone	934-34-9	N/A	N/A	N/A	N/A	N/A	N/A
Benzoyl and other peroxides	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Benzylbutyl phthalate	Butyl benzyl phthalate	85-68-7	2.00E-01	N/A	C	N/A	N/A	N/A
Biphenyl	1,1'-Biphenyl	92-52-4	5.00E-01	N/A	N/A	8.00E-03	2.30E-07	N/A
1,1'-Biphenyl, 4, 4', 5', 6'-tetramethoxy-	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
(N,N`-Bis(1,4-dimethylpentyl) pphenylendiamine) (7PPD)	N,N'-Bis(1,4-dimethylpentyl)-4-phenylenediamine	3081-14-9	N/A	N/A	N/A	N/A	N/A	N/A
Bis(2-ethylhexyl) phthalate	Di(2-ethylhexyl) phthalate	117-81-7	2.00E-02	N/A	B2	1.40E-02	4.00E-07	N/A
Bis-(2,2,6,6-tetramethyl-4-piperidinyl)sebacate	Bis(2,2,6,6-tetramethyl-4-piperidyl) sebacate	52829-07-9	N/A	N/A	N/A	N/A	N/A	N/A
Bisthiol acids	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Black rubber	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Bromodichloromethane	N/A	75-27-4	2.00E-02	N/A	B2	6.20E-02	1.80E-06	N/A
Bromoform	N/A	75-25-2	2.00E-02	N/A	B2	7.90E-03	2.30E-07	1.10E-06
1,3 Butadiene	N/A	106-99-0	N/A	2.00E-03	Carcinogenic to humans	N/A	N/A	3.00E-05
Butoxyethoxyethanol	2-(2-Butoxyethoxy)ethanol, diethylene glycol monobutyl ether	112-34-5	N/A	N/A	N/A	N/A	N/A	N/A
Butylated hydroxyanisole	N/A	25013-16-5	N/A	N/A	N/A	N/A	N/A	N/A
Butylated hydroxytoluene	2,6-Di-tert-butyl-4-methylphenol (BHT)	128-37-0	N/A	N/A	N/A	N/A	N/A	N/A
Butylbenzene	N/A	104-51-8	N/A	N/A	N/A	N/A	N/A	N/A
Caprolactam disulfide (CLD)	1,1'-Disulfanediyldiazepan-2-one	23847-08-7	N/A	N/A	N/A	N/A	N/A	N/A
Carbazole	N/A	86-74-8	N/A	N/A	N/A	N/A	N/A	N/A
Carbon Black	Furnace Black	1333-86-4	N/A	N/A	N/A	N/A	N/A	N/A
Carbon Disulfide	N/A	75-15-0	1.00E-01	7.00E-01	N/A	N/A	N/A	N/A
Carbon Tetrachloride	N/A	56-23-5	4.00E-03	1.00E-01	N/A	7.00E-02	2.00E-06	6.00E-06
Chlorobenzene	N/A	108-90-7	2.00E-02	N/A	D	N/A	N/A	N/A
Chloroform	Trichloromethane	67-66-3	1.00E-02	N/A	B2	1.00E-02	N/A	2.30E-05
Chloromethane	Methyl chloride	74-87-3	N/A	9.00E-02	D	N/A	N/A	N/A
Chrysene	N/A	218-01-9	N/A	N/A	B2	N/A	N/A	N/A
Coronene	N/A	191-07-1	N/A	N/A	N/A	N/A	N/A	N/A
o-Cyanobenzoic acid	2-Cyanobenzoic acid	3839-22-3	N/A	N/A	N/A	N/A	N/A	N/A
Cyclohexanamine	Cyclohexylamine	108-91-8	2.00E-01	N/A	N/A	N/A	N/A	N/A
Cyclohexanamine, N-cyclohexyl-	Dicyclohexylamine	101-83-7	N/A	N/A	N/A	N/A	N/A	N/A
Cyclohexanamine, N-cyclohexyl-N-methyl-	N-Cyclohexyl-N-methylcyclohexanamine	7560-83-0	N/A	N/A	N/A	N/A	N/A	N/A
Cyclohexane	N/A	110-82-7	N/A	6	N/A	N/A	N/A	N/A
Cyclohexane, isocyanato	Isocyanatocyclohexane	3173-53-3	N/A	N/A	N/A	N/A	N/A	N/A
Cyclohexane, isothiocyanato-	N/A	1122-82-3	N/A	N/A	N/A	N/A	N/A	N/A

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Cyclohexanone	N/A	108-94-1	5	N/A	N/A	N/A	N/A	N/A
N-Cyclohexyl-2-benzothiazolesulfenamide (CBS)	N-Cyclohexyl-2-benzothiazolesulfenamide	95-33-0	N/A	N/A	N/A	N/A	N/A	N/A
n-Cyclohexyl-formamide	N-Cyclohexylformamide, Formamide, N-cyclohexyl	766-93-8	N/A	N/A	N/A	N/A	N/A	N/A
Cycloninasiloxane, octadecamethyl-	Octadecamethylcyclononasiloxane	556-71-8	N/A	N/A	N/A	N/A	N/A	N/A
Cyclopenta[cd]pyrene	N/A	27208-37-3	N/A	N/A	N/A	N/A	N/A	N/A
4H-cyclopenta[def]phenanthren-4-one	4H-Cyclopenta(def)phenanthren-4-one	5737-13-3	N/A	N/A	N/A	N/A	N/A	N/A
4H-cyclopenta[def]-phenanthrene	4-H-Cyclopenta(d,e,f)phenanthrene	203-64-5	N/A	N/A	N/A	N/A	N/A	N/A
Cyclopentane, methyl-	Methylcyclopentane	96-37-7	N/A	N/A	N/A	N/A	N/A	N/A
Decane	N/A	124-18-5	N/A	N/A	N/A	N/A	N/A	N/A
Diazoaminobenzenes	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Dibenzo(a,h) anthracene	Dibenz(a,h)anthracene	53-70-3	N/A	N/A	B2	N/A	N/A	N/A
Dibenzofurane	Dibenzofuran	132-64-9	N/A	N/A	D	N/A	N/A	N/A
Dibenzo(ae)pyrene	Naphtho(1,2,3,4-def)chrysene	192-65-4	N/A	N/A	N/A	N/A	N/A	N/A
Dibenzo(ai)pyrene	Dibenzo[a,i]pyrene	189-55-9	N/A	N/A	N/A	N/A	N/A	N/A
Dibenzo(ah)pyrene	Dibenzo[a,h]pyrene	189-64-0	N/A	N/A	N/A	N/A	N/A	N/A
Dibenzothiophene	N/A	132-65-0	N/A	N/A	N/A	N/A	N/A	N/A
Dibutyl phthalate	N/A	84-74-2	1.00E-01	N/A	D	N/A	N/A	N/A
1,4-Dichlorobenzene	p-dichlorobenzene	106-46-7	N/A	8.00E-01	N/A	N/A	N/A	N/A
Dichlorodifluoromethane	Freon 12	75-71-8	2.00E-01	N/A	N/A	N/A	N/A	N/A
1,2-Dichloroethane	Ethylene dichloride	107-06-2	N/A	N/A	B	9.10E-02	2.60E-06	2.60E-05
cis-1,2-Dichloroethene	(Z)-1,2-Dichloroethylene	156-59-2	2.00E-03	N/A	N/A	N/A	N/A	N/A
1,2-Dichloropropane	N/A	78-87-5	N/A	4.00E-03	N/A	N/A	N/A	N/A
N,N-Dicyclohexyl-2-benzothiazolesulfenamide (DCBS)	N,N-Dicyclohexyl-2-benzothiazolesulfenamide	4979-32-2	N/A	N/A	N/A	N/A	N/A	N/A
Dicyclohexylphthalate (DCHP)	Dicyclohexyl phthalate	84-61-7	N/A	N/A	N/A	N/A	N/A	N/A
1,3-Dicyclohexylurea	N,N'-Dicyclohexylurea	2387-23-7	N/A	N/A	N/A	N/A	N/A	N/A
Diethenylbenzene	Divinylbenzene	1321-74-0	N/A	N/A	N/A	N/A	N/A	N/A
Di(2-ethylhexyl) adipate	Hexanedioic acid, bis(2-ehtylhexyl); Bis(2-ethylhexyl)hexanedioic acid	103-23-1	6.00E-01	N/A	C	1.20E-03	3.40E-08	N/A
Diethyl phthalate	N/A	84-66-2	8.00E-01	N/A	D	N/A	N/A	N/A
Diethylthiourea (DETU)	N,N'-Diethylthiourea	105-55-5	N/A	N/A	N/A	N/A	N/A	N/A
Dihydrocyclopentapyrene	2,3-Acepyrene	25732-74-5	N/A	N/A	N/A	N/A	N/A	N/A
Diisobutyl phthalate	N/A	84-69-5	N/A	N/A	N/A	N/A	N/A	N/A
Diisodecylphthalate	bis(8-Methylnonyl) phthalate	89-16-7	N/A	N/A	N/A	N/A	N/A	N/A
Diisononyl phthalate	DINP	28553-12-0	N/A	N/A	N/A	N/A	N/A	N/A
9,l0-Dimethyl-1,2-Benzanthracene	7,12-Dimethylbenz(a)anthracene	57-97-6	N/A	N/A	N/A	N/A	N/A	N/A
(N-1,3-dimethyl-butyl)-N'- phenyl-p-phenylenediamine (6PPD)	N-(1,3-Dimethylbutyl)-N'-phenyl-p-phenylenediamine	793-24-8	N/A	N/A	N/A	N/A	N/A	N/A
Dimethyldiphenylthiuram disulfide (MPTD)	Dimethyldiphenylthiuram disulfide	53880-86-7	N/A	N/A	N/A	N/A	N/A	N/A
2,6-Dimethylnaphthalene	N/A	581-42-0	N/A	N/A	N/A	N/A	N/A	N/A
2,4-Dimethylphenol	N/A	105-67-9	2.00E-02	N/A	N/A	N/A	N/A	N/A
Dimethyl phthalate	N/A	131-11-3	N/A	N/A	D	N/A	N/A	N/A
Dinitroarenes	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Di-n-octyl phthalate	Dioctyl phthalate	117-84-0	N/A	N/A	N/A	N/A	N/A	N/A
Di-ortho-tolylguanidine	N/A	97-39-2	N/A	N/A	N/A	N/A	N/A	N/A
Dipentamethylenethiuramtetrasulfide (DPTT)	Bis(pentamethylenethiuram)tetrasulfide	120-54-7	N/A	N/A	N/A	N/A	N/A	N/A
Diphenylamine	N/A	122-39-4	2.50E-02	N/A	N/A	N/A	N/A	N/A
N,N'-Diphenylguanidine (DPG)	1,3-Diphenylguanidine	102-06-7	N/A	N/A	N/A	N/A	N/A	N/A
N,N'-Diphenyl-p-phenylenediamine (DPPD)	N,N'-Diphenyl-p-phenylenediamine	74-31-7	N/A	N/A	N/A	N/A	N/A	N/A
Disulfides	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Di-(2-ethyl)hexylphosphorylpolysulfide (SDT)	Bis-(ethylhexylthiophosphoryl) polysulfide	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Chemical Constituent[a]	Synonym[b]	CAS Number[c]	EPA IRIS[1] RfD (mg/kg-day)	EPA IRIS RfC (mg/m^3)	EPA IRIS Cancer Classification	EPA IRIS Oral SF (mg/kg-day^{-1})	EPA IRIS Dr. Water UR (ug/L^{-1})	EPA IRIS UR (ug/m$^{3-1}$)
3,5-Di-tert-Butyl-4-hydroxybenzaldehyde	N/A	1620-98-0	N/A	N/A	N/A	N/A	N/A	N/A
2,2'-Dithiobis(benzothiazole)	2,2'-Dithiobisbenzothiazole	120-78-5	N/A	N/A	N/A	N/A	N/A	N/A
Dithiocarbamates	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Dithiomorpholine (DTDM)	4,4'-Dithiodimorpholine	103-34-4	N/A	N/A	N/A	N/A	N/A	N/A
Dithiophosphates	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
N,N`-Ditolyl-p-phenylenediamine (DTPD)	N,N'-Ditolyl-p-phenylenediamine	27417-40-9	N/A	N/A	N/A	N/A	N/A	N/A
Docosanoic acid	N/A	112-85-6	N/A	N/A	N/A	N/A	N/A	N/A
Dodecanoic acid	N/A	143-07-7	N/A	N/A	N/A	N/A	N/A	N/A
Dotriacontane	N/A	544-85-4	N/A	N/A	N/A	N/A	N/A	N/A
Drometrizol	2-(2H-Benzotriazol-2-yl)-4-methylphenol	2440-22-4	N/A	N/A	N/A	N/A	N/A	N/A
Eicosane	N/A	112-95-8	N/A	N/A	N/A	N/A	N/A	N/A
Erucylamide	Erucamide	112-84-5	N/A	N/A	N/A	N/A	N/A	N/A
Esters	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Ethanol, 2-butoxy-	2-Butoxyethanol	111-76-2	1.00E-01	1.6	N/A	N/A	N/A	N/A
Ethanol, 1-(2-butoxyethoxy)	1-(2-Butoxyethoxy)ethanol	54446-78-5	N/A	N/A	N/A	N/A	N/A	N/A
Ethanone, 1,1'-(1,3-phenylene)bis-	Benzene-1,3-bis(acetyl)	6781-42-6	N/A	N/A	N/A	N/A	N/A	N/A
Ethanone, 1,1'-(1,4-phenylene)bis-	1,1-(1,4-Phenylene)bis-ethanone	1009-61-6	N/A	N/A	N/A	N/A	N/A	N/A
Ethanone, 1-[4-(1-methylethenyl) phenyl]-	1-[4-(1-Methylethenyl)phenyl]ethanone	5359-04-6	N/A	N/A	N/A	N/A	N/A	N/A
Ethyl Acetate	N/A	141-78-6	9.00E-01	N/A	N/A	N/A	N/A	N/A
Ethyl benzene	Ethylbenzene	100-41-4	1.00E-01	1	D	N/A	N/A	N/A
Ethyl benzene aldehyde	Benzaldehyde, 2-ethyl-	22927-13-5	N/A	N/A	N/A	N/A	N/A	N/A
Ethylene thiourea (Ethylene thiourea)	N/A	96-45-7	8.00E-05	N/A	N/A	N/A	N/A	N/A
2-Ethyl-1-hexanol	N/A	104-76-7	N/A	N/A	N/A	N/A	N/A	N/A
1-Ethyl-4-Methyl Benzene	4-Ethyltoluene	622-96-8	N/A	N/A	N/A	N/A	N/A	N/A
Fluoranthene	N/A	206-44-0	4.00E-02	N/A	D	N/A	N/A	N/A
Fluorene	N/A	86-73-7	4.00E-02	N/A	D	N/A	N/A	N/A
Formaldehyde	N/A	50-00-0	2.00E-01	N/A	B1	N/A	N/A	N/A
Furan, 2-methyl	2-Methylfuran	534-22-5	N/A	N/A	N/A	N/A	N/A	N/A
2(3H)-Furanone,dihydro-4-hydroxy-	Dihydro-4-hydroxy-2(3H)-furanone; beta-Hydroxybutyrolactone	5469-16-9	N/A	N/A	N/A	N/A	N/A	N/A
Guanidines	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Halocarbon 11	Trichlorofluoromethane, Freon 11	75-69-4	3.00E-01	N/A	N/A	N/A	N/A	N/A
Hemeicosane [c]	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Heptadecane	N/A	629-78-7	N/A	N/A	N/A	N/A	N/A	N/A
Heptane	N/A	142-82-5	N/A	N/A	D	N/A	N/A	N/A
Heptanonitrile	Heptanenitrile	629-08-3	N/A	N/A	N/A	N/A	N/A	N/A
Hexacosane	N/A	630-01-3	N/A	N/A	N/A	N/A	N/A	N/A
Hexadecane	N/A	544-76-3	N/A	N/A	N/A	N/A	N/A	N/A
Hexa(methoxymethyl)melamine	N,N,N',N',N'',N''-Hexakis(methoxy methyl)-1,3,5-triazine-2,4,6-triamine	3089-11-0	N/A	N/A	N/A	N/A	N/A	N/A
Hexamethylenetetramine	Methenamine	100-97-0	N/A	N/A	N/A	N/A	N/A	N/A
Hexane	n-Hexane	110-54-3	N/A	7.00E-01	N/A	N/A	N/A	N/A
Hexanedioic acid, methyl ester	Methyl hexanedioate	627-91-8	N/A	N/A	N/A	N/A	N/A	N/A
Hexanoic acid, 2-ethyl-	2-Ethylhexanoic acid	149-57-5	N/A	N/A	N/A	N/A	N/A	N/A
Hydrocarbon (olefin/aromatic)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
7-Hydroxybenzo[f]flavone	7-Hydroxy-3-phenyl-1H-naphtho[2,1-b] pyran-1-one	86247-95-2	N/A	N/A	N/A	N/A	N/A	N/A
1-Hydroxypyrene	N/A	5315-79-7	N/A	N/A	N/A	N/A	N/A	N/A
Indeno[l,2,3-cd]pyrene	o-Phenylenepyrene	193-39-5	N/A	N/A	B2	N/A	N/A	N/A
1H-isoindole-1,3 (2H)-dione	Phthalimide	85-41-6	N/A	N/A	N/A	N/A	N/A	N/A
iso-nonylphenol	3-Nonylphenol	11066-49-2	N/A	N/A	N/A	N/A	N/A	N/A
Isophorone	N/A	78-59-1	2.00E-01	N/A	C	9.50E-04	2.70E-08	N/A
Isopropyl Alcohol	2-Propanol, Isopropanol	67-63-0	N/A	N/A	N/A	N/A	N/A	N/A

Chemical Constituent[a]	Synonym[b]	CAS Number[c]	EPA IRIS[1] RfD (mg/kg-day)	EPA IRIS RfC (mg/m^3)	EPA IRIS Cancer Classification	EPA IRIS Oral SF (mg/kg-day^{-1})	EPA IRIS Dr. Water UR (ug/L^{-1})	EPA IRIS UR (ug/m$^{3-1}$)
Isopropylbenzene	Cumene	98-82-8	1.00E-01	4.00E-01	D	N/A	N/A	N/A
Isopropyltoluene	1-Methyl-2-(propan-2-yl)benzene	527-84-4	N/A	N/A	N/A	N/A	N/A	N/A
Ketones	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Latex protein	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Limonene	N/A	138-86-3	N/A	N/A	N/A	N/A	N/A	N/A
MEK	Methyl ethyl ketone	78-93-3	6.00E-01	5	N/A	N/A	N/A	N/A
2-Mercaptobenzothiazole	N/A	149-30-4	N/A	N/A	N/A	N/A	N/A	N/A
Methane, diethoxy-cyclohexane	Diethoxycyclohexanemethane; Bis(cyclohexyloxy)methane	1453-21-0	N/A	N/A	N/A	N/A	N/A	N/A
Methyl Alcohol	Methanol	67-56-1	2	2.00E+01	N/A	N/A	N/A	N/A
2-Methylanthracene	N/A	613-12-7	N/A	N/A	N/A	N/A	N/A	N/A
2-Methyl-Butane	2-Methylbutane	78-78-4	N/A	N/A	N/A	N/A	N/A	N/A
2,2-Methylene-bis-(4-methyl-6-tert-butylphenol) (BPH)	N/A	119-47-1	N/A	N/A	N/A	N/A	N/A	N/A
Methylene Chloride	Dichloromethane	75-09-2	6.00E-03	6.00E-01	N/A	2.00E-03	N/A	1.00E-08
5-Methyl-2-hexanone	Methyl isoamyl ketone	110-12-3	N/A	N/A	N/A	N/A	N/A	N/A
1-Methylnaphthalene	N/A	90-12-0	N/A	N/A	N/A	N/A	N/A	N/A
2-Methylnaphthalene	N/A	91-57-6	4.00E-03	N/A	N/A	N/A	N/A	N/A
3-Methyl-Pentane	3-Methylpentane	96-14-0	N/A	N/A	N/A	N/A	N/A	N/A
4-Methyl-2-pentanone	MIBK, Methyl isobutyl ketone	108-10-1	N/A	3	N/A	N/A	N/A	N/A
1-Methylphenanthrene	1-Methyl phenanthrene	832-69-9	N/A	N/A	N/A	N/A	N/A	N/A
2-Methylphenanthrene	N/A	2531-84-2	N/A	N/A	N/A	N/A	N/A	N/A
3-Methylphenanthrene	N/A	832-71-3	N/A	N/A	N/A	N/A	N/A	N/A
9-Methylphenanthrene	N/A	883-20-5	N/A	N/A	N/A	N/A	N/A	N/A
2-Methylphenol	o-Cresol	95-48-7	5.00E-02	N/A	C	N/A	N/A	N/A
4-Methylphenol	p-Cresol	106-44-5	N/A	N/A	C	N/A	N/A	N/A
MES (special purified aromatic oil)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2-(4-morpholino)benzothiazole	2-morpholinothio benzothiazole (MBS); Morpholinothio-benzothiazole; N-Oxydiethylenebenzothiazole-2-sulfenamide	102-77-2	N/A	N/A	N/A	N/A	N/A	N/A
2-Morpholinodithiobenzothiazole (MBSS)	2-(Morpholin-4-yldithio)-1,3-benzothiazole	95-32-9	N/A	N/A	N/A	N/A	N/A	N/A
Naphthalene	N/A	91-20-3	2.00E-02	3.00E-03	C	N/A	N/A	N/A
Naphthalene, 2-(bromomethyl)-	2-Bromomethylnaphthalene	939-26-4	N/A	N/A	N/A	N/A	N/A	N/A
Naphthalic Anhydride	1H,3H-Naphtho(1,8-cd)pyran-1,3-dione	81-84-5	N/A	N/A	N/A	N/A	N/A	N/A
Napthenic oil	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Nitro compound (isomer of major peak)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Nitro compound (nitro-ether derivative)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Nitrogen containing substances	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Nitrosodibutylamine (n-)	N-Nitrosodibutylamine	924-16-3	N/A	N/A	B2	5.4	1.60E-04	1.60E-03
Nitrosodiethylamine (n-)	N-Nitrosodiethylamine	55-18-5	N/A	N/A	B2	1.50E+02	4.30E-03	4.30E-02
Nitrosodimethylamine (n-)	N-Nitrosodimethylamine	62-75-9	N/A	N/A	B2	5.10E+01	1.40E-03	1.40E-02
n-Nitrosodiphenylamine	N-Nitrosodiphenylamine	86-30-6	N/A	N/A	B2	4.90E-03	1.40E-07	N/A
Nitrosodipropylamine (n-)	N-Nitrosodipropylamine	621-64-7	N/A	N/A	B2	7	2.00E-04	N/A
Nitrosomorpholine (n-)	N-Nitrosomorpholine	59-89-2	N/A	N/A	N/A	N/A	N/A	N/A
Nitrosopiperidine (n-)	N-Nitrosopiperidine	100-75-4	N/A	N/A	N/A	N/A	N/A	N/A
Nitrosopyrrolidine (n-)	N-Nitrosopyrrolidine	930-55-2	N/A	N/A	B2	2.1	6.10E-05	6.10E-04
Nonadecane	N/A	629-92-5	N/A	N/A	N/A	N/A	N/A	N/A
Nonanale	Nonanal	124-19-6	N/A	N/A	N/A	N/A	N/A	N/A
Nonane	N/A	111-84-2	N/A	N/A	N/A	N/A	N/A	N/A
4-n-nonylphenol	4-Nonylphenol	104-40-5	N/A	N/A	N/A	N/A	N/A	N/A
Octadecanoic acid, methyl ester	Methyl stearate	112-61-8	N/A	N/A	N/A	N/A	N/A	N/A
Octane	N/A	111-65-9	N/A	N/A	N/A	N/A	N/A	N/A
4-t-octylphenol	4-(1,1,3,3-Tetramethylbutyl)phenol, 4-tert-(octyl)-phenol	140-66-9	N/A	N/A	N/A	N/A	N/A	N/A
Optadecane	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Chemical Constituent[a]	Synonym[b]	CAS Number[c]	EPA IRIS[1] RfD (mg/kg-day)	EPA IRIS RfC (mg/m^3)	EPA IRIS Cancer Classification	EPA IRIS Oral SF (mg/kg-day^{-1})	EPA IRIS Dr. Water UR (ug/L^{-1})	EPA IRIS UR (ug/m$^{3-1}$)
Organic thiola and sulfides	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Orthocarbonate - Carboxy compound)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
N-Oxydiethylenedithiocarbamyl-N`-oxydiethylenesulfenamide (OTOS)	N/A	13752-51-7	N/A	N/A	N/A	N/A	N/A	N/A
PAHs	Polycyclic aromatic hydrocarbons	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Parrafinic oils	Mineral oil	8012-95-1	N/A	N/A	N/A	N/A	N/A	N/A
PCB sum	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
PCDD/F sum	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Pentacosane	N/A	629-99-2	N/A	N/A	N/A	N/A	N/A	N/A
Pentane	N/A	109-66-0	N/A	N/A	N/A	N/A	N/A	N/A
Perylene	N/A	198-55-0	N/A	N/A	N/A	N/A	N/A	N/A
Petroleum Naphtha	Naphtha	8030-30-6	N/A	N/A	N/A	N/A	N/A	N/A
Phenalone	Phenalen-1-one	548-39-0	N/A	N/A	N/A	N/A	N/A	N/A
Phenanthrene	N/A	85-01-8	N/A	N/A	D	N/A	N/A	N/A
1-Phenanthrenecarboxylic acid, 1,2,3,4,4	1,2,3,4,4-1-Phenanthrene carboxylic acid; Dehydroabietic acid	1740-19-8	N/A	N/A	N/A	N/A	N/A	N/A
Phenol	2,4-Di-tert-butylphenol	108-95-2	3.00E-01	N/A	D	N/A	N/A	N/A
Phenolics	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Phenol, 2,4-bis(1,1-dimethylethyl)-	N/A	96-76-4	N/A	N/A	N/A	N/A	N/A	N/A
Phenol, 2,4-bis(1-methyl-1-phenylethyl)-	2,4-Bis(1-methyl-1-phenylethyl)phenol	2772-45-4	N/A	N/A	N/A	N/A	N/A	N/A
Phenol, m-tert-butyl-	3-tert-Butylphenol	585-34-2	N/A	N/A	N/A	N/A	N/A	N/A
Phenylbenzimidazole	2-Phenylbenzimidazole	716-79-0	N/A	N/A	N/A	N/A	N/A	N/A
p-Phenylenediamines	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Phenylenediamines	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2-(1-phenylethyl)-phenol	2-(1-Phenylethyl)phenol	26857-99-8	N/A	N/A	N/A	N/A	N/A	N/A
3-Phenyl-2-propenal	3-Phenylprop-2-enal	104-55-2	N/A	N/A	N/A	N/A	N/A	N/A
Phthalates	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
PM 2.5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
PM 10	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Poly- and di-nitrobenzenes	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Poly-p-dinitrosobenzene	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Propene	1-Propene; propylene	115-07-1	N/A	N/A	N/A	N/A	N/A	N/A
Propylbenzene	N/A	103-65-1	N/A	N/A	N/A	N/A	N/A	N/A
Pyrazole	N/A	288-13-1	N/A	N/A	N/A	N/A	N/A	N/A
Pyrene	N/A	129-00-0	3.00E-02	N/A	D	N/A	N/A	N/A
Pyrimidine, 2-(4-pentylphenyl)-5-propyl-	N/A	94320-32-8	N/A	N/A	N/A	N/A	N/A	N/A
2-Pyrrolidinone. 1-methyl-	N-Methyl-2-pyrrolidone	872-50-4	N/A	N/A	N/A	N/A	N/A	N/A
Quinones	N/A	106-51-4	N/A	N/A	N/A	N/A	N/A	N/A
Resorcinol	N/A	108-46-3	N/A	N/A	N/A	N/A	N/A	N/A
Rethene [c]	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Siloxanes	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Styrene	N/A	100-42-5	2.00E-01	1	N/A	N/A	N/A	N/A
Styrene oligomers	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Substituted p-Phenylenediamines	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Sulfur containing organics	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Sulfur Donors	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Sulphenamides	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
TDAE (special purified aromatic oil)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Tertbutylacetophenone	3,3-dimethyl-1-phenylbutan-1-one	31366-07-1	N/A	N/A	N/A	N/A	N/A	N/A
N-tert-Butyl-2-benzothiazolesulf enamide (TBBS)	N/A	95-31-8	N/A	N/A	N/A	N/A	N/A	N/A
4-tert butylphenol	4-tert-Butylphenol	98-54-4	N/A	N/A	N/A	N/A	N/A	N/A

Chemical Constituent[a]	Synonym[b]	CAS Number[c]	EPA IRIS[1] RfD (mg/kg-day)	EPA IRIS RfC (mg/m³)	EPA IRIS Cancer Classification	EPA IRIS Oral SF (mg/kg-day⁻¹)	EPA IRIS Dr. Water UR (ug/L⁻¹)	EPA IRIS UR (ug/m³⁻¹)
Tetraalkylthiuram disulfides	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Tetrabenzylthiuram disulfide (TBZTD)	N/A	10591-85-2	N/A	N/A	N/A	N/A	N/A	N/A
Tetrabutylthiuram disulfide (TBTD)	N/A	1634-02-2	N/A	N/A	N/A	N/A	N/A	N/A
Tetrachloroethene	Tetrachloroethylene; perchloroethylene	127-18-4	6.00E-03	4.00E-02	N/A	2.10E-03	6.10E-08	2.60E-07
Tetracosane	N/A	646-31-1	N/A	N/A	N/A	N/A	N/A	N/A
Tetraethylthiuram disulfide	Disulfiram	97-77-8	N/A	N/A	N/A	N/A	N/A	N/A
Tetrahydrofuran	N/A	109-99-9	9.00E-01	2	N/A	N/A	N/A	N/A
Tetramethylthiuram disulfide	Thiram	137-26-8	5.00E-03	N/A	N/A	N/A	N/A	N/A
Tetramethylthiuram monosulfide	N/A	97-74-5	N/A	N/A	N/A	N/A	N/A	N/A
Thiazoles	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Thioureas	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Thiurams	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Thiuram sulfides	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Toluene	N/A	108-88-3	8.00E-02	5	N/A	N/A	N/A	N/A
Total petroleum hydrocarbons	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Trans trans-muconic acid	(E,E)-Muconic acid	3588-17-8	N/A	N/A	N/A	N/A	N/A	N/A
Trimethyl-1,2-dihydroquinoline (TMDQ)	1,2-Dihydro-2,2,4-trimethylquinoline, polymer	26780-96-1	N/A	N/A	N/A	N/A	N/A	N/A
1,1,1-Trichloroethane	N/A	71-55-6	2 (chronic) 7 (subchronic)	5 (chronic, subchronic); 6-9 (acute)	N/A	N/A	N/A	N/A
Trichloroethylene	N/A	79-01-6	5.00E-04	2.00E-03	N/A	4.60E-02	N/A	4.10E-06
1,1,2-Trichloro-1,2,2-trifluoroethane	N/A	76-13-1	3.00E+01	N/A	N/A	N/A	N/A	N/A
Trichloro-trifluoroethane	1,1,1-Trichloro-2,2,2-trifluoroethane	354-58-5	N/A	N/A	N/A	N/A	N/A	N/A
Tricosane	N/A	638-67-5	N/A	N/A	N/A	N/A	N/A	N/A
1,2,3-Trimethyl benzene	1,2,3-Trimethylbenzene	526-73-8	N/A	N/A	N/A	N/A	N/A	N/A
1,2,4-Trimethyl benzene	1,2,4-Trimethylbenzene	95-63-6	N/A	N/A	N/A	N/A	N/A	N/A
1,3,5-Trimethyl benzene	1,3,5-Trimethylbenzene	108-67-8	N/A	N/A	N/A	N/A	N/A	N/A
2,2,4-Trimethyl-1,2-dihydroquinoline (TMQ)	1,2-Dihydro-2,2,4-trimethylquinoline, polymer	26780-96-1	N/A	N/A	N/A	N/A	N/A	N/A
Vinyl Acetate	N/A	108-05-4	N/A	2.00E-01	N/A	N/A	N/A	N/A
White gasoline	Natural gasoline	8006-61-9	N/A	N/A	N/A	N/A	N/A	N/A
o-Xylene	N/A	95-47-6	N/A	N/A	N/A	N/A	N/A	N/A
Xylenes	N/A	1330-20-7	2.00E-01	1.00E-01	N/A	N/A	N/A	N/A
Zn-Dibenzyldithiocarbamate (ZBEC)	N/A	136-23-2	N/A	N/A	N/A	N/A	N/A	N/A
Zn-Diethyldithiocarbamate (ZDEC)	Zinc diethyldithiocarbamate	14324-55-1	N/A	N/A	N/A	N/A	N/A	N/A
Zn-Dimethyldithiocarbamate (ZDMC)	Ziram	137-30-4	N/A	N/A	N/A	N/A	N/A	N/A
Zn-dibutyldithiocarbamate (ZDBC)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
ZnO	Zinc Oxide	1314-13-2	N/A	N/A	N/A	N/A	N/A	N/A
TOTALS 355	158	290	65	33	62	23	20	19
PERCENTS 100%	45%	82%	18%	9%	17%	6%	6%	5%

Chemical Constituent[a]	Synonym[b]	CAS Number[c]	EPA PPRTVs[2] Chronic RfD (mg/kg-day)	EPA PPRTVs Chronic RfC (mg/m^3)	EPA PPRTVs Subchronic RfD (mg/kg-day)	EPA PPRTVs Subchronic RfC (mg/m^3)	EPA PPRTVs Cancer Classification	EPA PPRTVs Oral SF ($mg/kg\text{-}day^{-1}$)	EPA PPRTVs Inhal. UR ($mg/m^{3\text{-}1}$)
Aluminum	N/A	7429-90-5	1.0	5.0E-03	N/A	N/A	N/A	N/A	N/A
Antimony	N/A	7440-36-0	N/A	N/A	4.00E-04	N/A	N/A	N/A	N/A
Arsenic	N/A	7440-38-2	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Barium	N/A	7440-39-3	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Beryllium	N/A	7440-41-7	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Cadmium	N/A	7440-43-9	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Calcium	N/A	7440-70-2	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Chloride	N/A	16887-00-6	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Chromium	N/A	7440-47-3; 16065-83-1 (CrIII); 18540-29-9 (CrVI)	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Cobalt	N/A	7440-48-4	3.00E-04	6.00E-06	3.00E-03	2.00E-05	N/A	N/A	9.0
Copper	N/A	7440-50-8	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Iron	N/A	7439-89-6	7.00E-01	N/A	7.00E-01	N/A	N/A	N/A	N/A
Lead	N/A	7439-92-1	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Lithium	N/A	7439-93-2	2.00E-03	N/A	2.00E-03	N/A	N/A	N/A	N/A
Magnesium	N/A	7439-95-4	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Manganese	N/A	7439-96-5	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Mercury	N/A	7439-97-6	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Molybdenum	N/A	7439-98-7	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Nickel	N/A	7440-02-0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Phosphorous	N/A	7723-14-0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Potassium	N/A	7440-09-7	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Rubidium	N/A	7440-17-7	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Selenium	N/A	7782-49-2	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Silver	N/A	7440-22-4	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Sodium	N/A	7440-23-5	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Strontium	N/A	7440-24-6	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Sulfur	N/A	7704-34-9	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Thallium	N/A	7440-28-0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Tin	N/A	7440-31-5	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Titanium	N/A	7440-32-6	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Tungsten	N/A	7440-33-7	8.00E-04	N/A	8.00E-03	N/A	N/A	N/A	N/A
Vanadium	N/A	7440-62-2	7.00E-05	N/A	7.00E-04	N/A	N/A	N/A	N/A

Chemical Constituent[a]	Synonym[b]	CAS Number[c]	EPA PPRTVs[2] Chronic RfD (mg/kg-day)	EPA PPRTVs Chronic RfC (mg/m^3)	EPA PPRTVs Subchronic RfD (mg/kg-day)	EPA PPRTVs Subchronic RfC (mg/m^3)	EPA PPRTVs Cancer Classification	EPA PPRTVs Oral SF $(mg/kg\text{-}day^{-1})$	EPA PPRTVs Inhal. UR (mg/m^{3-1})
Zinc	N/A	7440-66-6	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Cadmium and Zinc Soaps	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Acenaphthene	N/A	83-32-9	N/A	N/A	2.00E-01	N/A	N/A	N/A	N/A
Acenaphthylene	N/A	208-96-8	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Acetaldehyde	Ethanone	75-07-0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Acetamide, N-cyclohexyl-	N/A	1124-53-4	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Acetone	N/A	67-64-1	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Acetone-diphenylamine condensation product (ADPA)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Acetonitrile	N/A	75-05-8	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Acetophenone	N/A	98-86-2	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6-Acetoxy-2,2-dimethyl-m-dioxane	Dimethoxane	828-00-2	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Acrolein	N/A	107-02-8	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Alcohols	Ethanol	64-17-5	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Aldehydes	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Alkyl benzenes	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Alkyl dithiols	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Alkyl naphthalenes	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Alkyl phenols	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Alpha pinene	alpha-Pinene	80-56-8	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Amine (N-dialkyl analine derivative)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Amines	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Anathrene [c]	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Aniline	Benzeneamine; aminobenzene	62-53-3	7.00E-03	N/A	N/A	N/A	N/A	N/A	N/A
Anthanthrene	N/A	191-26-4	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Anthracene	N/A	120-12-7	N/A	N/A	1	N/A	N/A	N/A	N/A
Aromatic oil	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9,10-Anthracenedione, 2-ethyl	2-Ethylanthracene-9,10-dione	84-51-5	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Azobenzene	N/A	103-33-3	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Benz(e)acenaphthylene	Acephenanthrylene	201-06-9	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Benzaldehyde, 3-hydroxyl-4-methoxy	3-Hydroxy-4-methoxy-benzaldehyde	621-59-0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Benz(a)anthracene	N/A	56-55-3	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Benzene	N/A	71-43-2	N/A	N/A	1.00E-02	8.00E-02	N/A	N/A	N/A
Benzene, 1,3-bis(1-methylethenyl)-	1,3-bis(1-methylethenyl)benzene; 1,3-Diisopropenylbenzene	3748-13-8	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Benzene, 1,4-bis(1-methylethenyl)-	1,4-Bis(1-methylethenyl)benzene	1605-18-1	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1,4-Benzenediamine, N,N'-diphenyl-	N,N'-Diphenyl-p-phenylenediamine	74-31-7	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1,4-Benzendiamin, N-(1-methylethyl)-N'-phenyl-, (IPPD)	N-Isopropyl-N'-phenyl-p-phenylenediamine, Isopropylaminodephenylamine (IPPD)	101-72-4	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Benzene, isocyanato-	Phenyl isocyanate	103-71-9	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Benzenemethanol	Benzyl alcohol	100-51-6	1.00E-01	N/A	3.00E-01	N/A	N/A	N/A	N/A
Benzo(def)dibenzothiophene	Phenanthro[4,5-bcd]thiophene	30796-92-0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Benzo(g)dibenzothiophene	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Benzo(b)fluoranthene	N/A	205-99-2	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Benzo(bjk)fluoranthene	2,11-(Metheno)benzo[a]fluorene	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Benzo(ghi)fluoranthene	Benzo[ghi]fluoranthene	203-12-3	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Benzo(i)fluoranthene	Benzo(j)fluoranthene	205-82-3	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Benzo(k)fluoranthene	N/A	207-08-9	N/A	N/A	N/A	N/A	N/A	N/A	N/A

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Benzo(mno)fluoranthene	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Benzo(a)fluorene	11H-Benzo[a]fluorene	238-84-6	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Benzo(b)fluorene	2,3-Benzofluorene	243-17-4	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Benzo(def)naphthobenzothiophene	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6H-Benzo[cd]pyren-6-one	6H-Benzo(cd)pyren-6-one	3074-00-8	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Benzo(a)pyrene	N/A	50-32-8	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Benzo(e)pyrene	N/A	192-97-2	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Benzo(ghi)perylene	Benzo(g,h,i)perylene	191-24-2	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Benzoic acid	N/A	65-85-0	N/A	N/A	4	2.00E-03	N/A	N/A	N/A
Benzothiazole	N/A	95-16-9	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Benzothiazole, 2-(methylthio)	2-(Methylthio)benzothiazole	615-22-5	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Benzothiazole, 2-phenyl	2-Phenylbenzothiazole	883-93-2	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Benzothiazolone	2-Hydroxybenzothiazole, 2(3H)-Benzothiazolone, 2(3H) benzothiazolone	934-34-9	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Benzoyl and other peroxides	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Benzylbutyl phthalate	Butyl benzyl phthalate	85-68-7	N/A	N/A	N/A	N/A	N/A	1.90E-03	N/A
Biphenyl	1,1'-Biphenyl	92-52-4	N/A	N/A	1.00E-01	N/A	N/A	N/A	N/A
1,1'-Biphenyl, 4, 4', 5', 6'-tetramethoxy-	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
(N,N`-Bis(1,4-dimethylpentyl) pphenylendiamine) (7PPD)	N,N'-Bis(1,4-dimethylpentyl)-4-phenylenediamine	3081-14-9	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Bis(2-ethylhexyl) phthalate	Di(2-ethylhexyl) phthalate	117-81-7	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Bis-(2,2,6,6-tetramethyl-4-piperidinyl)sebacate	Bis(2,2,6,6-tetramethyl-4-piperidyl) sebacate	52829-07-9	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Bisthiol acids	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Black rubber	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Bromodichloromethane	N/A	75-27-4	N/A	N/A	8.00E-03	2.00E-02	N/A	N/A	N/A
Bromoform	N/A	75-25-2	N/A	N/A	3.00E-02	N/A	N/A	N/A	N/A
1,3 Butadiene	N/A	106-99-00	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Butoxyethoxyethanol	2-(2-Butoxyethoxy)ethanol, diethylene glycol monobutyl ether	112-34-5	3.00E-02	1.00E-04	3.00E-01	1.00E-03	N/A	N/A	N/A
Butylated hydroxyanisole	N/A	25013-16-5	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Butylated hydroxytoluene	2,6-Di-tert-butyl-4-methylphenol (BHT)	128-37-0	3.00E-01	N/A	1	N/A	N/A	3.60E-03	N/A
Butylbenzene	N/A	104-51-8	5.00E-02	N/A	1.00E-01	N/A	N/A	N/A	N/A
Caprolactam disulfide (CLD)	1,1'-Disulfanediyldiazepan-2-one	23847-08-7	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Carbazole	N/A	86-74-8	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Carbon Black	Furnace Black	1333-86-4	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Carbon Disulfide	N/A	75-15-0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Carbon Tetrachloride	N/A	56-23-5	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Chlorobenzene	N/A	108-90-7	N/A	5.00E-02	7.00E-02	5.00E-01	N/A	N/A	N/A
Chloroform	Trichloromethane	67-66-3	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Chemical Constituent[a]	Synonym[b]	CAS Number[c]	EPA PPRTVs[2] Chronic RfD (mg/kg-day)	EPA PPRTVs Chronic RfC (mg/m^3)	EPA PPRTVs Subchronic RfD (mg/kg-day)	EPA PPRTVs Subchronic RfC (mg/m^3)	EPA PPRTVs Cancer Classification	EPA PPRTVs Oral SF ($mg/kg\text{-}day^{-1}$)	EPA PPRTVs Inhal. UR (mg/m^{3-1})
Chloromethane	Methyl chloride	74-87-3	N/A	N/A	N/A	3	N/A	N/A	N/A
Chrysene	N/A	218-01-9	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Coronene	N/A	191-07-1	N/A	N/A	N/A	N/A	N/A	N/A	N/A
o-Cyanobenzoic acid	2-Cyanobenzoic acid	3839-22-3	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Cyclohexanamine	Cyclohexylamine	108-91-8	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Cyclohexanamine, N-cyclohexyl-	Dicyclohexylamine	101-83-7	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Cyclohexanamine, N-cyclohexyl-N-methyl-	N-Cyclohexyl-N-methylcyclohexanamine	7560-83-0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Cyclohexane	N/A	110-82-7	N/A	N/A	N/A	18	N/A	N/A	N/A
Cyclohexane, isocyanato	Isocyanatocyclohexane	3173-53-3	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Cyclohexane, isothiocyanato-	N/A	1122-82-3	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Cyclohexanone	N/A	108-94-1	N/A	7.00E-01	2	7.00E+00	N/A	N/A	N/A
N-Cyclohexyl-2-benzothiazolesulfenamide (CBS)	N-Cyclohexyl-2-benzothiazolesulfenamide	95-33-0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
n-Cyclohexyl-formamide	N-Cyclohexylformamide, Formamide, N-cyclohexyl	766-93-8	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Cycloninasiloxane, octadecamethyl-	Octadecamethylcyclononasiloxane	556-71-8	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Cyclopenta[cd]pyrene	N/A	27208-37-3	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4H-cyclopenta[def]phenanthren-4-one	4H-Cyclopenta(def)phenanthren-4-one	5737-13-3	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4H-cyclopenta[def]-phenanthrene	4-H-Cyclopenta(d,e,f)phenanthrene	203-64-5	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Cyclopentane, methyl-	Methylcyclopentane	96-37-7	N/A	N/A	4.00E-01	N/A	N/A	N/A	N/A
Decane	N/A	124-18-5	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Diazoaminobenzenes	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Dibenzo(a,h) anthracene	Dibenz(a,h)anthracene	53-70-3	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Dibenzofurane	Dibenzofuran	132-64-9	N/A	N/A	4.00E-03	N/A	N/A	N/A	N/A
Dibenzo(ae)pyrene	Naphtho(1,2,3,4-def)chrysene	192-65-4	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Dibenzo(ai)pyrene	Dibenzo[a,i]pyrene	189-55-9	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Dibenzo(ah)pyrene	Dibenzo[a,h]pyrene	189-64-0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Dibenzothiophene	N/A	132-65-0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Dibutyl phthalate	N/A	84-74-2	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1,4-Dichlorobenzene	p-dichlorobenzene	106-46-7	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Dichlorodifluoromethane	Freon 12	75-71-8	N/A	N/A	5.00E-02	1	N/A	N/A	N/A
1,2-Dichloroethane	Ethylene dichloride	107-06-2	N/A	7.00E-03	2.00E-02	7.00E-02	N/A	N/A	N/A
cis-1,2-Dichloroethene	(Z)-1,2-Dichloroethylene	156-59-2	N/A	N/A	2.00E-02	N/A	N/A	N/A	N/A
1,2-Dichloropropane	N/A	78-87-5	N/A	N/A	N/A	N/A	N/A	N/A	N/A
N,N-Dicyclohexyl-2-benzothiazolesulfenamide (DCBS)	N,N-Dicyclohexyl-2-benzothiazolesulfenamide	4979-32-2	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Dicyclohexylphthalate (DCHP)	Dicyclohexyl phthalate	84-61-7	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1,3-Dicyclohexylurea	N,N'-Dicyclohexylurea	2387-23-7	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Diethenylbenzene	Divinylbenzene	1321-74-0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Di(2-ethylhexyl) adipate	Hexanedioic acid, bis(2-ehtylhexyl); Bis(2-ethylhexyl)hexanedioic acid	103-23-1	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Diethyl phthalate	N/A	84-66-2	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Diethylthiourea (DETU)	N,N'-Diethylthiourea	105-55-5	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Dihydrocyclopentapyrene	2,3-Acepyrene	25732-74-5	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Diisobutyl phthalate	N/A	84-69-5	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Diisodecylphthalate	bis(8-Methylnonyl) phthalate	89-16-7	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Diisononyl phthalate	DINP	28553-12-0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9,l0-Dimethyl-1,2-Benzanthracene	7,12-Dimethylbenz(a)anthracene	57-97-6	N/A	N/A	N/A	N/A	N/A	N/A	N/A

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(N-1,3-dimethyl-butyl)-N'- phenyl-p-phenylenediamine (6PPD)	N-(1,3-Dimethylbutyl)-N'-phenyl-p-phenylenediamine	793-24-8	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Dimethyldiphenylthiuram disulfide (MPTD)	Dimethyldiphenylthiuram disulfide	53880-86-7	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2,6-Dimethylnaphthalene	N/A	581-42-0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2,4-Dimethylphenol	N/A	105-67-9	N/A	N/A	5.00E-02	N/A	N/A	N/A	N/A
Dimethyl phthalate	N/A	131-11-3	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Dinitroarenes	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Di-n-octyl phthalate	Dioctyl phthalate	117-84-0	1.00E-02	N/A	1.00E-01	N/A	N/A	N/A	N/A
Di-ortho-tolylguanidine	N/A	97-39-2	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Dipentamethylenethiuramtetrasulfide (DPTT)	Bis(pentamethylenethiuram)tetrasulfide	120-54-7	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Diphenylamine	N/A	122-39-4	N/A	N/A	N/A	N/A	N/A	N/A	N/A
N,N'-Diphenylguanidine (DPG)	1,3-Diphenylguanidine	102-06-7	N/A	N/A	N/A	N/A	N/A	N/A	N/A
N,N'-Diphenyl-p-phenylenediamine (DPPD)	N,N'-Diphenyl-p-phenylenediamine	74-31-7	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Disulfides	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Di-(2-ethyl)hexylphosphorylpolysul fide) (SDT)	Bis-(ethylhexylthiophosphoryl) polysulfide	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3,5-Di-tert-Butyl-4-hydroxybenzaldehyde	N/A	1620-98-0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2,2'-Dithiobis(benzothiazole)	2,2'-Dithiobisbenzothiazole	120-78-5	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Dithiocarbamates	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Dithiomorpholine (DTDM)	4,4'-Dithiodimorpholine	103-34-4	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Dithiophosphates	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
N,N`-Ditolyl-p-phenylenediamine (DTPD)	N,N'-Ditolyl-p-phenylenediamine	27417-40-9	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Docosanoic acid	N/A	112-85-6	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Dodecanoic acid	N/A	143-07-7	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Dotriacontane	N/A	544-85-4	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Drometrizol	2-(2H-Benzotriazol-2-yl)-4-methylphenol	2440-22-4	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Eicosane	N/A	112-95-8	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Erucylamide	Erucamide	112-84-5	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Esters	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Ethanol, 2-butoxy-	2-Butoxyethanol	111-76-2	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Ethanol, 1-(2-butoxyethoxy)	1-(2-Butoxyethoxy)ethanol	54446-78-5	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Ethanone, 1,1'-(1,3-phenylene)bis-	Benzene-1,3-bis(acetyl)	6781-42-6	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Ethanone, 1,1'-(1,4-phenylene)bis-	1,1-(1,4-Phenylene)bis-ethanone	1009-61-6	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Ethanone, 1-[4-(1-methylethenyl) phenyl]-	1-[4-(1-Methylethenyl)phenyl]ethanone	5359-04-6	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Ethyl Acetate	N/A	141-78-6	N/A	7.00E-02	7.00E-01	7.00E-01	N/A	N/A	N/A
Ethyl benzene	Ethylbenzene	100-41-4	N/A	N/A	5.00E-02	9	N/A	N/A	N/A
Ethyl benzene aldehyde	Benzaldehyde, 2-ethyl-	22927-13-5	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Ethylene thiourea (Ethylene thiourea)	N/A	96-45-7	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2-Ethyl-1-hexanol	N/A	104-76-7	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1-Ethyl-4-Methyl Benzene	4-Ethyltoluene	622-96-8	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Fluoranthene	N/A	206-44-0	N/A	N/A	1.00E-01	N/A	N/A	N/A	N/A
Fluorene	N/A	86-73-7	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Formaldehyde	N/A	50-00-0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Furan, 2-methyl	2-Methylfuran	534-22-5	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2(3H)-Furanone,dihydro-4-hydroxy-	Dihydro-4-hydroxy-2(3H)-furanone; beta-Hydroxybutyrolactone	5469-16-9	N/A	N/A	N/A	N/A	N/A	N/A	N/A

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Guanidines	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Halocarbon 11	Trichlorofluoromethane, Freon 11	75-69-4	N/A	N/A	N/A	1	N/A	N/A	N/A
Hemeicosane [c]	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Heptadecane	N/A	629-78-7	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Heptane	N/A	142-82-5	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Heptanonitrile	Heptanenitrile	629-08-3	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Hexacosane	N/A	630-01-3	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Hexadecane	N/A	544-76-3	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Hexa(methoxymethyl)melamine	N,N,N',N',N'',N''-Hexakis(methoxy methyl)-1,3,5-triazine-2,4,6-triamine	3089-11-0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Hexamethylenetetramine	Methenamine	100-97-0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Hexane	n-Hexane	110-54-3	N/A	N/A	3.00E-01	2	N/A	N/A	N/A
Hexanedioic acid, methyl ester	Methyl hexanedioate	627-91-8	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Hexanoic acid, 2-ethyl-	2-Ethylhexanoic acid	149-57-5	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Hydrocarbon (olefin/aromatic)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
7-Hydroxybenzo[f]flavone	7-Hydroxy-3-phenyl-1H-naphtho[2,1-b] pyran-1-one	86247-95-2	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1-Hydroxypyrene	N/A	5315-79-7	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Indeno[l,2,3-cd]pyrene	o-Phenylenepyrene	193-39-5	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1H-isoindole-1,3 (2H)-dione	Phthalimide	85-41-6	N/A	N/A	N/A	N/A	N/A	N/A	N/A
iso-nonylphenol	3-Nonylphenol	11066-49-2	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Isophorone	N/A	78-59-1	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Isopropyl Alcohol	2-Propanol, Isopropanol	67-63-0	2	2.00E-01	2	7	N/A	N/A	N/A
Isopropylbenzene	Cumene	98-82-8	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Isopropyltoluene	1-Methyl-2-(propan-2-yl)benzene	527-84-4	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Ketones	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Latex protein	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Limonene	N/A	138-86-3	N/A	N/A	N/A	N/A	N/A	N/A	N/A
MEK	Methyl ethyl ketone	78-93-3	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2-Mercaptobenzothiazole	N/A	149-30-4	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Methane, diethoxy-cyclohexane	Diethoxycyclohexanemethane; Bis(cyclohexyloxy)methane	1453-21-0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Methyl Alcohol	Methanol	67-56-1	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2-Methylanthracene	N/A	613-12-7	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2-Methyl-Butane	2-Methylbutane	78-78-4	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2,2-Methylene-bis-(4-methyl-6-tert-butylphenol) (BPH)	N/A	119-47-1	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Methylene Chloride	Dichloromethane	75-09-2	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5-Methyl-2-hexanone	Methyl isoamyl ketone	110-12-3	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1-Methylnaphthalene	N/A	90-12-0	N/A	N/A	N/A	N/A	N/A	2.90E-02	N/A
2-Methylnaphthalene	N/A	91-57-6	N/A	N/A	4.00E-03	N/A	N/A	N/A	N/A
3-Methyl-Pentane	3-Methylpentane	96-14-0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4-Methyl-2-pentanone	MIBK, Methyl isobutyl ketone	108-10-1	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1-Methylphenanthrene	1-Methyl phenanthrene	832-69-9	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2-Methylphenanthrene	N/A	2531-84-2	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3-Methylphenanthrene	N/A	832-71-3	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9-Methylphenanthrene	N/A	883-20-5	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2-Methylphenol	o-Cresol	95-48-7	N/A	N/A	2.00E-01	N/A	N/A	N/A	N/A
4-Methylphenol	p-Cresol	106-44-5	N/A	N/A	2.00E-02	N/A	N/A	N/A	N/A
MES (special purified aromatic oil)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

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2-(4-morpholino)benzothiazole	2-morpholinothio benzothiazole (MBS); Morpholinothio-benzothiazole; N-Oxydiethylenebenzothiazole-2-sulfenamide	102-77-2	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2-Morpholinodithiobenzothiazole (MBSS)	2-(Morpholin-4-yldithio)-1,3-benzothiazole	95-32-9	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Naphthalene	N/A	91-20-3	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Naphthalene, 2-(bromomethyl)-	2-Bromomethylnaphthalene	939-26-4	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Naphthalic Anhydride	1H,3H-Naphtho(1,8-cd)pyran-1,3-dione	81-84-5	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Napthenic oil	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Nitro compound (isomer of major peak)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Nitro compound (nitro-ether derivative)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Nitrogen containing substances	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Nitrosodibutylamine (n-)	N-Nitrosodibutylamine	924-16-3	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Nitrosodiethylamine (n-)	N-Nitrosodiethylamine	55-18-5	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Nitrosodimethylamine (n-)	N-Nitrosodimethylamine	62-75-9	8.00E-06	N/A	8.00E-06	N/A	N/A	N/A	N/A
n-Nitrosodiphenylamine	N-Nitrosodiphenylamine	86-30-6	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Nitrosodipropylamine (n-)	N-Nitrosodipropylamine	621-64-7	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Nitrosomorpholine (n-)	N-Nitrosomorpholine	59-89-2	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Nitrosopiperidine (n-)	N-Nitrosopiperidine	100-75-4	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Nitrosopyrrolidine (n-)	N-Nitrosopyrrolidine	930-55-2	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Nonadecane	N/A	629-92-5	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Nonanale	Nonanal	124-19-6	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Nonane	N/A	111-84-2	N/A	2.00E-02	3.00E-03	2.00E-01	N/A	N/A	N/A
4-n-nonylphenol	4-Nonylphenol	104-40-5	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Octadecanoic acid, methyl ester	Methyl stearate	112-61-8	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Octane	N/A	111-65-9	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4-t-octylphenol	4-(1,1,3,3-Tetramethylbutyl)phenol, 4-tert-(octyl)-phenol	140-66-9	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Optadecane	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Organic thiola and sulfides	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Orthocarbonate - Carboxy compound)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
N-Oxydiethylenedithiocarbamyl-N`-oxydiethylenesulfenamide (OTOS)	N/A	13752-51-7	N/A	N/A	N/A	N/A	N/A	N/A	N/A
PAHs	Polycyclic aromatic hydrocarbons	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Parrafinic oils	Mineral oil	8012-95-1	3	N/A	30	N/A	N/A	N/A	N/A
PCB sum	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
PCDD/F sum	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Pentacosane	N/A	629-99-2	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Pentane	N/A	109-66-0	N/A	1	N/A	10	N/A	N/A	N/A
Perylene	N/A	198-55-0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Petroleum Naphtha	Naphtha	8030-30-6	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Phenalone	Phenalen-1-one	548-39-0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Phenanthrene	N/A	85-01-8	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1-Phenanthrenecarboxylic acid, 1,2,3,4,4	1,2,3,4,4-1-Phenanthrene carboxylic acid; Dehydroabietic acid	1740-19-8	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Phenol	2,4-Di-tert-butylphenol	108-95-2	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Phenolics	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Phenol, 2,4-bis(1,1-dimethylethyl)-	N/A	96-76-4	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Phenol, 2,4-bis(1-methyl-1-phenylethyl)-	2,4-Bis(1-methyl-1-phenylethyl)phenol	2772-45-4	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Chemical Constituent[a]	Synonym[b]	CAS Number[c]	EPA PPRTVs[2] Chronic RfD (mg/kg-day)	EPA PPRTVs Chronic RfC (mg/m^3)	EPA PPRTVs Subchronic RfD (mg/kg-day)	EPA PPRTVs Subchronic RfC (mg/m^3)	EPA PPRTVs Cancer Classification	EPA PPRTVs Oral SF ($mg/kg\text{-}day^{-1}$)	EPA PPRTVs Inhal. UR (mg/m^{3-1})
Phenol, m-tert-butyl-	3-tert-Butylphenol	585-34-2	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Phenylbenzimidazole	2-Phenylbenzimidazole	716-79-0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
p-Phenylenediamines	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Phenylenediamines	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2-(1-phenylethyl)-phenol	2-(1-Phenylethyl)phenol	26857-99-8	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3-Phenyl-2-propenal	3-Phenylprop-2-enal	104-55-2	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Phthalates	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
PM 2.5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
PM 10	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Poly- and di-nitrobenzenes	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Poly-p-dinitrosobenzene	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Propene	1-Propene; propylene	115-07-1	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Propylbenzene	N/A	103-65-1	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Pyrazole	N/A	288-13-1	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Pyrene	N/A	129-00-0	N/A	N/A	3.00E-01	N/A	N/A	N/A	N/A
Pyrimidine, 2-(4-pentylphenyl)-5-propyl-	N/A	94320-32-8	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2-Pyrrolidinone. 1-methyl-	N-Methyl-2-pyrrolidone	872-50-4	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Quinones	N/A	106-51-4	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Resorcinol	N/A	108-46-3	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Rethene [c]	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Siloxanes	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Styrene	N/A	100-42-5	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Styrene oligomers	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Substituted p-Phenylenediamines	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Sulfur containing organics	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Sulfur Donors	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Sulphenamides	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
TDAE (special purified aromatic oil)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Tertbutylacetophenone	3,3-dimethyl-1-phenylbutan-1-one	31366-07-1	N/A	N/A	N/A	N/A	N/A	N/A	N/A
N-tert-Butyl-2-benzothiazolesulf enamide (TBBS)	N/A	95-31-8	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4-tert butylphenol	4-tert-Butylphenol	98-54-4	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Tetraalkylthiuram disulfides	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Tetrabenzylthiuram disulfide (TBZTD)	N/A	10591-85-2	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Tetrabutylthiuram disulfide (TBTD)	N/A	1634-02-2	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Tetrachloroethene	Tetrachloroethylene; perchloroethylene	127-18-4	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Tetracosane	N/A	646-31-1	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Tetraethylthiuram disulfide	Disulfiram	97-77-8	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Tetrahydrofuran	N/A	109-99-9	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Tetramethylthiuram disulfide	Thiram	137-26-8	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Tetramethylthiuram monosulfide	N/A	97-74-5	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Thiazoles	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Thioureas	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Thiurams	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Thiuram sulfides	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Toluene	N/A	108-88-3	N/A	N/A	8.00E-01	5	N/A	N/A	N/A
Total petroleum hydrocarbons	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Trans trans-muconic acid	(E,E)-Muconic acid	3588-17-8	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Trimethyl-1,2-dihydroquinoline (TMDQ)	1,2-Dihydro-2,2,4-trimethylquinoline, polymer	26780-96-1	N/A	N/A	N/A	N/A	N/A	N/A	N/A

	Chemical Constituent[a]	Synonym[b]	CAS Number[c]	EPA PPRTVs[2] Chronic RfD (mg/kg-day)	EPA PPRTVs Chronic RfC (mg/m^3)	EPA PPRTVs Subchronic RfD (mg/kg-day)	EPA PPRTVs Subchronic RfC (mg/m^3)	EPA PPRTVs Cancer Classification	EPA PPRTVs Oral SF ($mg/kg\text{-}day^{-1}$)	EPA PPRTVs Inhal. UR (mg/m^{3-1})
	1,1,1-Trichloroethane	N/A	71-55-6	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Trichloroethylene	N/A	79-01-6	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	1,1,2-Trichloro-1,2,2-trifluoroethane	N/A	76-13-1	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Trichloro-trifluoroethane	1,1,1-Trichloro-2,2,2-trifluoroethane	354-58-5	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Tricosane	N/A	638-67-5	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	1,2,3-Trimethyl benzene	1,2,3-Trimethylbenzene	526-73-8	N/A	5.00E-03	N/A	5.00E-02	N/A	N/A	N/A
	1,2,4-Trimethyl benzene	1,2,4-Trimethylbenzene	95-63-6	N/A	7.00E-03	N/A	7.00E-02	N/A	N/A	N/A
	1,3,5-Trimethyl benzene	1,3,5-Trimethylbenzene	108-67-8	N/A	N/A	N/A	1.00E-02	N/A	N/A	N/A
	2,2,4-Trimethyl-1,2-dihydroquinoline (TMQ)	1,2-Dihydro-2,2,4-trimethylquinoline, polymer	26780-96-1	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Vinyl Acetate	N/A	108-05-4	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	White gasoline	Natural gasoline	8006-61-9	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	o-Xylene	N/A	95-47-6	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Xylenes	N/A	1330-20-7	N/A	N/A	4.00E-01	4.00E-01	N/A	N/A	N/A
	Zn-Dibenzyldithiocarbamate (ZBEC)	N/A	136-23-2	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Zn-Diethyldithiocarbamate (ZDEC)	Zinc diethyldithiocarbamate	14324-55-1	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Zn-Dimethyldithiocarbamate (ZDMC)	Ziram	137-30-4	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Zn-dibutyldithiocarbamate (ZDBC)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	ZnO	Zinc Oxide	1314-13-2	N/A	N/A	N/A	N/A	N/A	N/A	N/A
TOTALS	**355**	**158**	**290**	**15**	**12**	**40**	**23**	**0**	**3**	**1**
PERCENTS	**100%**	**45%**	**82%**	**4%**	**3%**	**11%**	**6%**	**0%**	**1%**	**0%**

Chemical Constituent[a]	Synonym[b]	CAS Number[c]	EPA HEAST[3] Chronic RfD (mg/kg-day)	EPA HEAST Chronic RfC (mg/m^3)	EPA HEAST Subchronic RfD (mg/kg-day)	EPA HEAST Subchronic RfC (mg/m^3)	EPA HEAST Cancer Classification	EPA HEAST Oral SF (mg/kg-day^{-1})	EPA HEAST Inhal. SF (mg/kg-day^{-1})	EPA HEAST Inhal. UR (ug/m$^{3-1}$)
Aluminum	N/A	7429-90-5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Antimony	N/A	7440-36-0	N/A	N/A	4.00E-04	N/A	N/A	N/A	N/A	N/A
Arsenic	N/A	7440-38-2	N/A	N/A	3.00E-04	N/A	N/A	N/A	N/A	N/A
Barium	N/A	7440-39-3	N/A	5.00E-04	7.00E-02	5.00E-03	N/A	N/A	N/A	N/A
Beryllium	N/A	7440-41-7	N/A	N/A	5.00E-03	N/A	N/A	N/A	8.4	N/A
Cadmium	N/A	7440-43-9	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Calcium	N/A	7440-70-2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Chloride	N/A	16887-00-6	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Chromium	N/A	7440-47-3; 16065-83-1 (CrIII); 18540-29-9 (CrVI)	N/A	N/A	1.0 (CrIII) 2E-2 (CrVI)	N/A	N/A	N/A	40 (CrVI)	N/A
Cobalt	N/A	7440-48-4	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Copper	N/A	7440-50-8	1.3 mg/L	N/A	1.3 mg/L	N/A	N/A	N/A	N/A	N/A
Iron	N/A	7439-89-6	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Lead	N/A	7439-92-1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Lithium	N/A	7439-93-2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Magnesium	N/A	7439-95-4	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Manganese	N/A	7439-96-5	N/A	N/A	1.40E-01	N/A	N/A	N/A	N/A	N/A
Mercury	N/A	7439-97-6	N/A	3.00E-04	N/A	3.00E-04	N/A	N/A	N/A	N/A
Molybdenum	N/A	7439-98-7	N/A	N/A	5.00E-03	N/A	N/A	N/A	N/A	N/A
Nickel	N/A	7440-02-0	N/A	N/A	2E-2 (sol. salts)	N/A	N/A	N/A	8.4e-1 (refinery dust)	N/A
Phosphorous	N/A	7723-14-0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Potassium	N/A	7440-09-7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Rubidium	N/A	7440-17-7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Selenium	N/A	7782-49-2	N/A	N/A	5.00E-03	N/A	N/A	N/A	N/A	N/A
Silver	N/A	7440-22-4	N/A	N/A	5.00E-03	N/A	N/A	N/A	N/A	N/A
Sodium	N/A	7440-23-5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Strontium	N/A	7440-24-6	N/A	N/A	6.00E-01	N/A	N/A	N/A	N/A	N/A
Sulfur	N/A	7704-34-9	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Thallium	N/A	7440-28-0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Tin	N/A	7440-31-5	6.00E-01	N/A	6.00E-01	N/A	N/A	N/A	N/A	N/A
Titanium	N/A	7440-32-6	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Tungsten	N/A	7440-33-7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Vanadium	N/A	7440-62-2	7.00E-03	N/A	7.00E-03	N/A	N/A	N/A	N/A	N/A
Zinc	N/A	7440-66-6	N/A	N/A	3.00E-01	N/A	N/A	N/A	N/A	N/A
Cadmium and Zinc Soaps	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Acenaphthene	N/A	83-32-9	N/A	N/A	6.00E-01	N/A	N/A	N/A	N/A	N/A

Chemical Constituent[a]	Synonym[b]	CAS Number[c]	EPA HEAST[3] Chronic RfD (mg/kg-day)	EPA HEAST Chronic RfC (mg/m^3)	EPA HEAST Subchronic RfD (mg/kg-day)	EPA HEAST Subchronic RfC (mg/m^3)	EPA HEAST Cancer Classification	EPA HEAST Oral SF ($mg/kg\text{-}day^{-1}$)	EPA HEAST Inhal. SF ($mg/kg\text{-}day^{-1}$)	EPA HEAST Inhal. UR ($ug/m^{3\text{-}1}$)
Acenaphthylene	N/A	208-96-8	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Acetaldehyde	Ethanone	75-07-0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Acetamide, N-cyclohexyl-	N/A	1124-53-4	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Acetone	N/A	67-64-1	N/A	N/A	1	N/A	N/A	N/A	N/A	N/A
Acetone-diphenylamine condensation product (ADPA)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Acetonitrile	N/A	75-05-8	N/A	5.00E-02	0.06 (inhalation)	5.00E-01	N/A	N/A	N/A	N/A
Acetophenone	N/A	98-86-2	N/A	N/A	1	N/A	N/A	N/A	N/A	N/A
6-Acetoxy-2,2-dimethyl-m-dioxane	Dimethoxane	828-00-2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Acrolein	N/A	107-02-8	2.00E-02	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Alcohols	Ethanol	64-17-5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Aldehydes	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Alkyl benzenes	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Alkyl dithiols	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Alkyl naphthalenes	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Alkyl phenols	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Alpha pinene	alpha-Pinene	80-56-8	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Amine (N-dialkyl analine derivative)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Amines	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Anathrene [c]	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Aniline	Benzeneamine; aminobenzene	62-53-3	N/A	N/A	N/A	1.00E-02	N/A	N/A	N/A	N/A
Anthanthrene	N/A	191-26-4	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Anthracene	N/A	120-12-7	N/A	N/A	3	N/A	N/A	N/A	N/A	N/A
Aromatic oil	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9,10-Anthracenedione, 2-ethyl	2-Ethylanthracene-9,10-dione	84-51-5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Azobenzene	N/A	103-33-3	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Benz(e)acenaphthylene	Acephenanthrylene	201-06-9	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Benzaldehyde, 3-hydroxyl-4-methoxy	3-Hydroxy-4-methoxy-benzaldehyde	621-59-0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Benz(a)anthracene	N/A	56-55-3	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Benzene	N/A	71-43-2	N/A	N/A	N/A	N/A	N/A	N/A	2.90E-02	N/A
Benzene, 1,3-bis(1-methylethenyl)-	1,3-bis(1-methylethenyl)benzene; 1,3-Diisopropenylbenzene	3748-13-8	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Benzene, 1,4-bis(1-methylethenyl)-	1,4-Bis(1-methylethenyl)benzene	1605-18-1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1,4-Benzenediamine, N,N'-diphenyl-	N,N'-Diphenyl-p-phenylenediamine	74-31-7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1,4-Benzendiamin, N-(1-methylethyl)-N'-phenyl-, (IPPD)	N-Isopropyl-N'-phenyl-p-phenylenediamine, Isopropylaminodephenylamine (IPPD)	101-72-4	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Benzene, isocyanato-	Phenyl isocyanate	103-71-9	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Benzenemethanol	Benzyl alcohol	100-51-6	3.00E-01	N/A	1	N/A	N/A	N/A	N/A	N/A
Benzo(def)dibenzothiophene	Phenanthro[4,5-bcd]thiophene	30796-92-0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Benzo(g)dibenzothiophene	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Benzo(b)fluoranthene	N/A	205-99-2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Benzo(bjk)fluoranthene	2,11-(Metheno)benzo[a]fluorene	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Benzo(ghi)fluoranthene	Benzo[ghi]fluoranthene	203-12-3	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Benzo(i)fluoranthene	Benzo(j)fluoranthene	205-82-3	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Benzo(k)fluoranthene	N/A	207-08-9	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Benzo(mno)fluoranthene	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Benzo(a)fluorene	11H-Benzo[a]fluorene	238-84-6	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Benzo(b)fluorene	2,3-Benzofluorene	243-17-4	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Benzo(def)naphthobenzothiophene	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6H-Benzo[cd]pyren-6-one	6H-Benzo(cd)pyren-6-one	3074-00-8	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Chemical Constituent[a]	Synonym[b]	CAS Number[c]	EPA HEAST[3] Chronic RfD (mg/kg-day)	EPA HEAST Chronic RfC (mg/m^3)	EPA HEAST Subchronic RfD (mg/kg-day)	EPA HEAST Subchronic RfC (mg/m^3)	EPA HEAST Cancer Classification	EPA HEAST Oral SF ($mg/kg\text{-}day^{-1}$)	EPA HEAST Inhal. SF ($mg/kg\text{-}day^{-1}$)	EPA HEAST Inhal. UR ($ug/m^{3\text{-}1}$)
Benzo(a)pyrene	N/A	50-32-8	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Benzo(e)pyrene	N/A	192-97-2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Benzo(ghi)perylene	Benzo(g,h,i)perylene	191-24-2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Benzoic acid	N/A	65-85-0	N/A	N/A	4	N/A	N/A	N/A	N/A	N/A
Benzothiazole	N/A	95-16-9	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Benzothiazole, 2-(methylthio)	2-(Methylthio)benzothiazole	615-22-5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Benzothiazole, 2-phenyl	2-Phenylbenzothiazole	883-93-2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Benzothiazolone	2-Hydroxybenzothiazole, 2(3H)-Benzothiazolone, 2(3H) benzothiazolone	934-34-9	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Benzoyl and other peroxides	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Benzylbutyl phthalate	Butyl benzyl phthalate	85-68-7	N/A	N/A	2	N/A	N/A	N/A	N/A	N/A
Biphenyl	1,1'-Biphenyl	92-52-4	N/A	N/A	5.00E-02	N/A	N/A	N/A	N/A	N/A
1,1'-Biphenyl, 4, 4', 5', 6'-tetramethoxy-	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
(N,N`-Bis(1,4-dimethylpentyl) pphenylendiamine) (7PPD)	N,N'-Bis(1,4-dimethylpentyl)-4-phenylenediamine	3081-14-9	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Bis(2-ethylhexyl) phthalate	Di(2-ethylhexyl) phthalate	117-81-7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Bis-(2,2,6,6-tetramethyl-4-piperidinyl)sebacate	Bis(2,2,6,6-tetramethyl-4-piperidyl) sebacate	52829-07-9	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Bisthiol acids	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Black rubber	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Bromodichloromethane	N/A	75-27-4	N/A	N/A	2.00E-02	N/A	N/A	N/A	N/A	N/A
Bromoform	N/A	75-25-2	N/A	N/A	2.00E-01	N/A	N/A	N/A	N/A	N/A
1,3 Butadiene	N/A	106-99-0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Butoxyethoxyethanol	2-(2-Butoxyethoxy)ethanol, diethylene glycol monobutyl ether	112-34-5	N/A	2.00E-02	N/A	2.00E-01	N/A	N/A	N/A	N/A
Butylated hydroxyanisole	N/A	25013-16-5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Butylated hydroxytoluene	2,6-Di-tert-butyl-4-methylphenol (BHT)	128-37-0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Butylbenzene	N/A	104-51-8	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Caprolactam disulfide (CLD)	1,1'-Disulfanediyldiazepan-2-one	23847-08-7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Carbazole	N/A	86-74-8	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Carbon Black	Furnace Black	1333-86-4	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Carbon Disulfide	N/A	75-15-0	N/A	N/A	0.1 (inhalation)	0.7	N/A	N/A	N/A	N/A
Carbon Tetrachloride	N/A	56-23-5	N/A	N/A	N/A	N/A	N/A	N/A	3.00E-02	N/A
Chlorobenzene	N/A	108-90-7	N/A	2.00E-02	N/A	N/A	N/A	N/A	N/A	N/A
Chloroform	Trichloromethane	67-66-3	N/A	N/A	1.00E-02	N/A	N/A	N/A	N/A	N/A
Chloromethane	Methyl chloride	74-87-3	N/A	N/A	N/A	N/A	N/A	1.30E-02	6.30E-03	1.80E-06
Chrysene	N/A	218-01-9	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Coronene	N/A	191-07-1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
o-Cyanobenzoic acid	2-Cyanobenzoic acid	3839-22-3	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Cyclohexanamine	Cyclohexylamine	108-91-8	N/A	N/A	3.00E-01	N/A	N/A	N/A	N/A	N/A

Chemical Constituent[a]	Synonym[b]	CAS Number[c]	EPA HEAST[3] Chronic RfD (mg/kg-day)	EPA HEAST Chronic RfC (mg/m³)	EPA HEAST Subchronic RfD (mg/kg-day)	EPA HEAST Subchronic RfC (mg/m³)	EPA HEAST Cancer Classification	EPA HEAST Oral SF (mg/kg-day⁻¹)	EPA HEAST Inhal. SF (mg/kg-day⁻¹)	EPA HEAST Inhal. UR (ug/m³⁻¹)
Cyclohexanamine, N-cyclohexyl-	Dicyclohexylamine	101-83-7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Cyclohexanamine, N-cyclohexyl-N-methyl-	N-Cyclohexyl-N-methylcyclohexanamine	7560-83-0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Cyclohexane	N/A	110-82-7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Cyclohexane, isocyanato	Isocyanatocyclohexane	3173-53-3	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Cyclohexane, isothiocyanato-	N/A	1122-82-3	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Cyclohexanone	N/A	108-94-1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
N-Cyclohexyl-2-benzothiazolesulfenamide (CBS)	N-Cyclohexyl-2-benzothiazolesulfenamide	95-33-0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
n-Cyclohexyl-formamide	N-Cyclohexylformamide, Formamide, N-cyclohexyl	766-93-8	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Cycloninasiloxane, octadecamethyl-	Octadecamethylcyclononasiloxane	556-71-8	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Cyclopenta[cd]pyrene	N/A	27208-37-3	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4H-cyclopenta[def]phenanthren-4-one	4H-Cyclopenta(def)phenanthren-4-one	5737-13-3	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4H-cyclopenta[def]-phenanthrene	4-H-Cyclopenta(d,e,f)phenanthrene	203-64-5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Cyclopentane, methyl-	Methylcyclopentane	96-37-7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Decane	N/A	124-18-5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Diazoaminobenzenes	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Dibenzo(a,h) anthracene	Dibenz(a,h)anthracene	53-70-3	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Dibenzofurane	Dibenzofuran	132-64-9	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Dibenzo(ae)pyrene	Naphtho(1,2,3,4-def)chrysene	192-65-4	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Dibenzo(ai)pyrene	Dibenzo[a,i]pyrene	189-55-9	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Dibenzo(ah)pyrene	Dibenzo[a,h]pyrene	189-64-0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Dibenzothiophene	N/A	132-65-0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Dibutyl phthalate	N/A	84-74-2	N/A	N/A	1	N/A	N/A	N/A	N/A	N/A
1,4-Dichlorobenzene	p-dichlorobenzene	106-46-7	N/A	N/A	N/A	2.5	N/A	N/A	N/A	N/A
Dichlorodifluoromethane	Freon 12	75-71-8	N/A	2.00E-01	9.00E-01	2	N/A	N/A	N/A	N/A
1,2-Dichloroethane	Ethylene dichloride	107-06-2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
cis-1,2-Dichloroethene	(Z)-1,2-Dichloroethylene	156-59-2	1.00E-02	N/A	1.00E-01	N/A	N/A	N/A	N/A	N/A
1,2-Dichloropropane	N/A	78-87-5	N/A	N/A	N/A	1.30E-02	N/A	N/A	N/A	N/A
N,N-Dicyclohexyl-2-benzothiazolesulfenamide (DCBS)	N,N-Dicyclohexyl-2-benzothiazolesulfenamide	4979-32-2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Dicyclohexylphthalate (DCHP)	Dicyclohexyl phthalate	84-61-7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1,3-Dicyclohexylurea	N,N'-Dicyclohexylurea	2387-23-7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Diethenylbenzene	Divinylbenzene	1321-74-0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Di(2-ethylhexyl) adipate	Hexanedioic acid, bis(2-ehtylhexyl); Bis(2-ethylhexyl)hexanedioic acid	103-23-1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Diethyl phthalate	N/A	84-66-2	N/A	N/A	8	N/A	N/A	N/A	N/A	N/A
Diethylthiourea (DETU)	N,N'-Diethylthiourea	105-55-5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Dihydrocyclopentapyrene	2,3-Acepyrene	25732-74-5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Diisobutyl phthalate	N/A	84-69-5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Diisodecylphthalate	bis(8-Methylnonyl) phthalate	89-16-7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Diisononyl phthalate	DINP	28553-12-0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9,l0-Dimethyl-1,2-Benzanthracene	7,12-Dimethylbenz(a)anthracene	57-97-6	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
(N-1,3-dimethyl-butyl)-N'- phenyl-p-phenylenediamine (6PPD)	N-(1,3-Dimethylbutyl)-N'-phenyl-p-phenylenediamine	793-24-8	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Dimethyldiphenylthiuram disulfide (MPTD)	Dimethyldiphenylthiuram disulfide	53880-86-7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2,6-Dimethylnaphthalene	N/A	581-42-0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2,4-Dimethylphenol	N/A	105-67-9	N/A	N/A	2.00E-01	N/A	N/A	N/A	N/A	N/A
Dimethyl phthalate	N/A	131-11-3	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Dinitroarenes	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Di-n-octyl phthalate	Dioctyl phthalate	117-84-0	2.00E-02	N/A	2.00E-02	N/A	N/A	N/A	N/A	N/A
Di-ortho-tolylguanidine	N/A	97-39-2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Dipentamethylenethiuramtetrasulfide (DPTT)	Bis(pentamethylenethiuram)tetrasulfide	120-54-7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Chemical Constituent[a]	Synonym[b]	CAS Number[c]	EPA HEAST[3] Chronic RfD (mg/kg-day)	EPA HEAST Chronic RfC (mg/m^3)	EPA HEAST Subchronic RfD (mg/kg-day)	EPA HEAST Subchronic RfC (mg/m^3)	EPA HEAST Cancer Classification	EPA HEAST Oral SF ($mg/kg\text{-}day^{-1}$)	EPA HEAST Inhal. SF ($mg/kg\text{-}day^{-1}$)	EPA HEAST Inhal. UR (ug/m^{3-1})
Diphenylamine	N/A	122-39-4	N/A	N/A	2.50E-02	N/A	N/A	N/A	N/A	N/A
N,N'-Diphenylguanidine (DPG)	1,3-Diphenylguanidine	102-06-7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
N,N'-Diphenyl-p-phenylenediamine (DPPD)	N,N'-Diphenyl-p-phenylenediamine	74-31-7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Disulfides	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Di-(2-ethyl)hexylphosphorylpolysul fide) (SDT)	Bis-(ethylhexylthiophosphoryl) polysulfide	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3,5-Di-tert-Butyl-4-hydroxybenzaldehyde	N/A	1620-98-0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2,2’-Dithiobis(benzothiazole)	2,2'-Dithiobisbenzothiazole	120-78-5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Dithiocarbamates	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Dithiomorpholine (DTDM)	4,4'-Dithiodimorpholine	103-34-4	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Dithiophosphates	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
N,N`-Ditolyl-p-phenylenediamine (DTPD)	N,N'-Ditolyl-p-phenylenediamine	27417-40-9	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Docosanoic acid	N/A	112-85-6	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Dodecanoic acid	N/A	143-07-7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Dotriacontane	N/A	544-85-4	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Drometrizol	2-(2H-Benzotriazol-2-yl)-4-methylphenol	2440-22-4	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Eicosane	N/A	112-95-8	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Erucylamide	Erucamide	112-84-5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Esters	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Ethanol, 2-butoxy-	2-Butoxyethanol	111-76-2	N/A	2.00E-02	N/A	2.00E-01	N/A	N/A	N/A	N/A
Ethanol, 1-(2-butoxyethoxy)	1-(2-Butoxyethoxy)ethanol	54446-78-5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Ethanone, 1,1'-(1,3-phenylene)bis-	Benzene-1,3-bis(acetyl)	6781-42-6	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Ethanone, 1,1'-(1,4-phenylene)bis-	1,1-(1,4-Phenylene)bis-ethanone	1009-61-6	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Ethanone, 1-[4-(1-methylethenyl) phenyl]-	1-[4-(1-Methylethenyl)phenyl]ethanone	5359-04-6	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Ethyl Acetate	N/A	141-78-6	N/A	N/A	9	N/A	N/A	N/A	N/A	N/A
Ethyl benzene	Ethylbenzene	100-41-4	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Ethyl benzene aldehyde	Benzaldehyde, 2-ethyl-	22927-13-5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Ethylene thiourea (Ethylene thiourea)	N/A	96-45-7	N/A	N/A	8.00E-05	N/A	N/A	N/A	N/A	N/A
2-Ethyl-1-hexanol	N/A	104-76-7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1-Ethyl-4-Methyl Benzene	4-Ethyltoluene	622-96-8	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Fluoranthene	N/A	206-44-0	N/A	N/A	4.00E-01	N/A	N/A	N/A	N/A	N/A
Fluorene	N/A	86-73-7	N/A	N/A	4.00E-01	N/A	N/A	N/A	N/A	N/A
Formaldehyde	N/A	50-00-0	N/A	N/A	2.00E-01	N/A	N/A	N/A	N/A	N/A
Furan, 2-methyl	2-Methylfuran	534-22-5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2(3H)-Furanone,dihydro-4-hydroxy-	Dihydro-4-hydroxy-2(3H)-furanone; beta-Hydroxybutyrolactone	5469-16-9	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Guanidines	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Halocarbon 11	Trichlorofluoromethane, Freon 11	75-69-4	N/A	N/A	7.00E-01	N/A	N/A	N/A	N/A	N/A
Hemeicosane[c]	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Heptadecane	N/A	629-78-7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Heptane	N/A	142-82-5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Heptanonitrile	Heptanenitrile	629-08-3	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Hexacosane	N/A	630-01-3	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Hexadecane	N/A	544-76-3	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Hexa(methoxymethyl)melamine	N,N,N',N',N'',N''-Hexakis(methoxy methyl)-1,3,5-triazine-2,4,6-triamine	3089-11-0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Hexamethylenetetramine	Methenamine	100-97-0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Hexane	n-Hexane	110-54-3	6.00E-02	N/A	6.00E-01	2.00E-01	N/A	N/A	N/A	N/A
Hexanedioic acid, methyl ester	Methyl hexanedioate	627-91-8	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Hexanoic acid, 2-ethyl-	2-Ethylhexanoic acid	149-57-5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Hydrocarbon (olefin/aromatic)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Chemical Constituent[a]	Synonym[b]	CAS Number[c]	EPA HEAST[3] Chronic RfD (mg/kg-day)	EPA HEAST Chronic RfC (mg/m^3)	EPA HEAST Subchronic RfD (mg/kg-day)	EPA HEAST Subchronic RfC (mg/m^3)	EPA HEAST Cancer Classification	EPA HEAST Oral SF ($mg/kg\text{-}day^{-1}$)	EPA HEAST Inhal. SF ($mg/kg\text{-}day^{-1}$)	EPA HEAST Inhal. UR (ug/m^{3-1})
7-Hydroxybenzo[f]flavone	7-Hydroxy-3-phenyl-1H-naphtho[2,1-b] pyran-1-one	86247-95-2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1-Hydroxypyrene	N/A	5315-79-7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Indeno[l,2,3-cd]pyrene	o-Phenylenepyrene	193-39-5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1H-isoindole-1,3 (2H)-dione	Phthalimide	85-41-6	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
iso-nonylphenol	3-Nonylphenol	11066-49-2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Isophorone	N/A	78-59-1	N/A	N/A	2	N/A	N/A	N/A	N/A	N/A
Isopropyl Alcohol	2-Propanol, Isopropanol	67-63-0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Isopropylbenzene	Cumene	98-82-8	N/A	9.00E-03	4.00E-01	9.00E-02	N/A	N/A	N/A	N/A
Isopropyltoluene	1-Methyl-2-(propan-2-yl)benzene	527-84-4	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Ketones	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Latex protein	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Limonene	N/A	138-86-3	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
MEK	Methyl ethyl ketone	78-93-3	N/A	N/A	2	1	N/A	N/A	N/A	N/A
2-Mercaptobenzothiazole	N/A	149-30-4	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Methane, diethoxy-cyclohexane	Diethoxycyclohexanemethane; Bis(cyclohexyloxy)methane	1453-21-0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Methyl Alcohol	Methanol	67-56-1	N/A	N/A	5	N/A	N/A	N/A	N/A	N/A
2-Methylanthracene	N/A	613-12-7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2-Methyl-Butane	2-Methylbutane	78-78-4	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2,2-Methylene-bis-(4-methyl-6-tert-butylphenol) (BPH)	N/A	119-47-1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Methylene Chloride	Dichloromethane	75-09-2	N/A	3	6.00E-02	3	N/A	N/A	N/A	N/A
5-Methyl-2-hexanone	Methyl isoamyl ketone	110-12-3	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1-Methylnaphthalene	N/A	90-12-0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2-Methylnaphthalene	N/A	91-57-6	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3-Methyl-Pentane	3-Methylpentane	96-14-0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4-Methyl-2-pentanone	MIBK, Methyl isobutyl ketone	108-10-1	8.00E-02	N/A	8.00E-01	N/A	N/A	N/A	N/A	N/A
1-Methylphenanthrene	1-Methyl phenanthrene	832-69-9	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2-Methylphenanthrene	N/A	2531-84-2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3-Methylphenanthrene	N/A	832-71-3	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9-Methylphenanthrene	N/A	883-20-5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2-Methylphenol	o-Cresol	95-48-7	N/A	N/A	5.00E-01	N/A	N/A	N/A	N/A	N/A
4-Methylphenol	p-Cresol	106-44-5	5.00E-03	N/A	5.00E-03	N/A	N/A	N/A	N/A	N/A
MES (special purified aromatic oil)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2-(4-morpholino)benzothiazole	2-morpholinothio benzothiazole (MBS); Morpholinothio-benzothiazole; N-Oxydiethylenebenzothiazole-2-sulfenamide	102-77-2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2-Morpholinodithiobenzothiazole (MBSS)	2-(Morpholin-4-yldithio)-1,3-benzothiazole	95-32-9	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Naphthalene	N/A	91-20-3	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Naphthalene, 2-(bromomethyl)-	2-Bromomethylnaphthalene	939-26-4	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Naphthalic Anhydride	1H,3H-Naphtho(1,8-cd)pyran-1,3-dione	81-84-5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Napthenic oil	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Nitro compound (isomer of major peak)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Nitro compound (nitro-ether derivative)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Nitrogen containing substances	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Nitrosodibutylamine (n-)	N-Nitrosodibutylamine	924-16-3	N/A	N/A	N/A	N/A	N/A	N/A	5.4	N/A
Nitrosodiethylamine (n-)	N-Nitrosodiethylamine	55-18-5	N/A	N/A	N/A	N/A	N/A	N/A	1.50E+02	N/A
Nitrosodimethylamine (n-)	N-Nitrosodimethylamine	62-75-9	N/A	N/A	N/A	N/A	N/A	N/A	5.10E+01	N/A
n-Nitrosodiphenylamine	N-Nitrosodiphenylamine	86-30-6	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Nitrosodipropylamine (n-)	N-Nitrosodipropylamine	621-64-7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Nitrosomorpholine (n-)	N-Nitrosomorpholine	59-89-2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Nitrosopiperidine (n-)	N-Nitrosopiperidine	100-75-4	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Chemical Constituent[a]	Synonym[b]	CAS Number[c]	EPA HEAST[3] Chronic RfD (mg/kg-day)	EPA HEAST Chronic RfC (mg/m^3)	EPA HEAST Subchronic RfD (mg/kg-day)	EPA HEAST Subchronic RfC (mg/m^3)	EPA HEAST Cancer Classification	EPA HEAST Oral SF (mg/kg-day^{-1})	EPA HEAST Inhal. SF (mg/kg-day^{-1})	EPA HEAST Inhal. UR (ug/m$^{3-1}$)
Nitrosopyrrolidine (n-)	N-Nitrosopyrrolidine	930-55-2	N/A	N/A	N/A	N/A	N/A	N/A	2.1	N/A
Nonadecane	N/A	629-92-5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Nonanale	Nonanal	124-19-6	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Nonane	N/A	111-84-2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4-n-nonylphenol	4-Nonylphenol	104-40-5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Octadecanoic acid, methyl ester	Methyl stearate	112-61-8	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Octane	N/A	111-65-9	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4-t-octylphenol	4-(1,1,3,3-Tetramethylbutyl)phenol, 4-tert-(octyl)-phenol	140-66-9	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Optadecane	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Organic thiola and sulfides	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Orthocarbonate - Carboxy compound)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
N-Oxydiethylenedithiocarbamyl-N`-oxydiethylenesulfenamide (OTOS)	N/A	13752-51-7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
PAHs	Polycyclic aromatic hydrocarbons	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Parrafinic oils	Mineral oil	8012-95-1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
PCB sum	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
PCDD/F sum	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Pentacosane	N/A	629-99-2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Pentane	N/A	109-66-0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Perylene	N/A	198-55-0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Petroleum Naphtha	Naphtha	8030-30-6	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Phenalone	Phenalen-1-one	548-39-0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Phenanthrene	N/A	85-01-8	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1-Phenanthrenecarboxylic acid, 1,2,3,4,4	1,2,3,4,4-1-Phenanthrene carboxylic acid; Dehydroabietic acid	1740-19-8	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Phenol	2,4-Di-tert-butylphenol	108-95-2	N/A	N/A	6.00E-01	N/A	N/A	N/A	N/A	N/A
Phenolics	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Phenol, 2,4-bis(1,1-dimethylethyl)-	N/A	96-76-4	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Phenol, 2,4-bis(1-methyl-1-phenylethyl)-	2,4-Bis(1-methyl-1-phenylethyl)phenol	2772-45-4	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Phenol, m-tert-butyl-	3-tert-Butylphenol	585-34-2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Phenylbenzimidazole	2-Phenylbenzimidazole	716-79-0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
p-Phenylenediamines	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Phenylenediamines	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2-(1-phenylethyl)-phenol	2-(1-Phenylethyl)phenol	26857-99-8	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3-Phenyl-2-propenal	3-Phenylprop-2-enal	104-55-2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Phthalates	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
PM 2.5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
PM 10	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Poly- and di-nitrobenzenes	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Poly-p-dinitrosobenzene	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Propene	1-Propene; propylene	115-07-1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Propylbenzene	N/A	103-65-1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Pyrazole	N/A	288-13-1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Pyrene	N/A	129-00-0	N/A	N/A	3.00E-01	N/A	N/A	N/A	N/A	N/A
Pyrimidine, 2-(4-pentylphenyl)-5-propyl-	N/A	94320-32-8	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2-Pyrrolidinone. 1-methyl-	N-Methyl-2-pyrrolidone	872-50-4	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Quinones	N/A	106-51-4	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Resorcinol	N/A	108-46-3	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Rethene [c]	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Siloxanes	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

	Chemical Constituent[a]	Synonym[b]	CAS Number[c]	EPA HEAST[3] Chronic RfD (mg/kg-day)	EPA HEAST Chronic RfC (mg/m^3)	EPA HEAST Subchronic RfD (mg/kg-day)	EPA HEAST Subchronic RfC (mg/m^3)	EPA HEAST Cancer Classification	EPA HEAST Oral SF ($mg/kg\text{-}day^{-1}$)	EPA HEAST Inhal. SF ($mg/kg\text{-}day^{-1}$)	EPA HEAST Inhal. UR (ug/m^{3-1})
	Styrene	N/A	100-42-5	N/A	N/A	N/A	3	N/A	N/A	N/A	N/A
	Styrene oligomers	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Substituted p-Phenylenediamines	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Sulfur containing organics	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Sulfur Donors	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Sulphenamides	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	TDAE (special purified aromatic oil)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Tertbutylacetophenone	3,3-dimethyl-1-phenylbutan-1-one	31366-07-1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	N-tert-Butyl-2-benzothiazolesulf enamide (TBBS)	N/A	95-31-8	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	4-tert butylphenol	4-tert-Butylphenol	98-54-4	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Tetraalkylthiuram disulfides	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Tetrabenzylthiuram disulfide (TBZTD)	N/A	10591-85-2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Tetrabutylthiuram disulfide (TBTD)	N/A	1634-02-2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Tetrachloroethene	Tetrachloroethylene; perchloroethylene	127-18-4	N/A	N/A	1.00E-01	N/A	N/A	N/A	N/A	N/A
	Tetracosane	N/A	646-31-1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Tetraethylthiuram disulfide	Disulfiram	97-77-8	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Tetrahydrofuran	N/A	109-99-9	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Tetramethylthiuram disulfide	Thiram	137-26-8	N/A	N/A	6.00E-03	N/A	N/A	N/A	N/A	N/A
	Tetramethylthiuram monosulfide	N/A	97-74-5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Thiazoles	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Thioureas	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Thiurams	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Thiuram sulfides	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Toluene	N/A	108-88-3	N/A	N/A	2	N/A	N/A	N/A	N/A	N/A
	Total petroleum hydrocarbons	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Trans trans-muconic acid	(E,E)-Muconic acid	3588-17-8	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Trimethyl-1,2-dihydroquinoline (TMDQ)	1,2-Dihydro-2,2,4-trimethylquinoline, polymer	26780-96-1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	1,1,1-Trichloroethane	N/A	71-55-6	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Trichloroethylene	N/A	79-01-6	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	1,1,2-Trichloro-1,2,2-trifluoroethane	N/A	76-13-1	N/A	30	3	30	N/A	N/A	N/A	N/A
	Trichloro-trifluoroethane	1,1,1-Trichloro-2,2,2-trifluoroethane	354-58-5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Tricosane	N/A	638-67-5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	1,2,3-Trimethyl benzene	1,2,3-Trimethylbenzene	526-73-8	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	1,2,4-Trimethyl benzene	1,2,4-Trimethylbenzene	95-63-6	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	1,3,5-Trimethyl benzene	1,3,5-Trimethylbenzene	108-67-8	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	2,2,4-Trimethyl-1,2-dihydroquinoline (TMQ)	1,2-Dihydro-2,2,4-trimethylquinoline, polymer	26780-96-1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Vinyl Acetate	N/A	108-05-4	1	N/A	1	2.00E-01	N/A	N/A	N/A	N/A
	White gasoline	Natural gasoline	8006-61-9	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	o-Xylene	N/A	95-47-6	2	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Xylenes	N/A	1330-20-7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Zn-Dibenzyldithiocarbamate (ZBEC)	N/A	136-23-2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Zn-Diethyldithiocarbamate (ZDEC)	Zinc diethyldithiocarbamate	14324-55-1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Zn-Dimethyldithiocarbamate (ZDMC)	Ziram	137-30-4	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Zn-dibutyldithiocarbamate (ZDBC)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	ZnO	Zinc Oxide	1314-13-2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
TOTALS	**355**	**158**	**290**	**12**	**10**	**58**	**17**	**0**	**1**	**10**	**1**
PERCENTS	**100%**	**45%**	**82%**	**3%**	**3%**	**16%**	**5%**	**0%**	**0%**	**3%**	**0%**

Chemical Constituent[a]	Synonym[b]	CAS Number[c]	ATSDR MRLs[4] Oral Acute (mg/kg-day)	ATSDR MRLs Oral Interm. (mg/kg-day)	ATSDR MRLs Oral Chronic (mg/kg-day)	ATSDR MRLs Inhal. Acute (ppm)	ATSDR MRLs Inhal. Interm. (ppm)	ATSDR MRLs Inhal. Chronic (ppm)	ATSDR MRLs Inhal. Acute (mg/m^3)	ATSDR MRLs Inhal. Interm. (mg/m^3)	ATSDR MRLs Inhal. Chronic (mg/m^3)
Aluminum	N/A	7429-90-5	N/A	1.0	1.0	N/A	N/A	N/A	N/A	N/A	N/A
Antimony	N/A	7440-36-0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Arsenic	N/A	7440-38-2	0.005	0.0003	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Barium	N/A	7440-39-3	N/A	0.2	0.2	N/A	N/A	N/A	N/A	N/A	N/A
Beryllium	N/A	7440-41-7	N/A	N/A	0.002	N/A	N/A	N/A	N/A	N/A	N/A
Cadmium	N/A	7440-43-9	N/A	0.0005	0.0001	N/A	N/A	N/A	0.00003	N/A	0.00001
Calcium	N/A	7440-70-2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Chloride	N/A	16887-00-6	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Chromium	N/A	7440-47-3; 16065-83-1 (CrIII); 18540-29-9 (CrVI)	N/A	0.005 (CrVI)	0.0009 (CrVI)	N/A	N/A	N/A	N/A	0.0001 (CrIII sol. partic.) 0.005 (CrIII insol. partic.) 5E-6 (CrVI mists) 0.0003 (CrVI partic.)	5E-6 (CrVI mists)
Cobalt	N/A	7440-48-4	N/A	0.01	N/A	N/A	N/A	N/A	N/A	N/A	0.0001
Copper	N/A	7440-50-8	0.01	0.01	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Iron	N/A	7439-89-6	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Lead	N/A	7439-92-1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Lithium	N/A	7439-93-2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Magnesium	N/A	7439-95-4	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Manganese	N/A	7439-96-5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	3.00E-04
Mercury	N/A	7439-97-6	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.0002
Molybdenum	N/A	7439-98-7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Nickel	N/A	7440-02-0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.0002	0.00009
Phosphorous	N/A	7723-14-0	N/A	0.0002	N/A	N/A	N/A	N/A	0.02	N/A	N/A
Potassium	N/A	7440-09-7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Rubidium	N/A	7440-17-7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Selenium	N/A	7782-49-2	N/A	N/A	0.005	N/A	N/A	N/A	N/A	N/A	N/A
Silver	N/A	7440-22-4	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Sodium	N/A	7440-23-5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Strontium	N/A	7440-24-6	N/A	2.0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Sulfur	N/A	7704-34-9	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Thallium	N/A	7440-28-0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Tin	N/A	7440-31-5	N/A	0.3	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Titanium	N/A	7440-32-6	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Tungsten	N/A	7440-33-7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Vanadium	N/A	7440-62-2	N/A	0.01	N/A	N/A	N/A	N/A	0.0008	N/A	0.0001
Zinc	N/A	7440-66-6	N/A	0.3	0.3	N/A	N/A	N/A	N/A	N/A	N/A
Cadmium and Zinc Soaps	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Acenaphthene	N/A	83-32-9	N/A	0.6	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Acenaphthylene	N/A	208-96-8	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Acetaldehyde	Ethanone	75-07-0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Acetamide, N-cyclohexyl-	N/A	1124-53-4	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Acetone	N/A	67-64-1	N/A	2	N/A	26	13	13	N/A	N/A	N/A

Chemical Constituent[a]	Synonym[b]	CAS Number[c]	ATSDR MRLs[4] Oral Acute (mg/kg-day)	ATSDR MRLs Oral Interm. (mg/kg-day)	ATSDR MRLs Oral Chronic (mg/kg-day)	ATSDR MRLs Inhal. Acute (ppm)	ATSDR MRLs Inhal. Interm. (ppm)	ATSDR MRLs Inhal. Chronic (ppm)	ATSDR MRLs Inhal. Acute (mg/m^3)	ATSDR MRLs Inhal. Interm. (mg/m^3)	ATSDR MRLs Inhal. Chronic (mg/m^3)
Acetone-diphenylamine condensation product (ADPA)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Acetonitrile	N/A	75-05-8	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Acetophenone	N/A	98-86-2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6-Acetoxy-2,2-dimethyl-m-dioxane	Dimethoxane	828-00-2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Acrolein	N/A	107-02-8	N/A	0.004	N/A	0.003	0.00004	N/A	N/A	N/A	N/A
Alcohols	Ethanol	64-17-5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Aldehydes	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Alkyl benzenes	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Alkyl dithiols	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Alkyl naphthalenes	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Alkyl phenols	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Alpha pinene	alpha-Pinene	80-56-8	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Amine (N-dialkyl analine derivative)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Amines	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Anathrene [c]	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Aniline	Benzeneamine; aminobenzene	62-53-3	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Anthanthrene	N/A	191-26-4	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Anthracene	N/A	120-12-7	N/A	10	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Aromatic oil	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9,10-Anthracenedione, 2-ethyl	2-Ethylanthracene-9,10-dione	84-51-5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Azobenzene	N/A	103-33-3	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Benz(e)acenaphthylene	Acephenanthrylene	201-06-9	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Benzaldehyde, 3-hydroxyl-4-methoxy	3-Hydroxy-4-methoxy-benzaldehyde	621-59-0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Benz(a)anthracene	N/A	56-55-3	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Benzene	N/A	71-43-2	N/A	N/A	0.005	0.009	0.006	0.003	N/A	N/A	N/A
Benzene, 1,3-bis(1-methylethenyl)-	1,3-bis(1-methylethenyl)benzene; 1,3-Diisopropenylbenzene	3748-13-8	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Benzene, 1,4-bis(1-methylethenyl)-	1,4-Bis(1-methylethenyl)benzene	1605-18-1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1,4-Benzenediamine, N,N'-diphenyl-	N,N'-Diphenyl-p-phenylenediamine	74-31-7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1,4-Benzendiamin, N-(1-methylethyl)-N'-phenyl-, (IPPD)	N-Isopropyl-N'-phenyl-p-phenylenediamine, Isopropylaminodephenylamine (IPPD)	101-72-4	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Benzene, isocyanato-	Phenyl isocyanate	103-71-9	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Benzenemethanol	Benzyl alcohol	100-51-6	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Benzo(def)dibenzothiophene	Phenanthro[4,5-bcd]thiophene	30796-92-0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Benzo(g)dibenzothiophene	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Benzo(b)fluoranthene	N/A	205-99-2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Benzo(bjk)fluoranthene	2,11-(Metheno)benzo[a]fluorene	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Benzo(ghi)fluoranthene	Benzo[ghi]fluoranthene	203-12-3	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Benzo(i)fluoranthene	Benzo(j)fluoranthene	205-82-3	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Benzo(k)fluoranthene	N/A	207-08-9	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Benzo(mno)fluoranthene	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Benzo(a)fluorene	11H-Benzo[a]fluorene	238-84-6	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Benzo(b)fluorene	2,3-Benzofluorene	243-17-4	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Benzo(def)naphthobenzothiophene	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6H-Benzo[cd]pyren-6-one	6H-Benzo(cd)pyren-6-one	3074-00-8	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Benzo(a)pyrene	N/A	50-32-8	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Benzo(e)pyrene	N/A	192-97-2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Benzo(ghi)perylene	Benzo(g,h,i)perylene	191-24-2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Benzoic acid	N/A	65-85-0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Benzothiazole	N/A	95-16-9	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Benzothiazole, 2-(methylthio)	2-(Methylthio)benzothiazole	615-22-5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Benzothiazole, 2-phenyl	2-Phenylbenzothiazole	883-93-2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

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Benzothiazolone	2-Hydroxybenzothiazole, 2(3H)-Benzothiazolone, 2(3H) benzothiazolone	934-34-9	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Benzoyl and other peroxides	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Benzylbutyl phthalate	Butyl benzyl phthalate	85-68-7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Biphenyl	1,1'-Biphenyl	92-52-4	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1,1'-Biphenyl, 4, 4', 5', 6'-tetramethoxy-	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
(N,N`-Bis(1,4-dimethylpentyl) pphenylendiamine) (7PPD)	N,N'-Bis(1,4-dimethylpentyl)-4-phenylenediamine	3081-14-9	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Bis(2-ethylhexyl) phthalate	Di(2-ethylhexyl) phthalate	117-81-7	N/A	0.1	0.06	N/A	N/A	N/A	N/A	N/A	N/A
Bis-(2,2,6,6-tetramethyl-4-piperidinyl)sebacate	Bis(2,2,6,6-tetramethyl-4-piperidyl) sebacate	52829-07-9	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Bisthiol acids	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Black rubber	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Bromodichloromethane	N/A	75-27-4	0.04	N/A	0.02	N/A	N/A	N/A	N/A	N/A	N/A
Bromoform	N/A	75-25-2	0.7	0.2	0.02	N/A	N/A	N/A	N/A	N/A	N/A
1,3 Butadiene	N/A	106-99-0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Butoxyethoxyethanol	2-(2-Butoxyethoxy)ethanol, diethylene glycol monobutyl ether	112-34-5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Butylated hydroxyanisole	N/A	25013-16-5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Butylated hydroxytoluene	2,6-Di-tert-butyl-4-methylphenol (BHT)	128-37-0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Butylbenzene	N/A	104-51-8	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Caprolactam disulfide (CLD)	1,1'-Disulfanediyldiazepan-2-one	23847-08-7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Carbazole	N/A	86-74-8	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Carbon Black	Furnace Black	1333-86-4	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Carbon Disulfide	N/A	75-15-0	0.01	N/A	N/A	N/A	N/A	0.3	N/A	N/A	N/A
Carbon Tetrachloride	N/A	56-23-5	0.02	0.007	N/A	N/A	0.03	0.03	N/A	N/A	N/A
Chlorobenzene	N/A	108-90-7	N/A	0.4	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Chloroform	Trichloromethane	67-66-3	0.3	0.1	0.01	0.1	0.05	0.02	N/A	N/A	N/A
Chloromethane	Methyl chloride	74-87-3	N/A	N/A	N/A	0.5	0.2	0.05	N/A	N/A	N/A
Chrysene	N/A	218-01-9	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Coronene	N/A	191-07-1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
o-Cyanobenzoic acid	2-Cyanobenzoic acid	3839-22-3	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Cyclohexanamine	Cyclohexylamine	108-91-8	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Cyclohexanamine, N-cyclohexyl-	Dicyclohexylamine	101-83-7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Cyclohexanamine, N-cyclohexyl-N-methyl-	N-Cyclohexyl-N-methylcyclohexanamine	7560-83-0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Cyclohexane	N/A	110-82-7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Cyclohexane, isocyanato	Isocyanatocyclohexane	3173-53-3	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Cyclohexane, isothiocyanato-	N/A	1122-82-3	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Cyclohexanone	N/A	108-94-1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
N-Cyclohexyl-2-benzothiazolesulfenamide (CBS)	N-Cyclohexyl-2-benzothiazolesulfenamide	95-33-0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
n-Cyclohexyl-formamide	N-Cyclohexylformamide, Formamide, N-cyclohexyl	766-93-8	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Cycloninasiloxane, octadecamethyl-	Octadecamethylcyclononasiloxane	556-71-8	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Cyclopenta[cd]pyrene	N/A	27208-37-3	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4H-cyclopenta[def]phenanthren-4-one	4H-Cyclopenta(def)phenanthren-4-one	5737-13-3	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

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4H-cyclopenta[def]-phenanthrene	4-H-Cyclopenta(d,e,f)phenanthrene	203-64-5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Cyclopentane, methyl-	Methylcyclopentane	96-37-7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Decane	N/A	124-18-5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Diazoaminobenzenes	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Dibenzo(a,h) anthracene	Dibenz(a,h)anthracene	53-70-3	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Dibenzofurane	Dibenzofuran	132-64-9	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Dibenzo(ae)pyrene	Naphtho(1,2,3,4-def)chrysene	192-65-4	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Dibenzo(ai)pyrene	Dibenzo[a,i]pyrene	189-55-9	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Dibenzo(ah)pyrene	Dibenzo[a,h]pyrene	189-64-0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Dibenzothiophene	N/A	132-65-0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Dibutyl phthalate	N/A	84-74-2	0.5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1,4-Dichlorobenzene	p-dichlorobenzene	106-46-7	N/A	0.07	0.07	2	0.2	0.01	N/A	N/A	N/A
Dichlorodifluoromethane	Freon 12	75-71-8	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1,2-Dichloroethane	Ethylene dichloride	107-06-2	N/A	0.2	N/A	N/A	N/A	0.6	N/A	N/A	N/A
cis-1,2-Dichloroethene	(Z)-1,2-Dichloroethylene	156-59-2	1	0.3	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1,2-Dichloropropane	N/A	78-87-5	0.1	0.07	0.09	0.05	0.007	N/A	N/A	N/A	N/A
N,N-Dicyclohexyl-2-benzothiazolesulfenamide (DCBS)	N,N-Dicyclohexyl-2-benzothiazolesulfenamide	4979-32-2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Dicyclohexylphthalate (DCHP)	Dicyclohexyl phthalate	84-61-7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1,3-Dicyclohexylurea	N,N'-Dicyclohexylurea	2387-23-7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Diethenylbenzene	Divinylbenzene	1321-74-0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Di(2-ethylhexyl) adipate	Hexanedioic acid, bis(2-ehtylhexyl); Bis(2-ethylhexyl)hexanedioic acid	103-23-1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Diethyl phthalate	N/A	84-66-2	7	6	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Diethylthiourea (DETU)	N,N'-Diethylthiourea	105-55-5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Dihydrocyclopentapyrene	2,3-Acepyrene	25732-74-5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Diisobutyl phthalate	N/A	84-69-5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Diisodecylphthalate	bis(8-Methylnonyl) phthalate	89-16-7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Diisononyl phthalate	DINP	28553-12-0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9,l0-Dimethyl-1,2-Benzanthracene	7,12-Dimethylbenz(a)anthracene	57-97-6	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
(N-1,3-dimethyl-butyl)-N'- phenyl-p-phenylenediamine (6PPD)	N-(1,3-Dimethylbutyl)-N'-phenyl-p-phenylenediamine	793-24-8	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Dimethyldiphenylthiuram disulfide (MPTD)	Dimethyldiphenylthiuram disulfide	53880-86-7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2,6-Dimethylnaphthalene	N/A	581-42-0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2,4-Dimethylphenol	N/A	105-67-9	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Dimethyl phthalate	N/A	131-11-3	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Dinitroarenes	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Di-n-octyl phthalate	Dioctyl phthalate	117-84-0	3	0.4	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Di-ortho-tolylguanidine	N/A	97-39-2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Dipentamethylenethiuramtetrasulfide (DPTT)	Bis(pentamethylenethiuram)tetrasulfide	120-54-7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Diphenylamine	N/A	122-39-4	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
N,N'-Diphenylguanidine (DPG)	1,3-Diphenylguanidine	102-06-7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
N,N'-Diphenyl-p-phenylenediamine (DPPD)	N,N'-Diphenyl-p-phenylenediamine	74-31-7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Disulfides	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Di-(2-ethyl)hexylphosphorylpolysul fide) (SDT)	Bis-(ethylhexylthiophosphoryl) polysulfide	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3,5-Di-tert-Butyl-4-hydroxybenzaldehyde	N/A	1620-98-0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2,2'-Dithiobis(benzothiazole)	2,2'-Dithiobisbenzothiazole	120-78-5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Dithiocarbamates	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Dithiomorpholine (DTDM)	4,4'-Dithiodimorpholine	103-34-4	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Dithiophosphates	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
N,N`-Ditolyl-p-phenylenediamine (DTPD)	N,N'-Ditolyl-p-phenylenediamine	27417-40-9	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Docosanoic acid	N/A	112-85-6	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Dodecanoic acid	N/A	143-07-7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Dotriacontane	N/A	544-85-4	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Drometrizol	2-(2H-Benzotriazol-2-yl)-4-methylphenol	2440-22-4	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

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Eicosane	N/A	112-95-8	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Erucylamide	Erucamide	112-84-5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Esters	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Ethanol, 2-butoxy-	2-Butoxyethanol	111-76-2	0.4	0.07	N/A	6	3	0.2	N/A	N/A	N/A
Ethanol, 1-(2-butoxyethoxy)	1-(2-Butoxyethoxy)ethanol	54446-78-5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Ethanone, 1,1'-(1,3-phenylene)bis-	Benzene-1,3-bis(acetyl)	6781-42-6	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Ethanone, 1,1'-(1,4-phenylene)bis-	1,1-(1,4-Phenylene)bis-ethanone	1009-61-6	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Ethanone, 1-[4-(1-methylethenyl) phenyl]-	1-[4-(1-Methylethenyl)phenyl]ethanone	5359-04-6	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Ethyl Acetate	N/A	141-78-6	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Ethyl benzene	Ethylbenzene	100-41-4	N/A	0.4	N/A	5	2	0.06	N/A	N/A	N/A
Ethyl benzene aldehyde	Benzaldehyde, 2-ethyl-	22927-13-5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Ethylene thiourea (Ethylene thiourea)	N/A	96-45-7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2-Ethyl-1-hexanol	N/A	104-76-7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1-Ethyl-4-Methyl Benzene	4-Ethyltoluene	622-96-8	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Fluoranthene	N/A	206-44-0	N/A	0.4	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Fluorene	N/A	86-73-7	N/A	0.4	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Formaldehyde	N/A	50-00-0	N/A	0.3	0.2	0.04	0.03	0.008	N/A	N/A	N/A
Furan, 2-methyl	2-Methylfuran	534-22-5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2(3H)-Furanone,dihydro-4-hydroxy-	Dihydro-4-hydroxy-2(3H)-furanone; beta-Hydroxybutyrolactone	5469-16-9	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Guanidines	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Halocarbon 11	Trichlorofluoromethane, Freon 11	75-69-4	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Hemeicosane [c]	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Heptadecane	N/A	629-78-7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Heptane	N/A	142-82-5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Heptanonitrile	Heptanenitrile	629-08-3	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Hexacosane	N/A	630-01-3	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Hexadecane	N/A	544-76-3	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Hexa(methoxymethyl)melamine	N,N,N',N',N'',N''-Hexakis(methoxy methyl)-1,3,5-triazine-2,4,6-triamine	3089-11-0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Hexamethylenetetramine	Methenamine	100-97-0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Hexane	n-Hexane	110-54-3	N/A	N/A	N/A	N/A	N/A	0.6	N/A	N/A	N/A
Hexanedioic acid, methyl ester	Methyl hexanedioate	627-91-8	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Hexanoic acid, 2-ethyl-	2-Ethylhexanoic acid	149-57-5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Hydrocarbon (olefin/aromatic)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
7-Hydroxybenzo[f]flavone	7-Hydroxy-3-phenyl-1H-naphtho[2,1-b] pyran-1-one	86247-95-2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1-Hydroxypyrene	N/A	5315-79-7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Indeno[l,2,3-cd]pyrene	o-Phenylenepyrene	193-39-5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1H-isoindole-1,3 (2H)-dione	Phthalimide	85-41-6	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
iso-nonylphenol	3-Nonylphenol	11066-49-2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Isophorone	N/A	78-59-1	N/A	3	0.2	N/A	N/A	N/A	N/A	N/A	N/A
Isopropyl Alcohol	2-Propanol, Isopropanol	67-63-0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Isopropylbenzene	Cumene	98-82-8	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Isopropyltoluene	1-Methyl-2-(propan-2-yl)benzene	527-84-4	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Ketones	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Latex protein	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Limonene	N/A	138-86-3	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
MEK	Methyl ethyl ketone	78-93-3	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2-Mercaptobenzothiazole	N/A	149-30-4	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Methane, diethoxy-cyclohexane	Diethoxycyclohexanemethane; Bis(cyclohexyloxy)methane	1453-21-0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Methyl Alcohol	Methanol	67-56-1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2-Methylanthracene	N/A	613-12-7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2-Methyl-Butane	2-Methylbutane	78-78-4	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2,2-Methylene-bis-(4-methyl-6-tert-butylphenol) (BPH)	N/A	119-47-1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Methylene Chloride	Dichloromethane	75-09-2	0.2	N/A	0.06	0.6	0.3	0.3	N/A	N/A	N/A

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5-Methyl-2-hexanone	Methyl isoamyl ketone	110-12-3	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1-Methylnaphthalene	N/A	90-12-0	N/A	N/A	0.07	N/A	N/A	N/A	N/A	N/A	N/A
2-Methylnaphthalene	N/A	91-57-6	N/A	N/A	0.04	N/A	N/A	N/A	N/A	N/A	N/A
3-Methyl-Pentane	3-Methylpentane	96-14-0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4-Methyl-2-pentanone	MIBK, Methyl isobutyl ketone	108-10-1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1-Methylphenanthrene	1-Methyl phenanthrene	832-69-9	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2-Methylphenanthrene	N/A	2531-84-2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3-Methylphenanthrene	N/A	832-71-3	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9-Methylphenanthrene	N/A	883-20-5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2-Methylphenol	o-Cresol	95-48-7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4-Methylphenol	p-Cresol	106-44-5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
MES (special purified aromatic oil)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2-(4-morpholino)benzothiazole	2-morpholinothio benzothiazole (MBS); Morpholinothio-benzothiazole; N-Oxydiethylenebenzothiazole-2-sulfenamide	102-77-2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2-Morpholinodithiobenzothiazole (MBSS)	2-(Morpholin-4-yldithio)-1,3-benzothiazole	95-32-9	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Naphthalene	N/A	91-20-3	0.6	0.6	N/A	N/A	N/A	0.0007	N/A	N/A	N/A
Naphthalene, 2-(bromomethyl)-	2-Bromomethylnaphthalene	939-26-4	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Naphthalic Anhydride	1H,3H-Naphtho(1,8-cd)pyran-1,3-dione	81-84-5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Napthenic oil	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Nitro compound (isomer of major peak)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Nitro compound (nitro-ether derivative)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Nitrogen containing substances	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Nitrosodibutylamine (n-)	N-Nitrosodibutylamine	924-16-3	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Nitrosodiethylamine (n-)	N-Nitrosodiethylamine	55-18-5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Nitrosodimethylamine (n-)	N-Nitrosodimethylamine	62-75-9	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
n-Nitrosodiphenylamine	N-Nitrosodiphenylamine	86-30-6	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Nitrosodipropylamine (n-)	N-Nitrosodipropylamine	621-64-7	0.095	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Nitrosomorpholine (n-)	N-Nitrosomorpholine	59-89-2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Nitrosopiperidine (n-)	N-Nitrosopiperidine	100-75-4	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Nitrosopyrrolidine (n-)	N-Nitrosopyrrolidine	930-55-2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Nonadecane	N/A	629-92-5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Nonanale	Nonanal	124-19-6	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Nonane	N/A	111-84-2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4-n-nonylphenol	4-Nonylphenol	104-40-5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Octadecanoic acid, methyl ester	Methyl stearate	112-61-8	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Octane	N/A	111-65-9	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4-t-octylphenol	4-(1,1,3,3-Tetramethylbutyl)phenol, 4-tert-(octyl)-phenol	140-66-9	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Optadecane	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Organic thiola and sulfides	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Orthocarbonate - Carboxy compound)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
N-Oxydiethylenedithiocarbamyl-N`-oxydiethylenesulfenamide (OTOS)	N/A	13752-51-7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
PAHs	Polycyclic aromatic hydrocarbons	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Parrafinic oils	Mineral oil	8012-95-1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
PCB sum	N/A	N/A	N/A	3e-5 (Aroclor 1254)	2e-5 (Aroclor 1254)	N/A	N/A	N/A	N/A	N/A	N/A
PCDD/F sum	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Pentacosane	N/A	629-99-2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Pentane	N/A	109-66-0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Perylene	N/A	198-55-0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Petroleum Naphtha	Naphtha	8030-30-6	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Phenalone	Phenalen-1-one	548-39-0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Phenanthrene	N/A	85-01-8	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1-Phenanthrenecarboxylic acid, 1,2,3,4,4	1,2,3,4,4-1-Phenanthrene carboxylic acid; Dehydroabietic acid	1740-19-8	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

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Phenol	2,4-Di-tert-butylphenol	108-95-2	1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Phenolics	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Phenol, 2,4-bis(1,1-dimethylethyl)-	N/A	96-76-4	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Phenol, 2,4-bis(1-methyl-1-phenylethyl)-	2,4-Bis(1-methyl-1-phenylethyl)phenol	2772-45-4	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Phenol, m-tert-butyl-	3-tert-Butylphenol	585-34-2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Phenylbenzimidazole	2-Phenylbenzimidazole	716-79-0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
p-Phenylenediamines	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Phenylenediamines	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2-(1-phenylethyl)-phenol	2-(1-Phenylethyl)phenol	26857-99-8	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3-Phenyl-2-propenal	3-Phenylprop-2-enal	104-55-2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Phthalates	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
PM 2.5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
PM 10	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Poly- and di-nitrobenzenes	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Poly-p-dinitrosobenzene	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Propene	1-Propene; propylene	115-07-1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Propylbenzene	N/A	103-65-1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Pyrazole	N/A	288-13-1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Pyrene	N/A	129-00-0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Pyrimidine, 2-(4-pentylphenyl)-5-propyl-	N/A	94320-32-8	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2-Pyrrolidinone. 1-methyl-	N-Methyl-2-pyrrolidone	872-50-4	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Quinones	N/A	106-51-4	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Resorcinol	N/A	108-46-3	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Rethene [c]	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Siloxanes	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Styrene	N/A	100-42-5	0.1	N/A	N/A	5	N/A	0.2	N/A	N/A	N/A
Styrene oligomers	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Substituted p-Phenylenediamines	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Sulfur containing organics	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Sulfur Donors	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Sulphenamides	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
TDAE (special purified aromatic oil)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Tertbutylacetophenone	3,3-dimethyl-1-phenylbutan-1-one	31366-07-1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
N-tert-Butyl-2-benzothiazolesulf enamide (TBBS)	N/A	95-31-8	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4-tert butylphenol	4-tert-Butylphenol	98-54-4	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Tetraalkylthiuram disulfides	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Tetrabenzylthiuram disulfide (TBZTD)	N/A	10591-85-2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Tetrabutylthiuram disulfide (TBTD)	N/A	1634-02-2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Tetrachloroethene	Tetrachloroethylene; perchloroethylene	127-18-4	0.008	0.008	0.008	0.006	0.006	0.006	N/A	N/A	N/A
Tetracosane	N/A	646-31-1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Tetraethylthiuram disulfide	Disulfiram	97-77-8	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Tetrahydrofuran	N/A	109-99-9	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Tetramethylthiuram disulfide	Thiram	137-26-8	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Tetramethylthiuram monosulfide	N/A	97-74-5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Thiazoles	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Thioureas	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Thiurams	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Thiuram sulfides	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Toluene	N/A	108-88-3	0.8	0.2	N/A	2	N/A	1	N/A	N/A	N/A
Total petroleum hydrocarbons	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Trans trans-muconic acid	(E,E)-Muconic acid	3588-17-8	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Trimethyl-1,2-dihydroquinoline (TMDQ)	1,2-Dihydro-2,2,4-trimethylquinoline, polymer	26780-96-1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1,1,1-Trichloroethane	N/A	71-55-6	N/A	20	N/A	2	0.7	N/A	N/A	N/A	N/A
Trichloroethylene	N/A	79-01-6	N/A	0.0005	0.0005	N/A	0.0004	0.0004	N/A	N/A	N/A
1,1,2-Trichloro-1,2,2-trifluoroethane	N/A	76-13-1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Trichloro-trifluoroethane	1,1,1-Trichloro-2,2,2-trifluoroethane	354-58-5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Chemical Constituent[a]	Synonym[b]	CAS Number[c]	ATSDR MRLs[4] Oral Acute (mg/kg-day)	ATSDR MRLs Oral Interm. (mg/kg-day)	ATSDR MRLs Oral Chronic (mg/kg-day)	ATSDR MRLs Inhal. Acute (ppm)	ATSDR MRLs Inhal. Interm. (ppm)	ATSDR MRLs Inhal. Chronic (ppm)	ATSDR MRLs Inhal. Acute (mg/m^3)	ATSDR MRLs Inhal. Interm. (mg/m^3)	ATSDR MRLs Inhal. Chronic (mg/m^3)
Tricosane	N/A	638-67-5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1,2,3-Trimethyl benzene	1,2,3-Trimethylbenzene	526-73-8	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1,2,4-Trimethyl benzene	1,2,4-Trimethylbenzene	95-63-6	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1,3,5-Trimethyl benzene	1,3,5-Trimethylbenzene	108-67-8	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2,2,4-Trimethyl-1,2-dihydroquinoline (TMQ)	1,2-Dihydro-2,2,4-trimethylquinoline, polymer	26780-96-1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Vinyl Acetate	N/A	108-05-4	N/A	N/A	N/A	N/A	0.01	N/A	N/A	N/A	N/A
White gasoline	Natural gasoline	8006-61-9	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
o-Xylene	N/A	95-47-6	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Xylenes	N/A	1330-20-7	1	0.4	0.2	2	0.6	0.05	N/A	N/A	N/A
Zn-Dibenzyldithiocarbamate (ZBEC)	N/A	136-23-2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Zn-Diethyldithiocarbamate (ZDEC)	Zinc diethyldithiocarbamate	14324-55-1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Zn-Dimethyldithiocarbamate (ZDMC)	Ziram	137-30-4	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Zn-dibutyldithiocarbamate (ZDBC)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
ZnO	Zinc Oxide	1314-13-2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
TOTALS 355	158	290	21	40	23	16	17	19	3	2	7
PERCENTS 100%	45%	82%	6%	11%	6%	5%	5%	5%	1%	1%	2%

Chemical Constituent[a]	Synonym[b]	CAS Number[c]	IPCS CICAD[5] Tolerable Intake (mg/kg-d)	IPCS CICAD Tolerable Intake (ug/L)	IPCS CICAD Tolerable Conc. (ug/m^3)	IARC Monogr.[6] Cancer Class	CalEPA PR65[7] NSRL (ug/day)	CalEPA PR65 MADL (ug/day)
Aluminum	N/A	7429-90-5	N/A		N/A	N/A	N/A	N/A
Antimony	N/A	7440-36-0	N/A	N/A	N/A	N/A	N/A	N/A
Arsenic	N/A	7440-38-2	N/A	N/A	N/A	Group 1	0.06 inhal. 10 except inhal.	N/A
Barium	N/A	7440-39-3	0.02	N/A	N/A	N/A	N/A	N/A
Beryllium	N/A	7440-41-7	0.002	N/A	0.02	Group 1	0.1	N/A
Cadmium	N/A	7440-43-9	N/A	N/A	N/A	Group 1	0.05 (inhal.)	4.1 (oral)
Calcium	N/A	7440-70-2	N/A	N/A	N/A	N/A	N/A	N/A
Chloride	N/A	16887-00-6	N/A	N/A	N/A	N/A	N/A	N/A
Chromium	N/A	7440-47-3; 16065-83-1 (CrIII); 18540-29-9 (CrVI)	9E-4 (CrVI non-canc.)	N/A	27 (CrIII insol.) 6 (CrIII sol.) 0.005 (CrVI non-canc.) 0.03 (CrVI cancer)	Group 3	0.001 (CrVI inhal.)	8.2 (oral)
Cobalt	N/A	7440-48-4	N/A	N/A	1.00E-01	Group 2B	N/A	N/A
Copper	N/A	7440-50-8	N/A	N/A	N/A	N/A	N/A	N/A
Iron	N/A	7439-89-6	N/A	N/A	N/A	N/A	N/A	N/A
Lead	N/A	7439-92-1	N/A	N/A	N/A	Group 2B	15 (oral)	0.5
Lithium	N/A	7439-93-2	N/A	N/A	N/A	N/A	N/A	N/A
Magnesium	N/A	7439-95-4	N/A	N/A	N/A	N/A	N/A	N/A
Manganese	N/A	7439-96-5	N/A	N/A	N/A	N/A	N/A	N/A
Mercury	N/A	7439-97-6	2.00E-03	N/A	0.2	Group 3	N/A	N/A
Molybdenum	N/A	7439-98-7	N/A	N/A	N/A	N/A	N/A	N/A
Nickel	N/A	7440-02-0	N/A	N/A	N/A	Group 2B	0.8 (refinery dust)	N/A
Phosphorous	N/A	7723-14-0	N/A	N/A	N/A	N/A	N/A	N/A
Potassium	N/A	7440-09-7	N/A	N/A	N/A	N/A	N/A	N/A
Rubidium	N/A	7440-17-7	N/A	N/A	N/A	N/A	N/A	N/A
Selenium	N/A	7782-49-2	N/A	N/A	N/A	Group 3	N/A	N/A
Silver	N/A	7440-22-4	N/A	N/A	N/A	N/A	N/A	N/A
Sodium	N/A	7440-23-5	N/A	N/A	N/A	N/A	N/A	N/A
Strontium	N/A	7440-24-6	0.13	N/A	N/A	N/A	N/A	N/A
Sulfur	N/A	7704-34-9	N/A	N/A	N/A	N/A	N/A	N/A
Thallium	N/A	7440-28-0	N/A	N/A	N/A	N/A	N/A	N/A
Tin	N/A	7440-31-5	N/A	N/A	N/A	N/A	N/A	N/A
Titanium	N/A	7440-32-6	N/A	N/A	N/A	N/A	N/A	N/A
Tungsten	N/A	7440-33-7	N/A	N/A	N/A	N/A	N/A	N/A
Vanadium	N/A	7440-62-2	N/A	N/A	N/A	N/A	N/A	N/A
Zinc	N/A	7440-66-6	N/A	N/A	N/A	N/A	N/A	N/A
Cadmium and Zinc Soaps	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Acenaphthene	N/A	83-32-9	N/A	N/A	N/A	Group 3	N/A	N/A
Acenaphthylene	N/A	208-96-8	N/A	N/A	N/A	N/A	N/A	N/A
Acetaldehyde	Ethanone	75-07-0	N/A	N/A	N/A	Group 2B	90 (inhalation)	N/A

Chemical Constituent[a]	Synonym[b]	CAS Number[c]	IPCS CICAD[5] Tolerable Intake (mg/kg-d)	IPCS CICAD Tolerable Intake (ug/L)	IPCS CICAD Tolerable Conc. (ug/m^3)	IARC Monogr.[6] Cancer Class	CalEPA PR65[7] NSRL (ug/day)	CalEPA PR65 MADL (ug/day)
Acetamide, N-cyclohexyl-	N/A	1124-53-4	N/A	N/A	N/A	N/A	10	N/A
Acetone	N/A	67-64-1	N/A	N/A	N/A	N/A	N/A	N/A
Acetone-diphenylamine condensation product (ADPA)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Acetonitrile	N/A	75-05-8	N/A	N/A	N/A	N/A	N/A	N/A
Acetophenone	N/A	98-86-2	N/A	N/A	N/A	N/A	N/A	N/A
6-Acetoxy-2,2-dimethyl-m-dioxane	Dimethoxane	828-00-2	N/A	N/A	N/A	Group 3	N/A	N/A
Acrolein	N/A	107-02-8	N/A	1.5	0.4	Group 3	N/A	N/A
Alcohols	Ethanol	64-17-5	N/A	N/A	N/A	Group 1	N/A	N/A
Aldehydes	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Alkyl benzenes	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Alkyl dithiols	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Alkyl naphthalenes	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Alkyl phenols	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Alpha pinene	alpha-Pinene	80-56-8	N/A	N/A	N/A	N/A	N/A	N/A
Amine (N-dialkyl analine derivative)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Amines	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Anathrene [c]	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Aniline	Benzeneamine; aminobenzene	62-53-3	N/A	N/A	N/A	Group 3	100	N/A
Anthanthrene	N/A	191-26-4	N/A	N/A	N/A	Group 3	N/A	N/A
Anthracene	N/A	120-12-7	N/A	N/A	N/A	Group 3	N/A	N/A
Aromatic oil	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9,10-Anthracenedione, 2-ethyl	2-Ethylanthracene-9,10-dione	84-51-5	N/A	N/A	N/A	N/A	N/A	N/A
Azobenzene	N/A	103-33-3	N/A	N/A	N/A	Group 3	6	N/A
Benz(e)acenaphthylene	Acephenanthrylene	201-06-9	N/A	N/A	N/A	N/A	N/A	N/A
Benzaldehyde, 3-hydroxyl-4-methoxy	3-Hydroxy-4-methoxy-benzaldehyde	621-59-0	N/A	N/A	N/A	N/A	N/A	N/A
Benz(a)anthracene	N/A	56-55-3	N/A	N/A	N/A	Group 2B	0.033 (oral)	N/A
Benzene	N/A	71-43-2	N/A	N/A	N/A	Group 1	6.4 (oral) 13 (inhalation)	24 (oral) 49 (inhalation)
Benzene, 1,3-bis(1-methylethenyl)-	1,3-bis(1-methylethenyl)benzene; 1,3-Diisopropenylbenzene	3748-13-8	N/A	N/A	N/A	N/A	N/A	N/A
Benzene, 1,4-bis(1-methylethenyl)-	1,4-Bis(1-methylethenyl)benzene	1605-18-1	N/A	N/A	N/A	N/A	N/A	N/A
1,4-Benzenediamine, N,N'-diphenyl-	N,N'-Diphenyl-p-phenylenediamine	74-31-7	N/A	N/A	N/A	N/A	N/A	N/A
1,4-Benzendiamin, N-(1-methylethyl)-N'-phenyl-, (IPPD)	N-Isopropyl-N'-phenyl-p-phenylenediamine, Isopropylaminodephenylamine (IPPD)	101-72-4	N/A	N/A	N/A	N/A	N/A	N/A
Benzene, isocyanato-	Phenyl isocyanate	103-71-9	N/A	N/A	N/A	N/A	N/A	N/A
Benzenemethanol	Benzyl alcohol	100-51-6	N/A	N/A	N/A	N/A	N/A	N/A
Benzo(def)dibenzothiophene	Phenanthro[4,5-bcd]thiophene	30796-92-0	N/A	N/A	N/A	N/A	N/A	N/A
Benzo(g)dibenzothiophene	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Benzo(b)fluoranthene	N/A	205-99-2	N/A	N/A	N/A	Group 2B	0.096 (oral)	N/A
Benzo(bjk)fluoranthene	2,11-(Metheno)benzo[a]fluorene	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Benzo(ghi)fluoranthene	Benzo[ghi]fluoranthene	203-12-3	N/A	N/A	N/A	Group 3	N/A	N/A
Benzo(i)fluoranthene	Benzo(j)fluoranthene	205-82-3	N/A	N/A	N/A	Group 2B	0.11 (oral)	N/A
Benzo(k)fluoranthene	N/A	207-08-9	N/A	N/A	N/A	Group 2B	N/A	N/A
Benzo(mno)fluoranthene	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Benzo(a)fluorene	11H-Benzo[a]fluorene	238-84-6	N/A	N/A	N/A	Group 3	N/A	N/A
Benzo(b)fluorene	2,3-Benzofluorene	243-17-4	N/A	N/A	N/A	Group 3	N/A	N/A
Benzo(def)naphthobenzothiophene	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6H-Benzo[cd]pyren-6-one	6H-Benzo(cd)pyren-6-one	3074-00-8	N/A	N/A	N/A	N/A	N/A	N/A
Benzo(a)pyrene	N/A	50-32-8	N/A	N/A	N/A	Group 1	0.06	N/A
Benzo(e)pyrene	N/A	192-97-2	N/A	N/A	N/A	Group 3	N/A	N/A

Chemical Constituent[a]	Synonym[b]	CAS Number[c]	IPCS CICAD[5] Tolerable Intake (mg/kg-d)	IPCS CICAD Tolerable Intake (ug/L)	IPCS CICAD Tolerable Conc. (ug/m^3)	IARC Monogr.[6] Cancer Class	CalEPA PR65[7] NSRL (ug/day)	CalEPA PR65 MADL (ug/day)
Benzo(ghi)perylene	Benzo(g,h,i)perylene	191-24-2	N/A	N/A	N/A	Group 3	N/A	N/A
Benzoic acid	N/A	65-85-0	5	N/A	N/A	N/A	N/A	N/A
Benzothiazole	N/A	95-16-9	N/A	N/A	N/A	N/A	N/A	N/A
Benzothiazole, 2-(methylthio)	2-(Methylthio)benzothiazole	615-22-5	N/A	N/A	N/A	N/A	N/A	N/A
Benzothiazole, 2-phenyl	2-Phenylbenzothiazole	883-93-2	N/A	N/A	N/A	N/A	N/A	N/A
Benzothiazolone	2-Hydroxybenzothiazole, 2(3H)-Benzothiazolone, 2(3H) benzothiazolone	934-34-9	N/A	N/A	N/A	N/A	N/A	N/A
Benzoyl and other peroxides	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Benzylbutyl phthalate	Butyl benzyl phthalate	85-68-7	1.3	N/A	N/A	Group 3	N/A	1200 oral
Biphenyl	1,1'-Biphenyl	92-52-4	3.80E-02	N/A	N/A	N/A	N/A	N/A
1,1'-Biphenyl, 4, 4', 5', 6'-tetramethoxy-	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
(N,N`-Bis(1,4-dimethylpentyl) pphenylendiamine) (7PPD)	N,N'-Bis(1,4-dimethylpentyl)-4-phenylenediamine	3081-14-9	N/A	N/A	N/A	N/A	N/A	N/A
Bis(2-ethylhexyl) phthalate	Di(2-ethylhexyl) phthalate	117-81-7	N/A	N/A	N/A	Group 2B	310	410 (adult oral)
Bis-(2,2,6,6-tetramethyl-4-piperidinyl)sebacate	Bis(2,2,6,6-tetramethyl-4-piperidyl) sebacate	52829-07-9	N/A	N/A	N/A	N/A	N/A	N/A
Bisthiol acids	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Black rubber	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Bromodichloromethane	N/A	75-27-4	N/A	N/A	N/A	Group 2B	5	N/A
Bromoform	N/A	75-25-2	N/A	N/A	N/A	Group 3	64	N/A
1,3 Butadiene	N/A	106-99-0	N/A	N/A	carcinogenic potency is estimated to be 1.7 mg/m3 (the concentration associated with a 1% increase in mortality due to leukaemia); benchmark value for ovarian cancer in mice is 0.57 mg/m3	Group 1	N/A	N/A
Butoxyethoxyethanol	2-(2-Butoxyethoxy)ethanol, diethylene glycol monobutyl ether	112-34-5	N/A	N/A	N/A	N/A	N/A	N/A
Butylated hydroxyanisole	N/A	25013-16-5	N/A	N/A	N/A	Group 2B	4000	N/A
Butylated hydroxytoluene	2,6-Di-tert-butyl-4-methylphenol (BHT)	128-37-0	N/A	N/A	N/A	Group 3	N/A	N/A
Butylbenzene	N/A	104-51-8	N/A	N/A	N/A	N/A	N/A	N/A
Caprolactam disulfide (CLD)	1,1'-Disulfanediyldiazepan-2-one	23847-08-7	N/A	N/A	N/A	N/A	N/A	N/A
Carbazole	N/A	86-74-8	N/A	N/A	N/A	Group 2B	4.1	N/A
Carbon Black	Furnace Black	1333-86-4	N/A	N/A	N/A	Group 2B	N/A	N/A
Carbon Disulfide	N/A	75-15-0	N/A	N/A	100	N/A	N/A	N/A
Carbon Tetrachloride	N/A	56-23-5	N/A	N/A	N/A	Group 2B	5	N/A
Chlorobenzene	N/A	108-90-7	N/A	N/A	N/A	N/A	N/A	N/A
Chloroform	Trichloromethane	67-66-3	0.015	N/A	140	Group 2B	20 (oral) 40 (inhalation)	N/A
Chloromethane	Methyl chloride	74-87-3	N/A	N/A	18 (general popul. guidance) 1000 (occup. guidance)	Group 3	N/A	N/A
Chrysene	N/A	218-01-9	N/A	N/A	N/A	Group 2B	0.35 (oral)	N/A
Coronene	N/A	191-07-1	N/A	N/A	N/A	Group 3	N/A	N/A
o-Cyanobenzoic acid	2-Cyanobenzoic acid	3839-22-3	N/A	N/A	N/A	N/A	N/A	N/A
Cyclohexanamine	Cyclohexylamine	108-91-8	N/A	N/A	N/A	N/A	N/A	N/A
Cyclohexanamine, N-cyclohexyl-	Dicyclohexylamine	101-83-7	N/A	N/A	N/A	N/A	N/A	N/A
Cyclohexanamine, N-cyclohexyl-N-methyl-	N-Cyclohexyl-N-methylcyclohexanamine	7560-83-0	N/A	N/A	N/A	N/A	N/A	N/A
Cyclohexane	N/A	110-82-7	N/A	N/A	N/A	N/A	N/A	N/A

Chemical Constituent[a]	Synonym[b]	CAS Number[c]	IPCS CICAD[5] Tolerable Intake (mg/kg-d)	IPCS CICAD Tolerable Intake (ug/L)	IPCS CICAD Tolerable Conc. (ug/m^3)	IARC Monogr.[6] Cancer Class	CalEPA PR65[7] NSRL (ug/day)	CalEPA PR65 MADL (ug/day)
Cyclohexane, isocyanato	Isocyanatocyclohexane	3173-53-3	N/A	N/A	N/A	N/A	N/A	N/A
Cyclohexane, isothiocyanato-	N/A	1122-82-3	N/A	N/A	N/A	N/A	N/A	N/A
Cyclohexanone	N/A	108-94-1	N/A	N/A	N/A	Group 3	N/A	N/A
N-Cyclohexyl-2-benzothiazolesulfenamide (CBS)	N-Cyclohexyl-2-benzothiazolesulfenamide	95-33-0	N/A	N/A	N/A	N/A	N/A	N/A
n-Cyclohexyl-formamide	N-Cyclohexylformamide, Formamide, N-cyclohexyl	766-93-8	N/A	N/A	N/A	N/A	N/A	N/A
Cycloninasiloxane, octadecamethyl-	Octadecamethylcyclononasiloxane	556-71-8	N/A	N/A	N/A	N/A	N/A	N/A
Cyclopenta[cd]pyrene	N/A	27208-37-3	N/A	N/A	N/A	Group 2A	N/A	N/A
4H-cyclopenta[def]phenanthren-4-one	4H-Cyclopenta(def)phenanthren-4-one	5737-13-3	N/A	N/A	N/A	N/A	N/A	N/A
4H-cyclopenta[def]-phenanthrene	4-H-Cyclopenta(d,e,f)phenanthrene	203-64-5	N/A	N/A	N/A	N/A	N/A	N/A
Cyclopentane, methyl-	Methylcyclopentane	96-37-7	N/A	N/A	N/A	N/A	N/A	N/A
Decane	N/A	124-18-5	N/A	N/A	N/A	N/A	N/A	N/A
Diazoaminobenzenes	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Dibenzo(a,h) anthracene	Dibenz(a,h)anthracene	53-70-3	N/A	N/A	N/A	Group 2A	0.2	N/A
Dibenzofurane	Dibenzofuran	132-64-9	N/A	N/A	N/A	N/A	N/A	N/A
Dibenzo(ae)pyrene	Naphtho(1,2,3,4-def)chrysene	192-65-4	N/A	N/A	N/A	Group 3	N/A	N/A
Dibenzo(ai)pyrene	Dibenzo[a,i]pyrene	189-55-9	N/A	N/A	N/A	Group 2B	0.005	N/A
Dibenzo(ah)pyrene	Dibenzo[a,h]pyrene	189-64-0	N/A	N/A	N/A	Group 2B	0.0054	N/A
Dibenzothiophene	N/A	132-65-0	N/A	N/A	N/A	Group 3	N/A	N/A
Dibutyl phthalate	N/A	84-74-2	N/A	N/A	N/A	N/A	N/A	8.7
1,4-Dichlorobenzene	p-dichlorobenzene	106-46-7	N/A	N/A	N/A	Group 2B	20	N/A
Dichlorodifluoromethane	Freon 12	75-71-8	N/A	N/A	N/A	N/A	N/A	N/A
1,2-Dichloroethane	Ethylene dichloride	107-06-2	N/A	N/A	N/A	Group 2B	10	N/A
cis-1,2-Dichloroethene	(Z)-1,2-Dichloroethylene	156-59-2	N/A	N/A	N/A	N/A	N/A	N/A
1,2-Dichloropropane	N/A	78-87-5	N/A	N/A	N/A	Group 1	9.7	N/A
N,N-Dicyclohexyl-2-benzothiazolesulfenamide (DCBS)	N,N-Dicyclohexyl-2-benzothiazolesulfenamide	4979-32-2	N/A	N/A	N/A	N/A	N/A	N/A
Dicyclohexylphthalate (DCHP)	Dicyclohexyl phthalate	84-61-7	N/A	N/A	N/A	N/A	N/A	N/A
1,3-Dicyclohexylurea	N,N'-Dicyclohexylurea	2387-23-7	N/A	N/A	N/A	N/A	N/A	N/A
Diethenylbenzene	Divinylbenzene	1321-74-0	N/A	N/A	N/A	N/A	N/A	N/A
Di(2-ethylhexyl) adipate	Hexanedioic acid, bis(2-ehtylhexyl); Bis(2-ethylhexyl)hexanedioic acid	103-23-1	N/A	N/A	N/A	Group 3	N/A	N/A
Diethyl phthalate	N/A	84-66-2	5	N/A	N/A	N/A	N/A	N/A
Diethylthiourea (DETU)	N,N'-Diethylthiourea	105-55-5	N/A	N/A	N/A	Group 3	N/A	N/A
Dihydrocyclopentapyrene	2,3-Acepyrene	25732-74-5	N/A	N/A	N/A	Group 3	N/A	N/A
Diisobutyl phthalate	N/A	84-69-5	N/A	N/A	N/A	N/A	N/A	N/A
Diisodecylphthalate	bis(8-Methylnonyl) phthalate	89-16-7	N/A	N/A	N/A	N/A	N/A	2200
Diisononyl phthalate	DINP	28553-12-0	N/A	N/A	N/A	N/A	146	N/A
9,I0-Dimethyl-1,2-Benzanthracene	7,12-Dimethylbenz(a)anthracene	57-97-6	N/A	N/A	N/A	N/A	0.003	N/A
(N-1,3-dimethyl-butyl)-N'- phenyl-p-phenylenediamine (6PPD)	N-(1,3-Dimethylbutyl)-N'-phenyl-p-phenylenediamine	793-24-8	N/A	N/A	N/A	N/A	N/A	N/A
Dimethyldiphenylthiuram disulfide (MPTD)	Dimethyldiphenylthiuram disulfide	53880-86-7	N/A	N/A	N/A	N/A	N/A	N/A
2,6-Dimethylnaphthalene	N/A	581-42-0	N/A	N/A	N/A	N/A	N/A	N/A
2,4-Dimethylphenol	N/A	105-67-9	N/A	N/A	N/A	N/A	N/A	N/A
Dimethyl phthalate	N/A	131-11-3	N/A	N/A	N/A	N/A	N/A	N/A
Dinitroarenes	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Di-n-octyl phthalate	Dioctyl phthalate	117-84-0	N/A	N/A	N/A	N/A	N/A	N/A
Di-ortho-tolylguanidine	N/A	97-39-2	N/A	N/A	N/A	N/A	N/A	N/A
Dipentamethylenethiuramtetrasulfide (DPTT)	Bis(pentamethylenethiuram)tetrasulfide	120-54-7	N/A	N/A	N/A	N/A	N/A	N/A
Diphenylamine	N/A	122-39-4	N/A	N/A	N/A	N/A	N/A	N/A
N,N'-Diphenylguanidine (DPG)	1,3-Diphenylguanidine	102-06-7	N/A	N/A	N/A	N/A	N/A	N/A
N,N'-Diphenyl-p-phenylenediamine (DPPD)	N,N'-Diphenyl-p-phenylenediamine	74-31-7	N/A	N/A	N/A	N/A	N/A	N/A

Chemical Constituent[a]	Synonym[b]	CAS Number[c]	IPCS CICAD[5] Tolerable Intake (mg/kg-d)	IPCS CICAD Tolerable Intake (ug/L)	IPCS CICAD Tolerable Conc. (ug/m^3)	IARC Monogr.[6] Cancer Class	CalEPA PR65[7] NSRL (ug/day)	CalEPA PR65 MADL (ug/day)
Disulfides	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Di-(2-ethyl)hexylphosphorylpolysulfide) (SDT)	Bis-(ethylhexylthiophosphoryl) polysulfide	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3,5-Di-tert-Butyl-4-hydroxybenzaldehyde	N/A	1620-98-0	N/A	N/A	N/A	N/A	N/A	N/A
2,2'-Dithiobis(benzothiazole)	2,2'-Dithiobisbenzothiazole	120-78-5	N/A	N/A	N/A	N/A	N/A	N/A
Dithiocarbamates	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Dithiomorpholine (DTDM)	4,4'-Dithiodimorpholine	103-34-4	N/A	N/A	N/A	N/A	N/A	N/A
Dithiophosphates	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
N,N`-Ditolyl-p-phenylenediamine (DTPD)	N,N'-Ditolyl-p-phenylenediamine	27417-40-9	N/A	N/A	N/A	N/A	N/A	N/A
Docosanoic acid	N/A	112-85-6	N/A	N/A	N/A	N/A	N/A	N/A
Dodecanoic acid	N/A	143-07-7	N/A	N/A	N/A	N/A	N/A	N/A
Dotriacontane	N/A	544-85-4	N/A	N/A	N/A	N/A	N/A	N/A
Drometrizol	2-(2H-Benzotriazol-2-yl)-4-methylphenol	2440-22-4	N/A	N/A	N/A	N/A	N/A	N/A
Eicosane	N/A	112-95-8	N/A	N/A	N/A	N/A	N/A	N/A
Erucylamide	Erucamide	112-84-5	N/A	N/A	N/A	N/A	N/A	N/A
Esters	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Ethanol, 2-butoxy-	2-Butoxyethanol	111-76-2	N/A	N/A	13.1 mg/m^3	Group 3	N/A	N/A
Ethanol, 1-(2-butoxyethoxy)	1-(2-Butoxyethoxy)ethanol	54446-78-5	N/A	N/A	N/A	N/A	N/A	N/A
Ethanone, 1,1'-(1,3-phenylene)bis-	Benzene-1,3-bis(acetyl)	6781-42-6	N/A	N/A	N/A	N/A	N/A	N/A
Ethanone, 1,1'-(1,4-phenylene)bis-	1,1-(1,4-Phenylene)bis-ethanone	1009-61-6	N/A	N/A	N/A	N/A	N/A	N/A
Ethanone, 1-[4-(1-methylethenyl) phenyl]-	1-[4-(1-Methylethenyl)phenyl]ethanone	5359-04-6	N/A	N/A	N/A	N/A	N/A	N/A
Ethyl Acetate	N/A	141-78-6	N/A	N/A	N/A	N/A	N/A	N/A
Ethyl benzene	Ethylbenzene	100-41-4	N/A	N/A	N/A	Group 2B	41 (oral) 54 (inhalation)	N/A
Ethyl benzene aldehyde	Benzaldehyde, 2-ethyl-	22927-13-5	N/A	N/A	N/A	N/A	N/A	N/A
Ethylene thiourea (Ethylene thiourea)	N/A	96-45-7	N/A	N/A	N/A	Group 3	20	N/A
2-Ethyl-1-hexanol	N/A	104-76-7	N/A	N/A	N/A	N/A	N/A	N/A
1-Ethyl-4-Methyl Benzene	4-Ethyltoluene	622-96-8	N/A	N/A	N/A	N/A	N/A	N/A
Fluoranthene	N/A	206-44-0	N/A	N/A	N/A	Group 3	N/A	N/A
Fluorene	N/A	86-73-7	N/A	N/A	N/A	Group 3	N/A	N/A
Formaldehyde	N/A	50-00-0	N/A	2600	N/A	Group 1	40	N/A
Furan, 2-methyl	2-Methylfuran	534-22-5	N/A	N/A	N/A	N/A	N/A	N/A
2(3H)-Furanone,dihydro-4-hydroxy-	Dihydro-4-hydroxy-2(3H)-furanone; beta-Hydroxybutyrolactone	5469-16-9	N/A	N/A	N/A	N/A	N/A	N/A
Guanidines	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Halocarbon 11	Trichlorofluoromethane, Freon 11	75-69-4	N/A	N/A	N/A	N/A	N/A	N/A
Hemeicosane [c]	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Heptadecane	N/A	629-78-7	N/A	N/A	N/A	N/A	N/A	N/A
Heptane	N/A	142-82-5	N/A	N/A	N/A	N/A	N/A	N/A
Heptanonitrile	Heptanenitrile	629-08-3	N/A	N/A	N/A	N/A	N/A	N/A
Hexacosane	N/A	630-01-3	N/A	N/A	N/A	N/A	N/A	N/A
Hexadecane	N/A	544-76-3	N/A	N/A	N/A	N/A	N/A	N/A
Hexa(methoxymethyl)melamine	N,N,N',N',N'',N''-Hexakis(methoxy methyl)-1,3,5-triazine-2,4,6-triamine	3089-11-0	N/A	N/A	N/A	N/A	N/A	N/A
Hexamethylenetetramine	Methenamine	100-97-0	N/A	N/A	N/A	N/A	N/A	N/A
Hexane	n-Hexane	110-54-3	N/A	N/A	N/A	N/A	N/A	N/A
Hexanedioic acid, methyl ester	Methyl hexanedioate	627-91-8	N/A	N/A	N/A	N/A	N/A	N/A
Hexanoic acid, 2-ethyl-	2-Ethylhexanoic acid	149-57-5	N/A	N/A	N/A	N/A	N/A	N/A
Hydrocarbon (olefin/aromatic)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
7-Hydroxybenzo[f]flavone	7-Hydroxy-3-phenyl-1H-naphtho[2,1-b] pyran-1-one	86247-95-2	N/A	N/A	N/A	N/A	N/A	N/A
1-Hydroxypyrene	N/A	5315-79-7	N/A	N/A	N/A	N/A	N/A	N/A
Indeno[l,2,3-cd]pyrene	o-Phenylenepyrene	193-39-5	N/A	N/A	N/A	Group 2B	N/A	N/A

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1H-isoindole-1,3 (2H)-dione	Phthalimide	85-41-6	N/A	N/A	N/A	N/A	N/A	N/A
iso-nonylphenol	3-Nonylphenol	11066-49-2	N/A	N/A	N/A	N/A	N/A	N/A
Isophorone	N/A	78-59-1	N/A	N/A	N/A	N/A	N/A	N/A
Isopropyl Alcohol	2-Propanol, Isopropanol	67-63-0	N/A	N/A	N/A	Group 3	N/A	N/A
Isopropylbenzene	Cumene	98-82-8	0.1 (guidance)	N/A	400; 90 (guidance)	Group 2B	N/A	N/A
Isopropyltoluene	1-Methyl-2-(propan-2-yl)benzene	527-84-4	N/A	N/A	N/A	N/A	N/A	N/A
Ketones	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Latex protein	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Limonene	N/A	138-86-3	0.1	N/A	N/A	N/A	N/A	N/A
MEK	Methyl ethyl ketone	78-93-3	N/A	N/A	N/A	N/A	N/A	N/A
2-Mercaptobenzothiazole	N/A	149-30-4	N/A	N/A	N/A	Group 2A	N/A	N/A
Methane, diethoxy-cyclohexane	Diethoxycyclohexanemethane; Bis(cyclohexyloxy)methane	1453-21-0	N/A	N/A	N/A	N/A	N/A	N/A
Methyl Alcohol	Methanol	67-56-1	N/A	N/A	N/A	N/A	N/A	23000 (oral) 47000 (inhalation)
2-Methylanthracene	N/A	613-12-7	N/A	N/A	N/A	N/A	N/A	N/A
2-Methyl-Butane	2-Methylbutane	78-78-4	N/A	N/A	N/A	N/A	N/A	N/A
2,2-Methylene-bis-(4-methyl-6-tert-butylphenol) (BPH)	N/A	119-47-1	N/A	N/A	N/A	N/A	N/A	N/A
Methylene Chloride	Dichloromethane	75-09-2	N/A	N/A	N/A	Group 2A	200 (inhalation)	N/A
5-Methyl-2-hexanone	Methyl isoamyl ketone	110-12-3	N/A	N/A	N/A	N/A	N/A	N/A
1-Methylnaphthalene	N/A	90-12-0	N/A	N/A	N/A	N/A	N/A	N/A
2-Methylnaphthalene	N/A	91-57-6	N/A	N/A	N/A	N/A	N/A	N/A
3-Methyl-Pentane	3-Methylpentane	96-14-0	N/A	N/A	N/A	N/A	N/A	N/A
4-Methyl-2-pentanone	MIBK, Methyl isobutyl ketone	108-10-1	N/A	N/A	N/A	Group 2B	N/A	N/A
1-Methylphenanthrene	1-Methyl phenanthrene	832-69-9	N/A	N/A	N/A	Group 3	N/A	N/A
2-Methylphenanthrene	N/A	2531-84-2	N/A	N/A	N/A	N/A	N/A	N/A
3-Methylphenanthrene	N/A	832-71-3	N/A	N/A	N/A	N/A	N/A	N/A
9-Methylphenanthrene	N/A	883-20-5	N/A	N/A	N/A	N/A	N/A	N/A
2-Methylphenol	o-Cresol	95-48-7	N/A	N/A	N/A	N/A	N/A	N/A
4-Methylphenol	p-Cresol	106-44-5	N/A	N/A	N/A	N/A	N/A	N/A
MES (special purified aromatic oil)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2-(4-morpholino)benzothiazole	2-morpholinothio benzothiazole (MBS); Morpholinothio-benzothiazole; N-Oxydiethylenebenzothiazole-2-sulfenamide	102-77-2	N/A	N/A	N/A	N/A	N/A	N/A
2-Morpholinodithiobenzothiazole (MBSS)	2-(Morpholin-4-yldithio)-1,3-benzothiazole	95-32-9	N/A	N/A	N/A	N/A	N/A	N/A
Naphthalene	N/A	91-20-3	N/A	N/A	N/A	Group 2B	5.8	N/A
Naphthalene, 2-(bromomethyl)-	2-Bromomethylnaphthalene	939-26-4	N/A	N/A	N/A	N/A	N/A	N/A
Naphthalic Anhydride	1H,3H-Naphtho(1,8-cd)pyran-1,3-dione	81-84-5	N/A	N/A	N/A	N/A	N/A	N/A
Napthenic oil	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Nitro compound (isomer of major peak)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Nitro compound (nitro-ether derivative)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Nitrogen containing substances	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Nitrosodibutylamine (n-)	N-Nitrosodibutylamine	924-16-3	N/A	N/A	N/A	Group 2B	N/A	N/A
Nitrosodiethylamine (n-)	N-Nitrosodiethylamine	55-18-5	N/A	N/A	N/A	Group 2A	0.02	N/A
Nitrosodimethylamine (n-)	N-Nitrosodimethylamine	62-75-9	N/A	N/A	N/A	Group 2A	0.04	N/A
n-Nitrosodiphenylamine	N-Nitrosodiphenylamine	86-30-6	N/A	N/A	N/A	Group 3	80	N/A
Nitrosodipropylamine (n-)	N-Nitrosodipropylamine	621-64-7	N/A	N/A	N/A	Group 2B	0.1	N/A
Nitrosomorpholine (n-)	N-Nitrosomorpholine	59-89-2	N/A	N/A	N/A	Group 2B	0.1	N/A
Nitrosopiperidine (n-)	N-Nitrosopiperidine	100-75-4	N/A	N/A	N/A	Group 2B	0.07	N/A
Nitrosopyrrolidine (n-)	N-Nitrosopyrrolidine	930-55-2	N/A	N/A	N/A	Group 2B	0.3	N/A
Nonadecane	N/A	629-92-5	N/A	N/A	N/A	N/A	N/A	N/A
Nonanale	Nonanal	124-19-6	N/A	N/A	N/A	N/A	N/A	N/A
Nonane	N/A	111-84-2	N/A	N/A	N/A	N/A	N/A	N/A

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4-n-nonylphenol	4-Nonylphenol	104-40-5	N/A	N/A	N/A	N/A	N/A	N/A
Octadecanoic acid, methyl ester	Methyl stearate	112-61-8	N/A	N/A	N/A	N/A	N/A	N/A
Octane	N/A	111-65-9	N/A	N/A	N/A	N/A	N/A	N/A
4-t-octylphenol	4-(1,1,3,3-Tetramethylbutyl)phenol, 4-tert-(octyl)-phenol	140-66-9	N/A	N/A	N/A	N/A	N/A	N/A
Optadecane	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Organic thiola and sulfides	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Orthocarbonate - Carboxy compound)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
N-Oxydiethylenedithiocarbamyl-N`-oxydiethylenesulfenamide (OTOS)	N/A	13752-51-7	N/A	N/A	N/A	N/A	N/A	N/A
PAHs	Polycyclic aromatic hydrocarbons	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Parrafinic oils	Mineral oil	8012-95-1	N/A	N/A	N/A	N/A	N/A	N/A
PCB sum	N/A	N/A	2.00E-05	N/A	N/A	Group 1	0.09	N/A
PCDD/F sum	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Pentacosane	N/A	629-99-2	N/A	N/A	N/A	N/A	N/A	N/A
Pentane	N/A	109-66-0	N/A	N/A	N/A	N/A	N/A	N/A
Perylene	N/A	198-55-0	N/A	N/A	N/A	Group 3	N/A	N/A
Petroleum Naphtha	Naphtha	8030-30-6	N/A	N/A	N/A	N/A	N/A	N/A
Phenalone	Phenalen-1-one	548-39-0	N/A	N/A	N/A	N/A	N/A	N/A
Phenanthrene	N/A	85-01-8	N/A	N/A	N/A	Group 3	N/A	N/A
1-Phenanthrenecarboxylic acid, 1,2,3,4,4	1,2,3,4,4-1-Phenanthrene carboxylic acid; Dehydroabietic acid	1740-19-8	N/A	N/A	N/A	N/A	N/A	N/A
Phenol	2,4-Di-tert-butylphenol	108-95-2	N/A	N/A	N/A	Group 3	N/A	N/A
Phenolics	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Phenol, 2,4-bis(1,1-dimethylethyl)-	N/A	96-76-4	N/A	N/A	N/A	N/A	N/A	N/A
Phenol, 2,4-bis(1-methyl-1-phenylethyl)-	2,4-Bis(1-methyl-1-phenylethyl)phenol	2772-45-4	N/A	N/A	N/A	N/A	N/A	N/A
Phenol, m-tert-butyl-	3-tert-Butylphenol	585-34-2	N/A	N/A	N/A	N/A	N/A	N/A
Phenylbenzimidazole	2-Phenylbenzimidazole	716-79-0	N/A	N/A	N/A	N/A	N/A	N/A
p-Phenylenediamines	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Phenylenediamines	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2-(1-phenylethyl)-phenol	2-(1-Phenylethyl)phenol	26857-99-8	N/A	N/A	N/A	N/A	N/A	N/A
3-Phenyl-2-propenal	3-Phenylprop-2-enal	104-55-2	N/A	N/A	N/A	N/A	N/A	N/A
Phthalates	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
PM 2.5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
PM 10	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Poly- and di-nitrobenzenes	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Poly-p-dinitrosobenzene	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Propene	1-Propene; propylene	115-07-1	N/A	N/A	N/A	Group 3	N/A	N/A
Propylbenzene	N/A	103-65-1	N/A	N/A	N/A	N/A	N/A	N/A
Pyrazole	N/A	288-13-1	N/A	N/A	N/A	N/A	N/A	N/A
Pyrene	N/A	129-00-0	N/A	N/A	N/A	Group 3	N/A	N/A
Pyrimidine, 2-(4-pentylphenyl)-5-propyl-	N/A	94320-32-8	N/A	N/A	N/A	N/A	N/A	N/A
2-Pyrrolidinone. 1-methyl-	N-Methyl-2-pyrrolidone	872-50-4	0.6	N/A	300	N/A	N/A	N/A
Quinones	N/A	106-51-4	N/A	N/A	N/A	Group 3	N/A	N/A
Resorcinol	N/A	108-46-3	0.4	N/A	N/A	Group 3	N/A	N/A
Rethene [c]	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Siloxanes	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Styrene	N/A	100-42-5	N/A	N/A	N/A	Group 2B	N/A	N/A
Styrene oligomers	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Substituted p-Phenylenediamines	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Sulfur containing organics	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Sulfur Donors	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

	Chemical Constituent[a]	Synonym[b]	CAS Number[c]	IPCS CICAD[5] Tolerable Intake (mg/kg-d)	IPCS CICAD Tolerable Intake (ug/L)	IPCS CICAD Tolerable Conc. (ug/m^3)	IARC Monogr.[6] Cancer Class	CalEPA PR65[7] NSRL (ug/day)	CalEPA PR65 MADL (ug/day)
	Sulphenamides	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	TDAE (special purified aromatic oil)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Tertbutylacetophenone	3,3-dimethyl-1-phenylbutan-1-one	31366-07-1	N/A	N/A	N/A	N/A	N/A	N/A
	N-tert-Butyl-2-benzothiazolesulf enamide (TBBS)	N/A	95-31-8	N/A	N/A	N/A	N/A	N/A	N/A
	4-tert butylphenol	4-tert-Butylphenol	98-54-4	N/A	N/A	N/A	N/A	N/A	N/A
	Tetraalkylthiuram disulfides	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Tetrabenzylthiuram disulfide (TBZTD)	N/A	10591-85-2	N/A	N/A	N/A	N/A	N/A	N/A
	Tetrabutylthiuram disulfide (TBTD)	N/A	1634-02-2	N/A	N/A	N/A	N/A	N/A	N/A
	Tetrachloroethene	Tetrachloroethylene; perchloroethylene	127-18-4	0.05	N/A	200	Group 2A	N/A	N/A
	Tetracosane	N/A	646-31-1	N/A	N/A	N/A	N/A	N/A	N/A
	Tetraethylthiuram disulfide	Disulfiram	97-77-8	N/A	N/A	N/A	Group 3	N/A	N/A
	Tetrahydrofuran	N/A	109-99-9	N/A	N/A	N/A	N/A	N/A	N/A
	Tetramethylthiuram disulfide	Thiram	137-26-8	N/A	N/A	N/A	Group 3	N/A	N/A
	Tetramethylthiuram monosulfide	N/A	97-74-5	N/A	N/A	N/A	N/A	N/A	N/A
	Thiazoles	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Thioureas	N/A	N/A	<0.07	N/A	N/A	N/A	10	N/A
	Thiurams	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Thiuram sulfides	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Toluene	N/A	108-88-3	N/A	N/A	N/A	Group 3	N/A	7000
	Total petroleum hydrocarbons	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Trans trans-muconic acid	(E,E)-Muconic acid	3588-17-8	N/A	N/A	N/A	N/A	N/A	N/A
	Trimethyl-1,2-dihydroquinoline (TMDQ)	1,2-Dihydro-2,2,4-trimethylquinoline, polymer	26780-96-1	N/A	N/A	N/A	N/A	N/A	N/A
	1,1,1-Trichloroethane	N/A	71-55-6	N/A	N/A	N/A	Group 3	N/A	N/A
	Trichloroethylene	N/A	79-01-6	N/A	N/A	N/A	Group 1	14 (oral) 50 (inhalation)	N/A
	1,1,2-Trichloro-1,2,2-trifluoroethane	N/A	76-13-1	N/A	N/A	N/A	N/A	N/A	N/A
	Trichloro-trifluoroethane	1,1,1-Trichloro-2,2,2-trifluoroethane	354-58-5	N/A	N/A	N/A	N/A	N/A	N/A
	Tricosane	N/A	638-67-5	N/A	N/A	N/A	N/A	N/A	N/A
	1,2,3-Trimethyl benzene	1,2,3-Trimethylbenzene	526-73-8	N/A	N/A	N/A	N/A	N/A	N/A
	1,2,4-Trimethyl benzene	1,2,4-Trimethylbenzene	95-63-6	N/A	N/A	N/A	N/A	N/A	N/A
	1,3,5-Trimethyl benzene	1,3,5-Trimethylbenzene	108-67-8	N/A	N/A	N/A	N/A	N/A	N/A
	2,2,4-Trimethyl-1,2-dihydroquinoline (TMQ)	1,2-Dihydro-2,2,4-trimethylquinoline, polymer	26780-96-1	N/A	N/A	N/A	N/A	N/A	N/A
	Vinyl Acetate	N/A	108-05-4	N/A	N/A	N/A	Group 2B	N/A	N/A
	White gasoline	Natural gasoline	8006-61-9	N/A	N/A	N/A	N/A	N/A	N/A
	o-Xylene	N/A	95-47-6	N/A	N/A	N/A	N/A	N/A	N/A
	Xylenes	N/A	1330-20-7	N/A	N/A	N/A	Group 3	N/A	N/A
	Zn-Dibenzyldithiocarbamate (ZBEC)	N/A	136-23-2	N/A	N/A	N/A	N/A	N/A	N/A
	Zn-Diethyldithiocarbamate (ZDEC)	Zinc diethyldithiocarbamate	14324-55-1	N/A	N/A	N/A	N/A	N/A	N/A
	Zn-Dimethyldithiocarbamate (ZDMC)	Ziram	137-30-4	N/A	N/A	N/A	Group 3	N/A	N/A
	Zn-dibutyldithiocarbamate (ZDBC)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	ZnO	Zinc Oxide	1314-13-2	N/A	N/A	N/A	N/A	N/A	N/A
TOTALS	**355**	**158**	**290**	**17**	**2**	**13**	**96**	**46**	**10**
PERCENTS	**100%**	**45%**	**82%**	**5%**	**1%**	**4%**	**27%**	**13%**	**3%**

Chemical Constituent[a]	Synonym[b]	CAS Number[c]	CalEPA RELs[8] Oral REL Chronic (ug/kg-day)	CalEPA RELs Inhal. REL acute (ug/m^3)	CalEPA RELs Inhal. REL 8-hr (ug/m^3)	CalEPA RELs Inhal. REL Chronic (ug/m^3)	CalEPA Cancer Values[9] Oral SF (mg/kg-day^{-1})	CalEPA Cancer Values Inhal. SF (mg/kg-day^{-1})	CalEPA Cancer Values Inhal. UR (ug/m$^{3-1}$)
Aluminum	N/A	7429-90-5	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Antimony	N/A	7440-36-0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Arsenic	N/A	7440-38-2	0.0035	0.2	0.015	0.015	1.5	12	3.30E-03
Barium	N/A	7440-39-3	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Beryllium	N/A	7440-41-7	2.0	N/A	N/A	0.007	8.4	N/A	2.40E-03
Cadmium	N/A	7440-43-9	0.5	N/A	N/A	0.02	15	N/A	4.20E-03
Calcium	N/A	7440-70-2	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Chloride	N/A	16887-00-6	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Chromium	N/A	7440-47-3; 16065-83-1 (CrIII); 18540-29-9 (CrVI)	20 (CrVI)	N/A	N/A	0.2 (CrVI)	0.42 (CrVI)	510 (CrVI)	1.5E-1 (CrVI)
Cobalt	N/A	7440-48-4	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Copper	N/A	7440-50-8	N/A	100	N/A	N/A	N/A	N/A	N/A
Iron	N/A	7439-89-6	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Lead	N/A	7439-92-1	N/A	N/A	N/A	N/A	8.50E-03	4.20E-02	1.20E-05
Lithium	N/A	7439-93-2	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Magnesium	N/A	7439-95-4	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Manganese	N/A	7439-96-5	N/A	N/A	0.17	0.09	N/A	N/A	N/A
Mercury	N/A	7439-97-6	0.16	0.6	0.06	0.03	N/A	N/A	N/A
Molybdenum	N/A	7439-98-7	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Nickel	N/A	7440-02-0	11	0.2	0.06	0.014	9.10E-01	N/A	2.60E-04
Phosphorous	N/A	7723-14-0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Potassium	N/A	7440-09-7	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Rubidium	N/A	7440-17-7	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Selenium	N/A	7782-49-2	5	N/A	N/A	20	N/A	N/A	N/A
Silver	N/A	7440-22-4	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Sodium	N/A	7440-23-5	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Strontium	N/A	7440-24-6	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Sulfur	N/A	7704-34-9	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Thallium	N/A	7440-28-0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Tin	N/A	7440-31-5	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Titanium	N/A	7440-32-6	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Tungsten	N/A	7440-33-7	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Vanadium	N/A	7440-62-2	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Zinc	N/A	7440-66-6	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Cadmium and Zinc Soaps	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Acenaphthene	N/A	83-32-9	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Acenaphthylene	N/A	208-96-8	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Acetaldehyde	Ethanone	75-07-0	N/A	470	300	140	1.00E-02	N/A	2.70E-06
Acetamide, N-cyclohexyl-	N/A	1124-53-4	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Acetone	N/A	67-64-1	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Acetone-diphenylamine condensation product (ADPA)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Acetonitrile	N/A	75-05-8	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Chemical Constituent[a]	Synonym[b]	CAS Number[c]	CalEPA RELs[8] Oral REL Chronic (ug/kg-day)	CalEPA RELs Inhal. REL acute (ug/m^3)	CalEPA RELs Inhal. REL 8-hr (ug/m^3)	CalEPA RELs Inhal. REL Chronic (ug/m^3)	CalEPA Cancer Values[9] Oral SF ($mg/kg\text{-}day^{-1}$)	CalEPA Cancer Values Inhal. SF ($mg/kg\text{-}day^{-1}$)	CalEPA Cancer Values Inhal. UR ($ug/m^{3\text{-}1}$)
Acetophenone	N/A	98-86-2	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6-Acetoxy-2,2-dimethyl-m-dioxane	Dimethoxane	828-00-2	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Acrolein	N/A	107-02-8	N/A	2.5	0.7	0.35	N/A	N/A	N/A
Alcohols	Ethanol	64-17-5	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Aldehydes	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Alkyl benzenes	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Alkyl dithiols	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Alkyl naphthalenes	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Alkyl phenols	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Alpha pinene	alpha-Pinene	80-56-8	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Amine (N-dialkyl analine derivative)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Amines	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Anathrene [c]	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Aniline	Benzeneamine; aminobenzene	62-53-3	N/A	N/A	N/A	N/A	5.70E-03	N/A	1.60E-06
Anthanthrene	N/A	191-26-4	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Anthracene	N/A	120-12-7	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Aromatic oil	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9,10-Anthracenedione, 2-ethyl	2-Ethylanthracene-9,10-dione	84-51-5	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Azobenzene	N/A	103-33-3	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Benz(e)acenaphthylene	Acephenanthrylene	201-06-9	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Benzaldehyde, 3-hydroxyl-4-methoxy	3-Hydroxy-4-methoxy-benzaldehyde	621-59-0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Benz(a)anthracene	N/A	56-55-3	N/A	N/A	N/A	N/A	1.20E+00	3.90E-01	1.10E-04
Benzene	N/A	71-43-2	N/A	27	3	3	1.00E-01	N/A	2.90E-05
Benzene, 1,3-bis(1-methylethenyl)-	1,3-bis(1-methylethenyl)benzene; 1,3-Diisopropenylbenzene	3748-13-8	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Benzene, 1,4-bis(1-methylethenyl)-	1,4-Bis(1-methylethenyl)benzene	1605-18-1	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1,4-Benzenediamine, N,N'-diphenyl-	N,N'-Diphenyl-p-phenylenediamine	74-31-7	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1,4-Benzendiamin, N-(1-methylethyl)-N'-phenyl-, (IPPD)	N-Isopropyl-N'-phenyl-p-phenylenediamine, Isopropylaminodephenylamine (IPPD)	101-72-4	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Benzene, isocyanato-	Phenyl isocyanate	103-71-9	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Benzenemethanol	Benzyl alcohol	100-51-6	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Benzo(def)dibenzothiophene	Phenanthro[4,5-bcd]thiophene	30796-92-0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Benzo(g)dibenzothiophene	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Benzo(b)fluoranthene	N/A	205-99-2	N/A	N/A	N/A	N/A	1.20E+00	3.90E-01	1.10E-04
Benzo(bjk)fluoranthene	2,11-(Metheno)benzo[a]fluorene	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Benzo(ghi)fluoranthene	Benzo[ghi]fluoranthene	203-12-3	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Benzo(i)fluoranthene	Benzo(j)fluoranthene	205-82-3	N/A	N/A	N/A	N/A	1.20E+00	3.90E-01	1.10E-04
Benzo(k)fluoranthene	N/A	207-08-9	N/A	N/A	N/A	N/A	1.20E+00	3.90E-01	1.10E-04
Benzo(mno)fluoranthene	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Benzo(a)fluorene	11H-Benzo[a]fluorene	238-84-6	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Benzo(b)fluorene	2,3-Benzofluorene	243-17-4	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Benzo(def)naphthobenzothiophene	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6H-Benzo[cd]pyren-6-one	6H-Benzo(cd)pyren-6-one	3074-00-8	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Benzo(a)pyrene	N/A	50-32-8	N/A	N/A	N/A	N/A	1.20E+01	3.90E+00	1.10E-03
Benzo(e)pyrene	N/A	192-97-2	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Benzo(ghi)perylene	Benzo(g,h,i)perylene	191-24-2	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Benzoic acid	N/A	65-85-0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Benzothiazole	N/A	95-16-9	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Benzothiazole, 2-(methylthio)	2-(Methylthio)benzothiazole	615-22-5	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Benzothiazole, 2-phenyl	2-Phenylbenzothiazole	883-93-2	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Benzothiazolone	2-Hydroxybenzothiazole, 2(3H)-Benzothiazolone, 2(3H) benzothiazolone	934-34-9	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Benzoyl and other peroxides	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Benzylbutyl phthalate	Butyl benzyl phthalate	85-68-7	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Biphenyl	1,1'-Biphenyl	92-52-4	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Chemical Constituent[a]	Synonym[b]	CAS Number[c]	CalEPA RELs[8] Oral REL Chronic (ug/kg-day)	CalEPA RELs Inhal. REL acute (ug/m^3)	CalEPA RELs Inhal. REL 8-hr (ug/m^3)	CalEPA RELs Inhal. REL Chronic (ug/m^3)	CalEPA Cancer Values[9] Oral SF (mg/kg-day^{-1})	CalEPA Cancer Values Inhal. SF (mg/kg-day^{-1})	CalEPA Cancer Values Inhal. UR (ug/m$^{3-1}$)
1,1'-Biphenyl, 4, 4', 5', 6'-tetramethoxy-	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
(N,N`-Bis(1,4-dimethylpentyl) pphenylendiamine) (7PPD)	N,N'-Bis(1,4-dimethylpentyl)-4-phenylenediamine	3081-14-9	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Bis(2-ethylhexyl) phthalate	Di(2-ethylhexyl) phthalate	117-81-7	N/A	N/A	N/A	N/A	8.40E-03	N/A	2.40E-06
Bis-(2,2,6,6-tetramethyl-4-piperidinyl)sebacate	Bis(2,2,6,6-tetramethyl-4-piperidyl) sebacate	52829-07-9	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Bisthiol acids	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Black rubber	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Bromodichloromethane	N/A	75-27-4	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Bromoform	N/A	75-25-2	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Butoxyethoxyethanol	2-(2-Butoxyethoxy)ethanol, diethylene glycol monobutyl ether	112-34-5	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Butylated hydroxyanisole	N/A	25013-16-5	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Butylated hydroxytoluene	2,6-Di-tert-butyl-4-methylphenol (BHT)	128-37-0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Butylbenzene	N/A	104-51-8	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Caprolactam disulfide (CLD)	1,1'-Disulfanediyldiazepan-2-one	23847-08-7	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Carbazole	N/A	86-74-8	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Carbon Black	Furnace Black	1333-86-4	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Carbon Disulfide	N/A	75-15-0	N/A	6200	N/A	800	N/A	N/A	N/A
Carbon Tetrachloride	N/A	56-23-5	N/A	1900	N/A	40	1.50E-01	N/A	4.20E-05
Chlorobenzene	N/A	108-90-7	N/A	N/A	N/A	1000	N/A	N/A	N/A
Chloroform	Trichloromethane	67-66-3	N/A	150	N/A	300	1.90E-02	N/A	5.30E-06
Chloromethane	Methyl chloride	74-87-3	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Chrysene	N/A	218-01-9	N/A	N/A	N/A	N/A	1.20E-01	3.90E-02	1.10E-05
Coronene	N/A	191-07-1	N/A	N/A	N/A	N/A	N/A	N/A	N/A
o-Cyanobenzoic acid	2-Cyanobenzoic acid	3839-22-3	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Cyclohexanamine	Cyclohexylamine	108-91-8	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Cyclohexanamine, N-cyclohexyl-	Dicyclohexylamine	101-83-7	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Cyclohexanamine, N-cyclohexyl-N-methyl-	N-Cyclohexyl-N-methylcyclohexanamine	7560-83-0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Cyclohexane	N/A	110-82-7	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Cyclohexane, isocyanato	Isocyanatocyclohexane	3173-53-3	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Cyclohexane, isothiocyanato-	N/A	1122-82-3	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Cyclohexanone	N/A	108-94-1	N/A	N/A	N/A	N/A	N/A	N/A	N/A
N-Cyclohexyl-2-benzothiazolesulfenamide (CBS)	N-Cyclohexyl-2-benzothiazolesulfenamide	95-33-0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
n-Cyclohexyl-formamide	N-Cyclohexylformamide, Formamide, N-cyclohexyl	766-93-8	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Cycloninasiloxane, octadecamethyl-	Octadecamethylcyclononasiloxane	556-71-8	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Cyclopenta[cd]pyrene	N/A	27208-37-3	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4H-cyclopenta[def]phenanthren-4-one	4H-Cyclopenta(def)phenanthren-4-one	5737-13-3	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4H-cyclopenta[def]-phenanthrene	4-H-Cyclopenta(d,e,f)phenanthrene	203-64-5	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Cyclopentane, methyl-	Methylcyclopentane	96-37-7	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Decane	N/A	124-18-5	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Diazoaminobenzenes	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Dibenzo(a,h) anthracene	Dibenz(a,h)anthracene	53-70-3	N/A	N/A	N/A	N/A	4.10E+00	N/A	1.20E-03
Dibenzofurane	Dibenzofuran	132-64-9	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Dibenzo(ae)pyrene	Naphtho(1,2,3,4-def)chrysene	192-65-4	N/A	N/A	N/A	N/A	1.20E+01	3.90E+00	1.10E-03
Dibenzo(ai)pyrene	Dibenzo[a,i]pyrene	189-55-9	N/A	N/A	N/A	N/A	1.20E+02	3.90E+01	1.10E-02
Dibenzo(ah)pyrene	Dibenzo[a,h]pyrene	189-64-0	N/A	N/A	N/A	N/A	1.20E+02	3.90E+01	1.10E-02
Dibenzothiophene	N/A	132-65-0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Dibutyl phthalate	N/A	84-74-2	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1,4-Dichlorobenzene	p-dichlorobenzene	106-46-7	N/A	N/A	N/A	800	4.00E-02	N/A	1.10E-05
Dichlorodifluoromethane	Freon 12	75-71-8	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1,2-Dichloroethane	Ethylene dichloride	107-06-2	N/A	N/A	N/A	400	7.20E-02	N/A	2.10E-05
cis-1,2-Dichloroethene	(Z)-1,2-Dichloroethylene	156-59-2	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1,2-Dichloropropane	N/A	78-87-5	N/A	N/A	N/A	N/A	N/A	N/A	N/A

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N,N-Dicyclohexyl-2-benzothiazolesulfenamide (DCBS)	N,N-Dicyclohexyl-2-benzothiazolesulfenamide	4979-32-2	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Dicyclohexylphthalate (DCHP)	Dicyclohexyl phthalate	84-61-7	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1,3-Dicyclohexylurea	N,N'-Dicyclohexylurea	2387-23-7	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Diethenylbenzene	Divinylbenzene	1321-74-0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Di(2-ethylhexyl) adipate	Hexanedioic acid, bis(2-ehtylhexyl); Bis(2-ethylhexyl)hexanedioic acid	103-23-1	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Diethyl phthalate	N/A	84-66-2	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Diethylthiourea (DETU)	N,N'-Diethylthiourea	105-55-5	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Dihydrocyclopentapyrene	2,3-Acepyrene	25732-74-5	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Diisobutyl phthalate	N/A	84-69-5	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Diisodecylphthalate	bis(8-Methylnonyl) phthalate	89-16-7	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Diisononyl phthalate	DINP	28553-12-0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9,l0-Dimethyl-1,2-Benzanthracene	7,12-Dimethylbenz(a)anthracene	57-97-6	N/A	N/A	N/A	N/A	2.50E+02	N/A	7.10E-02
(N-1,3-dimethyl-butyl)-N'- phenyl-p-phenylenediamine (6PPD)	N-(1,3-Dimethylbutyl)-N'-phenyl-p-phenylenediamine	793-24-8	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Dimethyldiphenylthiuram disulfide (MPTD)	Dimethyldiphenylthiuram disulfide	53880-86-7	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2,6-Dimethylnaphthalene	N/A	581-42-0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2,4-Dimethylphenol	N/A	105-67-9	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Dimethyl phthalate	N/A	131-11-3	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Dinitroarenes	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Di-n-octyl phthalate	Dioctyl phthalate	117-84-0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Di-ortho-tolylguanidine	N/A	97-39-2	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Dipentamethylenethiuramtetrasulfide (DPTT)	Bis(pentamethylenethiuram)tetrasulfide	120-54-7	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Diphenylamine	N/A	122-39-4	N/A	N/A	N/A	N/A	N/A	N/A	N/A
N,N'-Diphenylguanidine (DPG)	1,3-Diphenylguanidine	102-06-7	N/A	N/A	N/A	N/A	N/A	N/A	N/A
N,N'-Diphenyl-p-phenylenediamine (DPPD)	N,N'-Diphenyl-p-phenylenediamine	74-31-7	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Disulfides	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Di-(2-ethyl)hexylphosphorylpolysul fide) (SDT)	Bis-(ethylhexylthiophosphoryl) polysulfide	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3,5-Di-tert-Butyl-4-hydroxybenzaldehyde	N/A	1620-98-0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2,2'-Dithiobis(benzothiazole)	2,2'-Dithiobisbenzothiazole	120-78-5	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Dithiocarbamates	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Dithiomorpholine (DTDM)	4,4'-Dithiodimorpholine	103-34-4	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Dithiophosphates	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
N,N`-Ditolyl-p-phenylenediamine (DTPD)	N,N'-Ditolyl-p-phenylenediamine	27417-40-9	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Docosanoic acid	N/A	112-85-6	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Dodecanoic acid	N/A	143-07-7	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Dotriacontane	N/A	544-85-4	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Drometrizol	2-(2H-Benzotriazol-2-yl)-4-methylphenol	2440-22-4	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Eicosane	N/A	112-95-8	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Erucylamide	Erucamide	112-84-5	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Esters	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Ethanol, 2-butoxy-	2-Butoxyethanol	111-76-2	N/A	14000	N/A	N/A	N/A	N/A	N/A
Ethanol, 1-(2-butoxyethoxy)	1-(2-Butoxyethoxy)ethanol	54446-78-5	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Ethanone, 1,1'-(1,3-phenylene)bis-	Benzene-1,3-bis(acetyl)	6781-42-6	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Ethanone, 1,1'-(1,4-phenylene)bis-	1,1-(1,4-Phenylene)bis-ethanone	1009-61-6	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Ethanone, 1-[4-(1-methylethenyl) phenyl]-	1-[4-(1-Methylethenyl)phenyl]ethanone	5359-04-6	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Ethyl Acetate	N/A	141-78-6	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Ethyl benzene	Ethylbenzene	100-41-4	N/A	N/A	N/A	2000	1.10E-02	8.70E-03	2.50E-06
Ethyl benzene aldehyde	Benzaldehyde, 2-ethyl-	22927-13-5	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Ethylene thiourea (Ethylene thiourea)	N/A	96-45-7	N/A	N/A	N/A	N/A	4.50E-02	N/A	1.30E-05
2-Ethyl-1-hexanol	N/A	104-76-7	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1-Ethyl-4-Methyl Benzene	4-Ethyltoluene	622-96-8	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Fluoranthene	N/A	206-44-0	N/A	N/A	N/A	N/A	N/A	N/A	N/A

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Fluorene	N/A	86-73-7	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Formaldehyde	N/A	50-00-0	N/A	55	9	9	2.10E-02	N/A	6.00E-06
Furan, 2-methyl	2-Methylfuran	534-22-5	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2(3H)-Furanone,dihydro-4-hydroxy-	Dihydro-4-hydroxy-2(3H)-furanone; beta-Hydroxybutyrolactone	5469-16-9	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Guanidines	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Halocarbon 11	Trichlorofluoromethane, Freon 11	75-69-4	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Hemeicosane[c]	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Heptadecane	N/A	629-78-7	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Heptane	N/A	142-82-5	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Heptanonitrile	Heptanenitrile	629-08-3	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Hexacosane	N/A	630-01-3	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Hexadecane	N/A	544-76-3	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Hexa(methoxymethyl)melamine	N,N,N',N',N'',N''-Hexakis(methoxy methyl)-1,3,5-triazine-2,4,6-triamine	3089-11-0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Hexamethylenetetramine	Methenamine	100-97-0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Hexane	n-Hexane	110-54-3	N/A	N/A	N/A	7000	N/A	N/A	N/A
Hexanedioic acid, methyl ester	Methyl hexanedioate	627-91-8	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Hexanoic acid, 2-ethyl-	2-Ethylhexanoic acid	149-57-5	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Hydrocarbon (olefin/aromatic)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
7-Hydroxybenzo[f]flavone	7-Hydroxy-3-phenyl-1H-naphtho[2,1-b] pyran-1-one	86247-95-2	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1-Hydroxypyrene	N/A	5315-79-7	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Indeno[l,2,3-cd]pyrene	o-Phenylenepyrene	193-39-5	N/A	N/A	N/A	N/A	1.20E+00	3.90E-01	1.10E-04
1H-isoindole-1,3 (2H)-dione	Phthalimide	85-41-6	N/A	N/A	N/A	N/A	N/A	N/A	N/A
iso-nonylphenol	3-Nonylphenol	11066-49-2	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Isophorone	N/A	78-59-1	N/A	N/A	N/A	2000	N/A	N/A	N/A
Isopropyl Alcohol	2-Propanol, Isopropanol	67-63-0	N/A	3200	N/A	7000	N/A	N/A	N/A
Isopropylbenzene	Cumene	98-82-8	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Isopropyltoluene	1-Methyl-2-(propan-2-yl)benzene	527-84-4	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Ketones	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Latex protein	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Limonene	N/A	138-86-3	N/A	N/A	N/A	N/A	N/A	N/A	N/A
MEK	Methyl ethyl ketone	78-93-3	N/A	13000	N/A	N/A	N/A	N/A	N/A
2-Mercaptobenzothiazole	N/A	149-30-4	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Methane, diethoxy-cyclohexane	Diethoxycyclohexanemethane; Bis(cyclohexyloxy)methane	1453-21-0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Methyl Alcohol	Methanol	67-56-1	N/A	28000	N/A	4000	N/A	N/A	N/A
2-Methylanthracene	N/A	613-12-7	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2-Methyl-Butane	2-Methylbutane	78-78-4	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2,2-Methylene-bis-(4-methyl-6-tert-butylphenol) (BPH)	N/A	119-47-1	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Methylene Chloride	Dichloromethane	75-09-2	N/A	14000	N/A	400	3.50E-03	N/A	1.00E-06
5-Methyl-2-hexanone	Methyl isoamyl ketone	110-12-3	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1-Methylnaphthalene	N/A	90-12-0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2-Methylnaphthalene	N/A	91-57-6	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3-Methyl-Pentane	3-Methylpentane	96-14-0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4-Methyl-2-pentanone	MIBK, Methyl isobutyl ketone	108-10-1	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1-Methylphenanthrene	1-Methyl phenanthrene	832-69-9	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2-Methylphenanthrene	N/A	2531-84-2	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3-Methylphenanthrene	N/A	832-71-3	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9-Methylphenanthrene	N/A	883-20-5	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2-Methylphenol	o-Cresol	95-48-7	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4-Methylphenol	p-Cresol	106-44-5	N/A	N/A	N/A	N/A	N/A	N/A	N/A
MES (special purified aromatic oil)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2-(4-morpholino)benzothiazole	2-morpholinothio benzothiazole (MBS); Morpholinothio-benzothiazole; N-Oxydiethylenebenzothiazole-2-sulfenamide	102-77-2	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2-Morpholinodithiobenzothiazole (MBSS)	2-(Morpholin-4-yldithio)-1,3-benzothiazole	95-32-9	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Chemical Constituent[a]	Synonym[b]	CAS Number[c]	CalEPA RELs[8] Oral REL Chronic (ug/kg-day)	CalEPA RELs Inhal. REL acute (ug/m^3)	CalEPA RELs Inhal. REL 8-hr (ug/m^3)	CalEPA RELs Inhal. REL Chronic (ug/m^3)	CalEPA Cancer Values[9] Oral SF ($mg/kg\text{-}day^{-1}$)	CalEPA Cancer Values Inhal. SF ($mg/kg\text{-}day^{-1}$)	CalEPA Cancer Values Inhal. UR (ug/m^{3-1})
Naphthalene	N/A	91-20-3	N/A	N/A	N/A	9	1.20E-01	N/A	3.40E-05
Naphthalene, 2-(bromomethyl)-	2-Bromomethylnaphthalene	939-26-4	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Naphthalic Anhydride	1H,3H-Naphtho(1,8-cd)pyran-1,3-dione	81-84-5	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Napthenic oil	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Nitro compound (isomer of major peak)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Nitro compound (nitro-ether derivative)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Nitrogen containing substances	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Nitrosodibutylamine (n-)	N-Nitrosodibutylamine	924-16-3	N/A	N/A	N/A	N/A	1.10E+01	N/A	3.10E-03
Nitrosodiethylamine (n-)	N-Nitrosodiethylamine	55-18-5	N/A	N/A	N/A	N/A	3.60E+01	N/A	1.00E-02
Nitrosodimethylamine (n-)	N-Nitrosodimethylamine	62-75-9	N/A	N/A	N/A	N/A	1.60E+01	N/A	4.60E-03
n-Nitrosodiphenylamine	N-Nitrosodiphenylamine	86-30-6	N/A	N/A	N/A	N/A	9.00E-03	N/A	2.60E-06
Nitrosodipropylamine (n-)	N-Nitrosodipropylamine	621-64-7	N/A	N/A	N/A	N/A	7.00E+00	N/A	2.00E-03
Nitrosomorpholine (n-)	N-Nitrosomorpholine	59-89-2	N/A	N/A	N/A	N/A	6.70E+00	N/A	1.90E-03
Nitrosopiperidine (n-)	N-Nitrosopiperidine	100-75-4	N/A	N/A	N/A	N/A	9.40E+00	N/A	2.70E-03
Nitrosopyrrolidine (n-)	N-Nitrosopyrrolidine	930-55-2	N/A	N/A	N/A	N/A	2.10E+00	N/A	6.00E-04
Nonadecane	N/A	629-92-5	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Nonanale	Nonanal	124-19-6	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Nonane	N/A	111-84-2	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4-n-nonylphenol	4-Nonylphenol	104-40-5	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Octadecanoic acid, methyl ester	Methyl stearate	112-61-8	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Octane	N/A	111-65-9	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4-t-octylphenol	4-(1,1,3,3-Tetramethylbutyl)phenol, 4-tert-(octyl)-phenol	140-66-9	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Optadecane	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Organic thiola and sulfides	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Orthocarbonate - Carboxy compound)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
N-Oxydiethylenedithiocarbamyl-N`-oxydiethylenesulfenamide (OTOS)	N/A	13752-51-7	N/A	N/A	N/A	N/A	N/A	N/A	N/A
PAHs	Polycyclic aromatic hydrocarbons	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Parrafinic oils	Mineral oil	8012-95-1	N/A	N/A	N/A	N/A	N/A	N/A	N/A
PCB sum	N/A	N/A	N/A	N/A	N/A	N/A	0.07 to 2	2e-5 to 5.7e-4	N/A
PCDD/F sum	N/A	N/A	1.00E-05	N/A	N/A	0.00004	N/A	N/A	N/A
Pentacosane	N/A	629-99-2	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Pentane	N/A	109-66-0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Perylene	N/A	198-55-0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Petroleum Naphtha	Naphtha	8030-30-6	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Phenalone	Phenalen-1-one	548-39-0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Phenanthrene	N/A	85-01-8	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1-Phenanthrenecarboxylic acid, 1,2,3,4,4	1,2,3,4,4-1-Phenanthrene carboxylic acid; Dehydroabietic acid	1740-19-8	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Phenol	2,4-Di-tert-butylphenol	108-95-2	N/A	5800	N/A	200	N/A	N/A	N/A
Phenolics	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Phenol, 2,4-bis(1,1-dimethylethyl)-	N/A	96-76-4	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Phenol, 2,4-bis(1-methyl-1-phenylethyl)-	2,4-Bis(1-methyl-1-phenylethyl)phenol	2772-45-4	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Phenol, m-tert-butyl-	3-tert-Butylphenol	585-34-2	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Phenylbenzimidazole	2-Phenylbenzimidazole	716-79-0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
p-Phenylenediamines	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Phenylenediamines	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2-(1-phenylethyl)-phenol	2-(1-Phenylethyl)phenol	26857-99-8	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3-Phenyl-2-propenal	3-Phenylprop-2-enal	104-55-2	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Phthalates	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
PM 2.5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
PM 10	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Poly- and di-nitrobenzenes	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Poly-p-dinitrosobenzene	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Propene	1-Propene; propylene	115-07-1	N/A	N/A	N/A	3000	N/A	N/A	N/A
Propylbenzene	N/A	103-65-1	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Pyrazole	N/A	288-13-1	N/A	N/A	N/A	N/A	N/A	N/A	N/A

	Chemical Constituent[a]	Synonym[b]	CAS Number[c]	CalEPA RELs[8] Oral REL Chronic (ug/kg-day)	CalEPA RELs Inhal. REL acute (ug/m^3)	CalEPA RELs Inhal. REL 8-hr (ug/m^3)	CalEPA RELs Inhal. REL Chronic (ug/m^3)	CalEPA Cancer Values[9] Oral SF (mg/kg-day^{-1})	CalEPA Cancer Values Inhal. SF (mg/kg-day^{-1})	CalEPA Cancer Values Inhal. UR (ug/m$^{3-1}$)
	Pyrene	N/A	129-00-0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Pyrimidine, 2-(4-pentylphenyl)-5-propyl-	N/A	94320-32-8	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	2-Pyrrolidinone. 1-methyl-	N-Methyl-2-pyrrolidone	872-50-4	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Quinones	N/A	106-51-4	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Resorcinol	N/A	108-46-3	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Rethene [c]	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Siloxanes	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Styrene	N/A	100-42-5	N/A	21000	N/A	900	N/A	N/A	N/A
	Styrene oligomers	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Substituted p-Phenylenediamines	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Sulfur containing organics	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Sulfur Donors	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Sulphenamides	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	TDAE (special purified aromatic oil)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Tertbutylacetophenone	3,3-dimethyl-1-phenylbutan-1-one	31366-07-1	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	N-tert-Butyl-2-benzothiazolesulf enamide (TBBS)	N/A	95-31-8	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	4-tert butylphenol	4-tert-Butylphenol	98-54-4	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Tetraalkylthiuram disulfides	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Tetrabenzylthiuram disulfide (TBZTD)	N/A	10591-85-2	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Tetrabutylthiuram disulfide (TBTD)	N/A	1634-02-2	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Tetrachloroethene	Tetrachloroethylene; perchloroethylene	127-18-4	N/A	20000	N/A	35	5.10E-02	2.10E-02	5.90E-06
	Tetracosane	N/A	646-31-1	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Tetraethylthiuram disulfide	Disulfiram	97-77-8	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Tetrahydrofuran	N/A	109-99-9	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Tetramethylthiuram disulfide	Thiram	137-26-8	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Tetramethylthiuram monosulfide	N/A	97-74-5	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Thiazoles	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Thioureas	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Thiurams	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Thiuram sulfides	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Toluene	N/A	108-88-3	N/A	37000	N/A	300	N/A	N/A	N/A
	Total petroleum hydrocarbons	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Trans trans-muconic acid	(E,E)-Muconic acid	3588-17-8	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Trimethyl-1,2-dihydroquinoline (TMDQ)	1,2-Dihydro-2,2,4-trimethylquinoline, polymer	26780-96-1	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	1,1,1-Trichloroethane	N/A	71-55-6	N/A	68000	N/A	1000	N/A	N/A	N/A
	Trichloroethylene	N/A	79-01-6	N/A	N/A	N/A	600	1.50E-02	7.00E-03	2.00E-06
	1,1,2-Trichloro-1,2,2-trifluoroethane	N/A	76-13-1	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Trichloro-trifluoroethane	1,1,1-Trichloro-2,2,2-trifluoroethane	354-58-5	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Tricosane	N/A	638-67-5	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	1,2,3-Trimethyl benzene	1,2,3-Trimethylbenzene	526-73-8	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	1,2,4-Trimethyl benzene	1,2,4-Trimethylbenzene	95-63-6	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	1,3,5-Trimethyl benzene	1,3,5-Trimethylbenzene	108-67-8	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	2,2,4-Trimethyl-1,2-dihydroquinoline (TMQ)	1,2-Dihydro-2,2,4-trimethylquinoline, polymer	26780-96-1	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Vinyl Acetate	N/A	108-05-4	N/A	N/A	N/A	200	N/A	N/A	N/A
	White gasoline	Natural gasoline	8006-61-9	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	o-Xylene	N/A	95-47-6	N/A	22000	N/A	700	N/A	N/A	N/A
	Xylenes	N/A	1330-20-7	N/A	22000	N/A	700	N/A	N/A	N/A
	Zn-Dibenzyldithiocarbamate (ZBEC)	N/A	136-23-2	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Zn-Diethyldithiocarbamate (ZDEC)	Zinc diethyldithiocarbamate	14324-55-1	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Zn-Dimethyldithiocarbamate (ZDMC)	Ziram	137-30-4	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Zn-dibutyldithiocarbamate (ZDBC)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	ZnO	Zinc Oxide	1314-13-2	N/A	N/A	N/A	N/A	N/A	N/A	N/A
TOTALS	**355**	**158**	**290**	**8**	**24**	**9**	**37**	**43**	**18**	**42**
PERCENTS	**100%**	**45%**	**82%**	**2%**	**7%**	**3%**	**10%**	**12%**	**5%**	**12%**

Chemical Constituent[a]	Synonym[b]	CAS Number[c]	OSHA[10] PEL (ppm)	OSHA PEL (mg/m^3)	OSHA 8-hr TWA (mg/m^3)	OSHA 8-hr TWA (ppm)	OSHA Ceiling (mg/m^3)	OSHA Ceiling (ppm)	CalOSHA PEL[11] 8-hr TWA (ppm)	CalOSHA PEL 8-hr TWA (mg/m^3)	CalOSHA PEL STEL (ppm)	CalOSHA PEL STEL (mg/m^3)	CalOSHA PEL Ceiling (ppm)	CalOSHA PEL Ceiling (mg/m^3)
Aluminum	N/A	7429-90-5	N/A	15 (total dust) 5 (resp. frac.)	N/A	N/A	N/A	N/A	N/A	10 (total dust) 5 (resp. frac.)	N/A	N/A	N/A	N/A
Antimony	N/A	7440-36-0	N/A	0.5	N/A	N/A	N/A	N/A	N/A	0.5	N/A	N/A	N/A	N/A
Arsenic	N/A	7440-38-2	N/A	0.5	N/A	N/A	N/A	N/A	N/A	0.2	N/A	N/A	N/A	N/A
Barium	N/A	7440-39-3	N/A	0.5	N/A	N/A	N/A	N/A	N/A	0.5	N/A	N/A	N/A	N/A
Beryllium	N/A	7440-41-7	N/A	N/A	2.00E-03	N/A	5.00E-03	N/A	N/A	2.00E-04	N/A	N/A	N/A	2.50E-02
Cadmium	N/A	7440-43-9	N/A	N/A	0.1 (fume) 0.2 (dust)	N/A	0.3 (fume) 0.6 (dust)	N/A	N/A	0.005	N/A	N/A	N/A	N/A
Calcium	N/A	7440-70-2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Chloride	N/A	16887-00-6	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Chromium	N/A	7440-47-3; 16065-83-1 (CrIII); 18540-29-9 (CrVI)	N/A	0.5 (CrIII cmpds) 1 (metal, insol salts)	N/A	N/A	N/A	N/A	N/A	0.5 (CrIII) 0.005 (CrVI)	N/A	N/A	N/A	0.1 (CrVI)
Cobalt	N/A	7440-48-4	N/A	0.1	N/A	N/A	N/A	N/A	N/A	0.02	N/A	N/A	N/A	N/A
Copper	N/A	7440-50-8	N/A	0.1 (fume) 1 (dust)	N/A	N/A	N/A	N/A	N/A	0.1 (fume) 1 (dust)	N/A	N/A	N/A	N/A
Iron	N/A	7439-89-6	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Lead	N/A	7439-92-1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.05	N/A	N/A	N/A	N/A
Lithium	N/A	7439-93-2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Magnesium	N/A	7439-95-4	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Manganese	N/A	7439-96-5	N/A	N/A	N/A	N/A	5	N/A	N/A	0.2	N/A	N/A	N/A	N/A
Mercury	N/A	7439-97-6	N/A	N/A	N/A	N/A	0.1	N/A	N/A	0.025	N/A	N/A	N/A	N/A
Molybdenum	N/A	7439-98-7	N/A	5.0 (sol.) 15 (total dust)	N/A	N/A	N/A	N/A	N/A	0.5 (sol.) 10 (total dust) 3.0 (insol. resp.)	N/A	N/A	N/A	N/A
Nickel	N/A	7440-02-0	N/A	1	N/A	N/A	N/A	N/A	N/A	0.5 (metal) 0.1 (insol.) 0.05 (sol.)	N/A	N/A	N/A	N/A
Phosphorous	N/A	7723-14-0	N/A	0.1	N/A	N/A	N/A	N/A	N/A	0.1	N/A	N/A	N/A	N/A
Potassium	N/A	7440-09-7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Rubidium	N/A	7440-17-7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Selenium	N/A	7782-49-2	N/A	0.2	N/A	N/A	N/A	N/A	N/A	0.2	N/A	N/A	N/A	N/A
Silver	N/A	7440-22-4	N/A	0.01	N/A	N/A	N/A	N/A	N/A	0.01	N/A	N/A	N/A	N/A
Sodium	N/A	7440-23-5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Strontium	N/A	7440-24-6	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Sulfur	N/A	7704-34-9	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Thallium	N/A	7440-28-0	N/A	0.1 (sol.)	N/A	N/A	N/A	N/A	N/A	0.1 (sol.)	N/A	N/A	N/A	N/A
Tin	N/A	7440-31-5	N/A	2 (inorg. cmpds.) 0.1 (org. cmpds.)	N/A	N/A	N/A	N/A	N/A	2 (inorg. cmpds.) 0.1 (org. cmpds.)	N/A	N/A	N/A	N/A
Titanium	N/A	7440-32-6	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Tungsten	N/A	7440-33-7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	5 (insol.) 1 (sol.)	N/A	N/A	N/A	N/A
Vanadium	N/A	7440-62-2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.05 (as V pentoxide)	N/A	N/A	N/A	N/A
Zinc	N/A	7440-66-6	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Cadmium and Zinc Soaps	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Acenaphthene	N/A	83-32-9	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Acenaphthylene	N/A	208-96-8	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Acetaldehyde	Ethanone	75-07-0	200	360	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	25	45
Acetamide, N-cyclohexyl-	N/A	1124-53-4	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Acetone	N/A	67-64-1	1000	2400	N/A	N/A	N/A	N/A	500	1200	750	1780	3000	N/A
Acetone-diphenylamine condensation product (ADPA)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Acetonitrile	N/A	75-05-8	40	70	N/A	N/A	N/A	N/A	40	70	60	105	N/A	N/A
Acetophenone	N/A	98-86-2	N/A	N/A	N/A	N/A	N/A	N/A	10	49	N/A	N/A	N/A	N/A
6-Acetoxy-2,2-dimethyl-m-dioxane	Dimethoxane	828-00-2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Acrolein	N/A	107-02-8	0.1	0.25	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.1	0.25
Alcohols	Ethanol	64-17-5	1000	1900	N/A	N/A	N/A	N/A	1000	1900	N/A	N/A	N/A	N/A

Chemical Constituent[a]	Synonym[b]	CAS Number[c]	OSHA[10] PEL (ppm)	OSHA PEL (mg/m^3)	OSHA 8-hr TWA (mg/m^3)	OSHA 8-hr TWA (ppm)	OSHA Ceiling (mg/m^3)	OSHA Ceiling (ppm)	CalOSHA PEL[11] 8-hr TWA (ppm)	CalOSHA PEL 8-hr TWA (mg/m^3)	CalOSHA PEL STEL (ppm)	CalOSHA PEL STEL (mg/m^3)	CalOSHA PEL Ceiling (ppm)	CalOSHA PEL Ceiling (mg/m^3)
Aldehydes	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Alkyl benzenes	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Alkyl dithiols	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Alkyl naphthalenes	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Alkyl phenols	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Alpha pinene	alpha-Pinene	80-56-8	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Amine (N-dialkyl analine derivative)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Amines	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Anathrene [c]	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Aniline	Benzeneamine; aminobenzene	62-53-3	5	19	N/A	N/A	N/A	N/A	2	7.6	N/A	N/A	N/A	N/A
Anthanthrene	N/A	191-26-4	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Anthracene	N/A	120-12-7	N/A	0.2 (coal tar pitch volatiles)	N/A	N/A	N/A	N/A	N/A	0.2 (coal tar pitch volatiles)	N/A	N/A	N/A	N/A
Aromatic oil	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9,10-Anthracenedione, 2-ethyl	2-Ethylanthracene-9,10-dione	84-51-5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Azobenzene	N/A	103-33-3	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Benz(e)acenaphthylene	Acephenanthrylene	201-06-9	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Benzaldehyde, 3-hydroxyl-4-methoxy	3-Hydroxy-4-methoxy-benzaldehyde	621-59-0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Benz(a)anthracene	N/A	56-55-3	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Benzene	N/A	71-43-2	N/A	N/A	N/A	10	N/A	25	1	N/A	5	N/A	N/A	N/A
Benzene, 1,3-bis(1-methylethenyl)-	1,3-bis(1-methylethenyl)benzene; 1,3-Diisopropenylbenzene	3748-13-8	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Benzene, 1,4-bis(1-methylethenyl)-	1,4-Bis(1-methylethenyl)benzene	1605-18-1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1,4-Benzenediamine, N,N'-diphenyl-	N,N'-Diphenyl-p-phenylenediamine	74-31-7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1,4-Benzendiamin, N-(1-methylethyl)-N’-phenyl-, (IPPD)	N-Isopropyl-N'-phenyl-p-phenylenediamine, Isopropylaminodephenylamine (IPPD)	101-72-4	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Benzene, isocyanato-	Phenyl isocyanate	103-71-9	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Benzenemethanol	Benzyl alcohol	100-51-6	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Benzo(def)dibenzothiophene	Phenanthro[4,5-bcd]thiophene	30796-92-0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Benzo(g)dibenzothiophene	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Benzo(b)fluoranthene	N/A	205-99-2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Benzo(bjk)fluoranthene	2,11-(Metheno)benzo[a]fluorene	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Benzo(ghi)fluoranthene	Benzo[ghi]fluoranthene	203-12-3	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Benzo(i)fluoranthene	Benzo(j)fluoranthene	205-82-3	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Benzo(k)fluoranthene	N/A	207-08-9	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Benzo(mno)fluoranthene	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Benzo(a)fluorene	11H-Benzo[a]fluorene	238-84-6	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Benzo(b)fluorene	2,3-Benzofluorene	243-17-4	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Benzo(def)naphthobenzothiophene	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6H-Benzo[cd]pyren-6-one	6H-Benzo(cd)pyren-6-one	3074-00-8	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Benzo(a)pyrene	N/A	50-32-8	N/A	0.2 (coal tar pitch volatiles)	N/A	N/A	N/A	N/A	N/A	0.2 (coal tar pitch volatiles)	N/A	N/A	N/A	N/A
Benzo(e)pyrene	N/A	192-97-2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Benzo(ghi)perylene	Benzo(g,h,i)perylene	191-24-2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Benzoic acid	N/A	65-85-0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Benzothiazole	N/A	95-16-9	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Benzothiazole, 2-(methylthio)	2-(Methylthio)benzothiazole	615-22-5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Benzothiazole, 2-phenyl	2-Phenylbenzothiazole	883-93-2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Benzothiazolone	2-Hydroxybenzothiazole, 2(3H)-Benzothiazolone, 2(3H) benzothiazolone	934-34-9	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Benzoyl and other peroxides	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Benzylbutyl phthalate	Butyl benzyl phthalate	85-68-7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Biphenyl	1,1'-Biphenyl	92-52-4	0.2	1	N/A	N/A	N/A	N/A	0.2	1.5	N/A	N/A	N/A	N/A
1,1'-Biphenyl, 4, 4', 5', 6'-tetramethoxy-	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
(N,N`-Bis(1,4-dimethylpentyl) pphenylendiamine) (7PPD)	N,N'-Bis(1,4-dimethylpentyl)-4-phenylenediamine	3081-14-9	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Bis(2-ethylhexyl) phthalate	Di(2-ethylhexyl) phthalate	117-81-7	N/A	5	N/A	N/A	N/A	N/A	N/A	5	N/A	N/A	N/A	N/A
Bis-(2,2,6,6-tetramethyl-4-piperidinyl)sebacate	Bis(2,2,6,6-tetramethyl-4-piperidyl) sebacate	52829-07-9	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Bisthiol acids	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Black rubber	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Chemical Constituent[a]	Synonym[b]	CAS Number[c]	OSHA[10] PEL (ppm)	OSHA PEL (mg/m^3)	OSHA 8-hr TWA (mg/m^3)	OSHA 8-hr TWA (ppm)	OSHA Ceiling (mg/m^3)	OSHA Ceiling (ppm)	CalOSHA PEL[11] 8-hr TWA (ppm)	CalOSHA PEL 8-hr TWA (mg/m^3)	CalOSHA PEL STEL (ppm)	CalOSHA PEL STEL (mg/m^3)	CalOSHA PEL Ceiling (ppm)	CalOSHA PEL Ceiling (mg/m^3)
Bromodichloromethane	N/A	75-27-4	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Bromoform	N/A	75-25-2	0.5	5	N/A	N/A	N/A	N/A	0.5	5	N/A	N/A	N/A	N/A
1,3 Butadiene	N/A	106-99-0	1	N/A	N/A	N/A	N/A	N/A	1	2.2	5	11	N/A	N/A
Butoxyethoxyethanol	2-(2-Butoxyethoxy)ethanol, diethylene glycol monobutyl ether	112-34-5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Butylated hydroxyanisole	N/A	25013-16-5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Butylated hydroxytoluene	2,6-Di-tert-butyl-4-methylphenol (BHT)	128-37-0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Butylbenzene	N/A	104-51-8	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Caprolactam disulfide (CLD)	1,1'-Disulfanediyldiazepan-2-one	23847-08-7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Carbazole	N/A	86-74-8	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Carbon Black	Furnace Black	1333-86-4	N/A	3.5	N/A	N/A	N/A	N/A	N/A	3.5	N/A	N/A	N/A	N/A
Carbon Disulfide	N/A	75-15-0	N/A	N/A	N/A	20	N/A	30	1	3	12	36	30	N/A
Carbon Tetrachloride	N/A	56-23-5	N/A	N/A	N/A	10	N/A	25	2	12.6	10	63	200	N/A
Chlorobenzene	N/A	108-90-7	75	350	N/A	N/A	N/A	N/A	10	46	N/A	N/A	N/A	N/A
Chloroform	Trichloromethane	67-66-3	N/A	N/A	N/A	N/A	240	50	2	9.78	N/A	N/A	N/A	N/A
Chloromethane	Methyl chloride	74-87-3	N/A	N/A	N/A	100	N/A	200	50	105	100	210	300	N/A
Chrysene	N/A	218-01-9	N/A	0.2 (coal tar pitch volatiles)	N/A	N/A	N/A	N/A	N/A	0.2 (coal tar pitch volatiles)	N/A	N/A	N/A	N/A
Coronene	N/A	191-07-1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
o-Cyanobenzoic acid	2-Cyanobenzoic acid	3839-22-3	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Cyclohexanamine	Cyclohexylamine	108-91-8	N/A	N/A	N/A	N/A	N/A	N/A	10	40	N/A	N/A	N/A	N/A
Cyclohexanamine, N-cyclohexyl-	Dicyclohexylamine	101-83-7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Cyclohexanamine, N-cyclohexyl-N-methyl-	N-Cyclohexyl-N-methylcyclohexanamine	7560-83-0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Cyclohexane	N/A	110-82-7	300	1050	N/A	N/A	N/A	N/A	300	1015	N/A	N/A	N/A	N/A
Cyclohexane, isocyanato	Isocyanatocyclohexane	3173-53-3	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Cyclohexane, isothiocyanato-	N/A	1122-82-3	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Cyclohexanone	N/A	108-94-1	50	200	N/A	N/A	N/A	N/A	25	100	N/A	N/A	N/A	N/A
N-Cyclohexyl-2-benzothiazolesulfenamide (CBS)	N-Cyclohexyl-2-benzothiazolesulfenamide	95-33-0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
n-Cyclohexyl-formamide	N-Cyclohexylformamide, Formamide, N-cyclohexyl	766-93-8	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Cycloninasiloxane, octadecamethyl-	Octadecamethylcyclononasiloxane	556-71-8	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Cyclopenta[cd]pyrene	N/A	27208-37-3	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4H-cyclopenta[def]phenanthren-4-one	4H-Cyclopenta(def)phenanthren-4-one	5737-13-3	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4H-cyclopenta[def]-phenanthrene	4-H-Cyclopenta(d,e,f)phenanthrene	203-64-5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Cyclopentane, methyl-	Methylcyclopentane	96-37-7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Decane	N/A	124-18-5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Diazoaminobenzenes	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Dibenzo(a,h) anthracene	Dibenz(a,h)anthracene	53-70-3	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Dibenzofurane	Dibenzofuran	132-64-9	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Dibenzo(ae)pyrene	Naphtho(1,2,3,4-def)chrysene	192-65-4	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Dibenzo(ai)pyrene	Dibenzo[a,i]pyrene	189-55-9	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Dibenzo(ah)pyrene	Dibenzo[a,h]pyrene	189-64-0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Dibenzothiophene	N/A	132-65-0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Dibutyl phthalate	N/A	84-74-2	N/A	5	N/A	N/A	N/A	N/A	N/A	5	N/A	N/A	N/A	N/A
1,4-Dichlorobenzene	p-dichlorobenzene	106-46-7	75	450	N/A	N/A	N/A	N/A	10	60	110	675	200	N/A
Dichlorodifluoromethane	Freon 12	75-71-8	1000	4950	N/A	N/A	N/A	N/A	1000	4950	N/A	N/A	6200	N/A
1,2-Dichloroethane	Ethylene dichloride	107-06-2	N/A	N/A	N/A	50	N/A	100	1	4	2	8	200	N/A
cis-1,2-Dichloroethene	(Z)-1,2-Dichloroethylene	156-59-2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1,2-Dichloropropane	N/A	78-87-5	75	350	N/A	N/A	N/A	N/A	75	350	110	510	N/A	N/A
N,N-Dicyclohexyl-2-benzothiazolesulfenamide (DCBS)	N,N-Dicyclohexyl-2-benzothiazolesulfenamide	4979-32-2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Dicyclohexylphthalate (DCHP)	Dicyclohexyl phthalate	84-61-7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1,3-Dicyclohexylurea	N,N'-Dicyclohexylurea	2387-23-7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Diethenylbenzene	Divinylbenzene	1321-74-0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Di(2-ethylhexyl) adipate	Hexanedioic acid, bis(2-ehtylhexyl); Bis(2-ethylhexyl)hexanedioic acid	103-23-1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Diethyl phthalate	N/A	84-66-2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	5	N/A	N/A	N/A	N/A
Diethylthiourea (DETU)	N,N'-Diethylthiourea	105-55-5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Dihydrocyclopentapyrene	2,3-Acepyrene	25732-74-5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Diisobutyl phthalate	N/A	84-69-5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Diisodecylphthalate	bis(8-Methylnonyl) phthalate	89-16-7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Diisononyl phthalate	DINP	28553-12-0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Chemical Constituent[a]	Synonym[b]	CAS Number[c]	OSHA[10] PEL (ppm)	OSHA PEL (mg/m^3)	OSHA 8-hr TWA (mg/m^3)	OSHA 8-hr TWA (ppm)	OSHA Ceiling (mg/m^3)	OSHA Ceiling (ppm)	CalOSHA PEL[11] 8-hr TWA (ppm)	CalOSHA PEL 8-hr TWA (mg/m^3)	CalOSHA PEL STEL (ppm)	CalOSHA PEL STEL (mg/m^3)	CalOSHA PEL Ceiling (ppm)	CalOSHA PEL Ceiling (mg/m^3)
9,l0-Dimethyl-1,2-Benzanthracene	7,12-Dimethylbenz(a)anthracene	57-97-6	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
(N-1,3-dimethyl-butyl)-N'- phenyl-p-phenylenediamine (6PPD)	N-(1,3-Dimethylbutyl)-N'-phenyl-p-phenylenediamine	793-24-8	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Dimethyldiphenylthiuram disulfide (MPTD)	Dimethyldiphenylthiuram disulfide	53880-86-7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2,6-Dimethylnaphthalene	N/A	581-42-0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2,4-Dimethylphenol	N/A	105-67-9	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Dimethyl phthalate	N/A	131-11-3	N/A	5	N/A	N/A	N/A	N/A	N/A	5	N/A	N/A	N/A	N/A
Dinitroarenes	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Di-n-octyl phthalate	Dioctyl phthalate	117-84-0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Di-ortho-tolylguanidine	N/A	97-39-2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Dipentamethylenethiuramtetrasulfide (DPTT)	Bis(pentamethylenethiuram)tetrasulfide	120-54-7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Diphenylamine	N/A	122-39-4	N/A	N/A	N/A	N/A	N/A	N/A	N/A	10	N/A	N/A	N/A	N/A
N,N'-Diphenylguanidine (DPG)	1,3-Diphenylguanidine	102-06-7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
N,N'-Diphenyl-p-phenylenediamine (DPPD)	N,N'-Diphenyl-p-phenylenediamine	74-31-7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Disulfides	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Di-(2-ethyl)hexylphosphorylpolysul fide) (SDT)	Bis-(ethylhexylthiophosphoryl) polysulfide	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3,5-Di-tert-Butyl-4-hydroxybenzaldehyde	N/A	1620-98-0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2,2'-Dithiobis(benzothiazole)	2,2'-Dithiobisbenzothiazole	120-78-5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Dithiocarbamates	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Dithiomorpholine (DTDM)	4,4'-Dithiodimorpholine	103-34-4	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Dithiophosphates	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
N,N`-Ditolyl-p-phenylenediamine (DTPD)	N,N'-Ditolyl-p-phenylenediamine	27417-40-9	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Docosanoic acid	N/A	112-85-6	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Dodecanoic acid	N/A	143-07-7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Dotriacontane	N/A	544-85-4	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Drometrizol	2-(2H-Benzotriazol-2-yl)-4-methylphenol	2440-22-4	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Eicosane	N/A	112-95-8	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Erucylamide	Erucamide	112-84-5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Esters	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Ethanol, 2-butoxy-	2-Butoxyethanol	111-76-2	50	240	N/A	N/A	N/A	N/A	20	97	N/A	N/A	N/A	N/A
Ethanol, 1-(2-butoxyethoxy)	1-(2-Butoxyethoxy)ethanol	54446-78-5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Ethanone, 1,1'-(1,3-phenylene)bis-	Benzene-1,3-bis(acetyl)	6781-42-6	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Ethanone, 1,1'-(1,4-phenylene)bis-	1,1-(1,4-Phenylene)bis-ethanone	1009-61-6	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Ethanone, 1-[4-(1-methylethenyl) phenyl]-	1-[4-(1-Methylethenyl)phenyl]ethanone	5359-04-6	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Ethyl Acetate	N/A	141-78-6	400	1400	N/A	N/A	N/A	N/A	400	1400	N/A	N/A	N/A	N/A
Ethyl benzene	Ethylbenzene	100-41-4	100	435	N/A	N/A	N/A	N/A	5	22	30	130	N/A	N/A
Ethyl benzene aldehyde	Benzaldehyde, 2-ethyl-	22927-13-5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Ethylene thiourea (Ethylene thiourea)	N/A	96-45-7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2-Ethyl-1-hexanol	N/A	104-76-7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1-Ethyl-4-Methyl Benzene	4-Ethyltoluene	622-96-8	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Fluoranthene	N/A	206-44-0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Fluorene	N/A	86-73-7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Formaldehyde	N/A	50-00-0	N/A	N/A	N/A	N/A	N/A	N/A	0.75	N/A	2	N/A	N/A	N/A
Furan, 2-methyl	2-Methylfuran	534-22-5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2(3H)-Furanone,dihydro-4-hydroxy-	Dihydro-4-hydroxy-2(3H)-furanone; beta-Hydroxybutyrolactone	5469-16-9	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Guanidines	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Halocarbon 11	Trichlorofluoromethane, Freon 11	75-69-4	1000	5600	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1000	5600
Hemeicosane[c]	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Heptadecane	N/A	629-78-7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Heptane	N/A	142-82-5	500	2000	N/A	N/A	N/A	N/A	400	1600	500	2000	N/A	N/A
Heptanonitrile	Heptanenitrile	629-08-3	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Hexacosane	N/A	630-01-3	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Hexadecane	N/A	544-76-3	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Hexa(methoxymethyl)melamine	N,N,N',N',N'',N''-Hexakis(methoxy methyl)-1,3,5-triazine-2,4,6-triamine	3089-11-0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Hexamethylenetetramine	Methenamine	100-97-0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Hexane	n-Hexane	110-54-3	500	1800	N/A	N/A	N/A	N/A	50	180	N/A	N/A	N/A	N/A

Chemical Constituent[a]	Synonym[b]	CAS Number[c]	OSHA[10] PEL (ppm)	OSHA PEL (mg/m^3)	OSHA 8-hr TWA (mg/m^3)	OSHA 8-hr TWA (ppm)	OSHA Ceiling (mg/m^3)	OSHA Ceiling (ppm)	CalOSHA PEL[11] 8-hr TWA (ppm)	CalOSHA PEL 8-hr TWA (mg/m^3)	CalOSHA PEL STEL (ppm)	CalOSHA PEL STEL (mg/m^3)	CalOSHA PEL Ceiling (ppm)	CalOSHA PEL Ceiling (mg/m^3)
Hexanedioic acid, methyl ester	Methyl hexanedioate	627-91-8	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Hexanoic acid, 2-ethyl-	2-Ethylhexanoic acid	149-57-5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Hydrocarbon (olefin/aromatic)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
7-Hydroxybenzo[f]flavone	7-Hydroxy-3-phenyl-1H-naphtho[2,1-b] pyran-1-one	86247-95-2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1-Hydroxypyrene	N/A	5315-79-7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Indeno[l,2,3-cd]pyrene	o-Phenylenepyrene	193-39-5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1H-isoindole-1,3 (2H)-dione	Phthalimide	85-41-6	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
iso-nonylphenol	3-Nonylphenol	11066-49-2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Isophorone	N/A	78-59-1	25	140	N/A	N/A	N/A	N/A	4	23	N/A	N/A	N/A	N/A
Isopropyl Alcohol	2-Propanol, Isopropanol	67-63-0	400	980	N/A	N/A	N/A	N/A	400	980	500	1225	N/A	N/A
Isopropylbenzene	Cumene	98-82-8	50	245	N/A	N/A	N/A	N/A	50	245	N/A	N/A	N/A	N/A
Isopropyltoluene	1-Methyl-2-(propan-2-yl)benzene	527-84-4	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Ketones	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Latex protein	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Limonene	N/A	138-86-3	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
MEK	Methyl ethyl ketone	78-93-3	200	590	N/A	N/A	N/A	N/A	200	590	300	885	N/A	N/A
2-Mercaptobenzothiazole	N/A	149-30-4	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Methane, diethoxy-cyclohexane	Diethoxycyclohexanemethane; Bis(cyclohexyloxy)methane	1453-21-0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Methyl Alcohol	Methanol	67-56-1	200	260	N/A	N/A	N/A	N/A	200	260	250	3325	1000	N/A
2-Methylanthracene	N/A	613-12-7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2-Methyl-Butane	2-Methylbutane	78-78-4	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2,2-Methylene-bis-(4-methyl-6-tert-butylphenol) (BPH)	N/A	119-47-1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Methylene Chloride	Dichloromethane	75-09-2	N/A	N/A	N/A	N/A	N/A	N/A	25	87	125	435	N/A	N/A
5-Methyl-2-hexanone	Methyl isoamyl ketone	110-12-3	100	475	N/A	N/A	N/A	N/A	50	234	N/A	N/A	N/A	N/A
1-Methylnaphthalene	N/A	90-12-0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2-Methylnaphthalene	N/A	91-57-6	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3-Methyl-Pentane	3-Methylpentane	96-14-0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4-Methyl-2-pentanone	MIBK, Methyl isobutyl ketone	108-10-1	100	410	N/A	N/A	N/A	N/A	50	205	75	300	N/A	N/A
1-Methylphenanthrene	1-Methyl phenanthrene	832-69-9	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2-Methylphenanthrene	N/A	2531-84-2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3-Methylphenanthrene	N/A	832-71-3	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9-Methylphenanthrene	N/A	883-20-5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2-Methylphenol	o-Cresol	95-48-7	5	22	N/A	N/A	N/A	N/A	5	22	N/A	N/A	N/A	N/A
4-Methylphenol	p-Cresol	106-44-5	5	22	N/A	N/A	N/A	N/A	5	22	N/A	N/A	N/A	N/A
MES (special purified aromatic oil)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2-(4-morpholino)benzothiazole	2-morpholinothio benzothiazole (MBS); Morpholinothio-benzothiazole; N-Oxydiethylenebenzothiazole-2-sulfenamide	102-77-2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2-Morpholinodithiobenzothiazole (MBSS)	2-(Morpholin-4-yldithio)-1,3-benzothiazole	95-32-9	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Naphthalene	N/A	91-20-3	10	50	N/A	N/A	N/A	N/A	0.1 (skin)	0.5 (skin)	N/A	N/A	N/A	N/A
Naphthalene, 2-(bromomethyl)-	2-Bromomethylnaphthalene	939-26-4	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Naphthalic Anhydride	1H,3H-Naphtho(1,8-cd)pyran-1,3-dione	81-84-5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Napthenic oil	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Nitro compound (isomer of major peak)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Nitro compound (nitro-ether derivative)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Nitrogen containing substances	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Nitrosodibutylamine (n-)	N-Nitrosodibutylamine	924-16-3	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Nitrosodiethylamine (n-)	N-Nitrosodiethylamine	55-18-5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Nitrosodimethylamine (n-)	N-Nitrosodimethylamine	62-75-9	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
n-Nitrosodiphenylamine	N-Nitrosodiphenylamine	86-30-6	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Nitrosodipropylamine (n-)	N-Nitrosodipropylamine	621-64-7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Nitrosomorpholine (n-)	N-Nitrosomorpholine	59-89-2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Nitrosopiperidine (n-)	N-Nitrosopiperidine	100-75-4	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Nitrosopyrrolidine (n-)	N-Nitrosopyrrolidine	930-55-2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Nonadecane	N/A	629-92-5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Nonanale	Nonanal	124-19-6	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Nonane	N/A	111-84-2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4-n-nonylphenol	4-Nonylphenol	104-40-5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Octadecanoic acid, methyl ester	Methyl stearate	112-61-8	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Octane	N/A	111-65-9	500	2350	N/A	N/A	N/A	N/A	300	1450	375	1800	N/A	N/A

Chemical Constituent[a]	Synonym[b]	CAS Number[c]	OSHA[10] PEL (ppm)	OSHA PEL (mg/m^3)	OSHA 8-hr TWA (mg/m^3)	OSHA 8-hr TWA (ppm)	OSHA Ceiling (mg/m^3)	OSHA Ceiling (ppm)	CalOSHA PEL[11] 8-hr TWA (ppm)	CalOSHA PEL 8-hr TWA (mg/m^3)	CalOSHA PEL STEL (ppm)	CalOSHA PEL STEL (mg/m^3)	CalOSHA PEL Ceiling (ppm)	CalOSHA PEL Ceiling (mg/m^3)
4-t-octylphenol	4-(1,1,3,3-Tetramethylbutyl)phenol, 4-tert-(octyl)-phenol	140-66-9	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Optadecane	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Organic thiola and sulfides	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Orthocarbonate - Carboxy compound)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
N-Oxydiethylenedithiocarbamyl-N`-oxydiethylenesulfenamide (OTOS)	N/A	13752-51-7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
PAHs	Polycyclic aromatic hydrocarbons	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Parrafinic oils	Mineral oil	8012-95-1	N/A	5	N/A	N/A	N/A	N/A	N/A	5	N/A	N/A	N/A	N/A
PCB sum	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
PCDD/F sum	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Pentacosane	N/A	629-99-2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Pentane	N/A	109-66-0	1000	2950	N/A	N/A	N/A	N/A	600	1800	N/A	N/A	N/A	N/A
Perylene	N/A	198-55-0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Petroleum Naphtha	Naphtha	8030-30-6	100	400	N/A	N/A	N/A	N/A	300	1350	400	1800	N/A	N/A
Phenalone	Phenalen-1-one	548-39-0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Phenanthrene	N/A	85-01-8	N/A	0.2 (coal tar pitch volatiles)	N/A	N/A	N/A	N/A	N/A	0.2 (coal tar pitch volatiles)	N/A	N/A	N/A	N/A
1-Phenanthrenecarboxylic acid, 1,2,3,4,4	1,2,3,4,4-1-Phenanthrene carboxylic acid; Dehydroabietic acid	1740-19-8	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Phenol	2,4-Di-tert-butylphenol	108-95-2	5	19	N/A	N/A	N/A	N/A	5	19	N/A	N/A	N/A	N/A
Phenolics	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Phenol, 2,4-bis(1,1-dimethylethyl)-	N/A	96-76-4	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Phenol, 2,4-bis(1-methyl-1-phenylethyl)-	2,4-Bis(1-methyl-1-phenylethyl)phenol	2772-45-4	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Phenol, m-tert-butyl-	3-tert-Butylphenol	585-34-2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Phenylbenzimidazole	2-Phenylbenzimidazole	716-79-0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
p-Phenylenediamines	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Phenylenediamines	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2-(1-phenylethyl)-phenol	2-(1-Phenylethyl)phenol	26857-99-8	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3-Phenyl-2-propenal	3-Phenylprop-2-enal	104-55-2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Phthalates	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
PM 2.5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
PM 10	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Poly- and di-nitrobenzenes	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Poly-p-dinitrosobenzene	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Propene	1-Propene; propylene	115-07-1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Propylbenzene	N/A	103-65-1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Pyrazole	N/A	288-13-1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Pyrene	N/A	129-00-0	N/A	0.2 (coal tar pitch volatiles)	N/A	N/A	N/A	N/A	N/A	0.2 (coal tar pitch volatiles)	N/A	N/A	N/A	N/A
Pyrimidine, 2-(4-pentylphenyl)-5-propyl-	N/A	94320-32-8	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2-Pyrrolidinone. 1-methyl-	N-Methyl-2-pyrrolidone	872-50-4	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Quinones	N/A	106-51-4	0.1	0.4	N/A	N/A	N/A	N/A	0.1	0.4	N/A	N/A	N/A	N/A
Resorcinol	N/A	108-46-3	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Rethene [c]	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Siloxanes	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Styrene	N/A	100-42-5	N/A	N/A	N/A	100	N/A	200	50	215	100	425	500	N/A
Styrene oligomers	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Substituted p-Phenylenediamines	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Sulfur containing organics	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Sulfur Donors	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Sulphenamides	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
TDAE (special purified aromatic oil)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Tertbutylacetophenone	3,3-dimethyl-1-phenylbutan-1-one	31366-07-1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
N-tert-Butyl-2-benzothiazolesulf enamide (TBBS)	N/A	95-31-8	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4-tert butylphenol	4-tert-Butylphenol	98-54-4	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Tetraalkylthiuram disulfides	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Tetrabenzylthiuram disulfide (TBZTD)	N/A	10591-85-2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Tetrabutylthiuram disulfide (TBTD)	N/A	1634-02-2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Tetrachloroethene	Tetrachloroethylene; perchloroethylene	127-18-4	N/A	N/A	N/A	100	N/A	200	25	170	100	685	300	N/A
Tetracosane	N/A	646-31-1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Tetraethylthiuram disulfide	Disulfiram	97-77-8	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

	Chemical Constituent[a]	Synonym[b]	CAS Number[c]	OSHA[10] PEL (ppm)	OSHA PEL (mg/m^3)	OSHA 8-hr TWA (mg/m^3)	OSHA 8-hr TWA (ppm)	OSHA Ceiling (mg/m^3)	OSHA Ceiling (ppm)	CalOSHA PEL[11] 8-hr TWA (ppm)	CalOSHA PEL 8-hr TWA (mg/m^3)	CalOSHA PEL STEL (ppm)	CalOSHA PEL STEL (mg/m^3)	CalOSHA PEL Ceiling (ppm)	CalOSHA PEL Ceiling (mg/m^3)
	Tetrahydrofuran	N/A	109-99-9	200	590	N/A	N/A	N/A	N/A	200	590	250	735	N/A	N/A
	Tetramethylthiuram disulfide	Thiram	137-26-8	N/A	5	N/A	N/A	N/A	N/A	N/A	5	N/A	N/A	N/A	N/A
	Tetramethylthiuram monosulfide	N/A	97-74-5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Thiazoles	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Thioureas	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Thiurams	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Thiuram sulfides	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Toluene	N/A	108-88-3	N/A	N/A	N/A	200	N/A	300	10	37	150	560	500	N/A
	Total petroleum hydrocarbons	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Trans trans-muconic acid	(E,E)-Muconic acid	3588-17-8	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Trimethyl-1,2-dihydroquinoline (TMDQ)	1,2-Dihydro-2,2,4-trimethylquinoline, polymer	26780-96-1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	1,1,1-Trichloroethane	N/A	71-55-6	350	1900	N/A	N/A	N/A	N/A	350	1900	450	2450	800	N/A
	Trichloroethylene	N/A	79-01-6	N/A	N/A	N/A	100	N/A	200	25	135	100	537	300	N/A
	1,1,2-Trichloro-1,2,2-trifluoroethane	N/A	76-13-1	1000	7600	N/A	N/A	N/A	N/A	1000	7600	1250	9500	2000	N/A
	Trichloro-trifluoroethane	1,1,1-Trichloro-2,2,2-trifluoroethane	354-58-5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Tricosane	N/A	638-67-5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	1,2,3-Trimethyl benzene	1,2,3-Trimethylbenzene	526-73-8	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	1,2,4-Trimethyl benzene	1,2,4-Trimethylbenzene	95-63-6	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	1,3,5-Trimethyl benzene	1,3,5-Trimethylbenzene	108-67-8	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	2,2,4-Trimethyl-1,2-dihydroquinoline (TMQ)	1,2-Dihydro-2,2,4-trimethylquinoline, polymer	26780-96-1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Vinyl Acetate	N/A	108-05-4	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	White gasoline	Natural gasoline	8006-61-9	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	o-Xylene	N/A	95-47-6	100	435	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Xylenes	N/A	1330-20-7	100	435	N/A	N/A	N/A	N/A	100	435	150	655	300	N/A
	Zn-Dibenzyldithiocarbamate (ZBEC)	N/A	136-23-2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Zn-Diethyldithiocarbamate (ZDEC)	Zinc diethyldithiocarbamate	14324-55-1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Zn-Dimethyldithiocarbamate (ZDMC)	Ziram	137-30-4	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Zn-dibutyldithiocarbamate (ZDBC)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	ZnO	Zinc Oxide	1314-13-2	N/A	5 (fume) 15 (dust) 5 (resp. frac.)	N/A	N/A	N/A	N/A	N/A	5 (fume) 10 (dust) 5 (resp. frac.)	N/A	10 (fume)	N/A	N/A
TOTALS	**355**	**158**	**290**	**41**	**66**	**2**	**9**	**5**	**10**	**51**	**84**	**28**	**27**	**18**	**5**
PERCENTS	**100%**	**45%**	**82%**	**12%**	**19%**	**1%**	**3%**	**1%**	**3%**	**14%**	**24%**	**8%**	**8%**	**5%**	**1%**

Chemical Constituent[a]	Synonym[b]	CAS Number[c]	NIOSH REL[10, 12] 10-hr TWA (ppm)	NIOSH REL 10-hr TWA (mg/m^3)	NIOSH REL STEL (ppm)	NIOSH REL STEL (mg/m^3)	NIOSH REL Ceiling (ppm)	NIOSH REL Ceiling (mg/m^3)	ACGIH TLV 8-hr TWA (ppm)	ACGIH TLV 8-hr TWA (mg/m^3)	ACGIH TLV STEL (ppm)	ACGIH TLV STEL (mg/m^3)	ACGIH TLV Ceiling (ppm)	ACGIH TLV Ceiling (mg/m^3)	TOTAL
Aluminum	N/A	7429-90-5	N/A	10 (total dust) 5 (resp. frac.)	N/A	N/A	N/A	N/A	N/A	1 (resp. frac.)	N/A	N/A	N/A	N/A	**8**
Antimony	N/A	7440-36-0	N/A	0.5	N/A	N/A	N/A	N/A	N/A	0.5	N/A	N/A	N/A	N/A	**7**
Arsenic	N/A	7440-38-2	N/A	N/A	N/A	N/A	N/A	0.002 (inorg.)	N/A	N/A	N/A	N/A	N/A	N/A	**20**
Barium	N/A	7440-39-3	N/A	0.5	N/A	N/A	N/A	N/A	N/A	0.5	N/A	N/A	N/A	N/A	**12**
Beryllium	N/A	7440-41-7	N/A	N/A	N/A	N/A	N/A	5.00E-04	N/A	5.00E-05	N/A	N/A	N/A	N/A	**21**
Cadmium	N/A	7440-43-9	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.01 (total) 0.002 (resp.)	N/A	N/A	N/A	N/A	**18**
Calcium	N/A	7440-70-2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**0**
Chloride	N/A	16887-00-6	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**0**
Chromium	N/A	7440-47-3; 16065-83-1 (CrIII); 18540-29-9 (CrVI)	N/A	0.5	N/A	N/A	N/A	N/A	N/A	0.5 (CrIII) 0.05 (CrVI sol.) 0.01 (CrVI insol.)	N/A	N/A	N/A	N/A	**25**
Cobalt	N/A	7440-48-4	N/A	0.05	N/A	N/A	N/A	N/A	N/A	0.02	N/A	N/A	N/A	N/A	**13**
Copper	N/A	7440-50-8	N/A	0.1 (fume) 1 (dust)	N/A	N/A	N/A	N/A	N/A	0.2 (fume) 1 (dust)	N/A	N/A	N/A	N/A	**10**
Iron	N/A	7439-89-6	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**2**
Lead	N/A	7439-92-1	N/A	0.05	N/A	N/A	N/A	N/A	N/A	0.05	N/A	N/A	N/A	N/A	**10**
Lithium	N/A	7439-93-2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**2**
Magnesium	N/A	7439-95-4	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**0**
Manganese	N/A	7439-96-5	N/A	1	N/A	3	N/A	N/A	N/A	0.02 (resp. 0.1 (IHL)	N/A	N/A	N/A	N/A	**12**
Mercury	N/A	7439-97-6	N/A	0.05 (vapor, skin)	N/A	N/A	N/A	0.1 (skin)	N/A	0.025	N/A	N/A	N/A	N/A	**17**
Molybdenum	N/A	7439-98-7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.5 (sol. resp.) 10 (insol. IHL) 3 (insol. resp.)	N/A	N/A	N/A	N/A	**5**
Nickel	N/A	7440-02-0	N/A	0.015	N/A	N/A	N/A	N/A	N/A	1.5 (IHL elemental) 0.2 IHL insol. inorg. cmpds.) 0.1 IHL sol. Inorg. cmpds.	N/A	N/A	N/A	N/A	**17**
Phosphorous	N/A	7723-14-0	N/A	0.1	N/A	N/A	N/A	N/A	N/A	0.1	N/A	N/A	N/A	N/A	**6**
Potassium	N/A	7440-09-7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**0**
Rubidium	N/A	7440-17-7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**0**
Selenium	N/A	7782-49-2	N/A	0.2	N/A	N/A	N/A	N/A	N/A	0.2	N/A	N/A	N/A	N/A	**11**
Silver	N/A	7440-22-4	N/A	0.01	N/A	N/A	N/A	N/A	N/A	0.01 (sol. cmpds.)	N/A	N/A	N/A	N/A	**7**
Sodium	N/A	7440-23-5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**0**
Strontium	N/A	7440-24-6	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**4**
Sulfur	N/A	7704-34-9	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**0**
Thallium	N/A	7440-28-0	N/A	0.1 (sol.)	N/A	N/A	N/A	N/A	N/A	0.02 (sol. IHL)	N/A	N/A	N/A	N/A	**4**
Tin	N/A	7440-31-5	N/A	2 (inorg. cmpds.) 0.1 (org. cmpds.)	N/A	N/A	N/A	N/A	N/A	2 (inorg. cmpds.) 0.1 (org. cmpds.)	N/A	0.2 (org. cmpds.)	N/A	N/A	**8**
Titanium	N/A	7440-32-6	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**0**
Tungsten	N/A	7440-33-7	N/A	5 (insol.) 1 (sol.)	N/A	10 (insol.) 3 (sol.)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**5**
Vanadium	N/A	7440-62-2	N/A	N/A	N/A	N/A	N/A	0.05 (dust, fume)	N/A	0.05 (IHL V pentoxide)	N/A	N/A	N/A	N/A	**10**
Zinc	N/A	7440-66-6	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**5**
Cadmium and Zinc Soaps	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**0**
Acenaphthene	N/A	83-32-9	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**5**
Acenaphthylene	N/A	208-96-8	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**1**
Acetaldehyde	Ethanone	75-07-0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	25	N/A	**15**
Acetamide, N-cyclohexyl-	N/A	1124-53-4	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**1**
Acetone	N/A	67-64-1	250	590	N/A	N/A	N/A	N/A	250	N/A	500	N/A	N/A	N/A	**17**
Acetone-diphenylamine condensation product (ADPA)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**0**
Acetonitrile	N/A	75-05-8	20	34	N/A	N/A	N/A	N/A	20	N/A	N/A	N/A	N/A	N/A	**14**
Acetophenone	N/A	98-86-2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**5**
6-Acetoxy-2,2-dimethyl-m-dioxane	Dimethoxane	828-00-2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**1**
Acrolein	N/A	107-02-8	0.1	0.25	0.3	0.8	N/A	N/A	N/A	N/A	N/A	N/A	0.1	N/A	**21**
Alcohols	Ethanol	64-17-5	1000	1900	N/A	N/A	N/A	N/A	N/A	N/A	1000	N/A	N/A	N/A	**8**
Aldehydes	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**0**
Alkyl benzenes	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**0**
Alkyl dithiols	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**0**
Alkyl naphthalenes	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**0**
Alkyl phenols	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**0**
Alpha pinene	alpha-Pinene	80-56-8	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**0**

Chemical Constituent[a]	Synonym[b]	CAS Number[c]	NIOSH REL[10, 12] 10-hr TWA (ppm)	NIOSH REL 10-hr TWA (mg/m^3)	NIOSH REL STEL (ppm)	NIOSH REL STEL (mg/m^3)	NIOSH REL Ceiling (ppm)	NIOSH REL Ceiling (mg/m^3)	ACGIH TLV 8-hr TWA (ppm)	ACGIH TLV 8-hr TWA (mg/m^3)	ACGIH TLV STEL (ppm)	ACGIH TLV STEL (mg/m^3)	ACGIH TLV Ceiling (ppm)	ACGIH TLV Ceiling (mg/m^3)	TOTAL
Amine (N-dialkyl analine derivative)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**0**
Amines	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**0**
Anathrene [c]	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**0**
Aniline	Benzeneamine; aminobenzene	62-53-3	N/A	N/A	N/A	N/A	N/A	N/A	2	N/A	N/A	N/A	N/A	N/A	**15**
Anthanthrene	N/A	191-26-4	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**1**
Anthracene	N/A	120-12-7	N/A	0.1 (cyclohexane extractable fraction)	N/A	N/A	N/A	N/A	N/A	0.2 (coal tar pitch volatiles)	N/A	N/A	N/A	N/A	**10**
Aromatic oil	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**0**
9,10-Anthracenedione, 2-ethyl	2-Ethylanthracene-9,10-dione	84-51-5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**0**
Azobenzene	N/A	103-33-3	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**6**
Benz(e)acenaphthylene	Acephenanthrylene	201-06-9	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**0**
Benzaldehyde, 3-hydroxyl-4-methoxy	3-Hydroxy-4-methoxy-benzaldehyde	621-59-0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**0**
Benz(a)anthracene	N/A	56-55-3	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**6**
Benzene	N/A	71-43-2	0.1	N/A	1	N/A	N/A	N/A	0.5	N/A	2.5	N/A	N/A	N/A	**29**
Benzene, 1,3-bis(1-methylethenyl)-	1,3-bis(1-methylethenyl)benzene; 1,3-Diisopropenylbenzene	3748-13-8	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**0**
Benzene, 1,4-bis(1-methylethenyl)-	1,4-Bis(1-methylethenyl)benzene	1605-18-1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**0**
1,4-Benzenediamine, N,N'-diphenyl-	N,N'-Diphenyl-p-phenylenediamine	74-31-7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**0**
1,4-Benzendiamin, N-(1-methylethyl)-N'-phenyl-, (IPPD)	N-Isopropyl-N'-phenyl-p-phenylenediamine, Isopropylaminodephenylamine (IPPD)	101-72-4	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**0**
Benzene, isocyanato-	Phenyl isocyanate	103-71-9	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**0**
Benzenemethanol	Benzyl alcohol	100-51-6	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**4**
Benzo(def)dibenzothiophene	Phenanthro[4,5-bcd]thiophene	30796-92-0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**0**
Benzo(g)dibenzothiophene	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**0**
Benzo(b)fluoranthene	N/A	205-99-2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**6**
Benzo(bjk)fluoranthene	2,11-(Metheno)benzo[a]fluorene	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**0**
Benzo(ghi)fluoranthene	Benzo[ghi]fluoranthene	203-12-3	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**1**
Benzo(i)fluoranthene	Benzo(j)fluoranthene	205-82-3	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**5**
Benzo(k)fluoranthene	N/A	207-08-9	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**5**
Benzo(mno)fluoranthene	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**0**
Benzo(a)fluorene	11H-Benzo[a]fluorene	238-84-6	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**1**
Benzo(b)fluorene	2,3-Benzofluorene	243-17-4	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**1**
Benzo(def)naphthobenzothiophene	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**0**
6H-Benzo[cd]pyren-6-one	6H-Benzo(cd)pyren-6-one	3074-00-8	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**0**
Benzo(a)pyrene	N/A	50-32-8	N/A	0.1 (cyclohexane extractable fraction)	N/A	N/A	N/A	N/A	N/A	0.2 (coal tar pitch volatiles)	N/A	N/A	N/A	N/A	**12**
Benzo(e)pyrene	N/A	192-97-2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**1**
Benzo(ghi)perylene	Benzo(g,h,i)perylene	191-24-2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**2**
Benzoic acid	N/A	65-85-0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**6**
Benzothiazole	N/A	95-16-9	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**0**
Benzothiazole, 2-(methylthio)	2-(Methylthio)benzothiazole	615-22-5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**0**
Benzothiazole, 2-phenyl	2-Phenylbenzothiazole	883-93-2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**0**
Benzothiazolone	2-Hydroxybenzothiazole, 2(3H)-Benzothiazolone, 2(3H) benzothiazolone	934-34-9	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**0**
Benzoyl and other peroxides	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**0**
Benzylbutyl phthalate	Butyl benzyl phthalate	85-68-7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**7**
Biphenyl	1,1'-Biphenyl	92-52-4	0.2	1	N/A	N/A	N/A	N/A	0.2	N/A	N/A	N/A	N/A	N/A	**13**
1,1'-Biphenyl, 4, 4', 5', 6'-tetramethoxy-	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**0**
(N,N`-Bis(1,4-dimethylpentyl) pphenylendiamine) (7PPD)	N,N'-Bis(1,4-dimethylpentyl)-4-phenylenediamine	3081-14-9	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**0**
Bis(2-ethylhexyl) phthalate	Di(2-ethylhexyl) phthalate	117-81-7	N/A	5	N/A	10	N/A	N/A	N/A	5	N/A	N/A	N/A	N/A	**16**
Bis-(2,2,6,6-tetramethyl-4-piperidinyl)sebacate	Bis(2,2,6,6-tetramethyl-4-piperidyl) sebacate	52829-07-9	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**0**
Bisthiol acids	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**0**
Black rubber	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**0**
Bromodichloromethane	N/A	75-27-4	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**11**
Bromoform	N/A	75-25-2	0.5	5	N/A	N/A	N/A	N/A	0.5	N/A	N/A	N/A	N/A	N/A	**19**
															17
Butoxyethoxyethanol	2-(2-Butoxyethoxy)ethanol, diethylene glycol monobutyl ether	112-34-5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**6**
Butylated hydroxyanisole	N/A	25013-16-5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**2**
Butylated hydroxytoluene	2,6-Di-tert-butyl-4-methylphenol (BHT)	128-37-0	N/A	10	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**5**
Butylbenzene	N/A	104-51-8	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**2**
Caprolactam disulfide (CLD)	1,1'-Disulfanediyldiazepan-2-one	23847-08-7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**0**

Chemical Constituent[a]	Synonym[b]	CAS Number[c]	NIOSH REL[10, 12] 10-hr TWA (ppm)	NIOSH REL 10-hr TWA (mg/m^3)	NIOSH REL STEL (ppm)	NIOSH REL STEL (mg/m^3)	NIOSH REL Ceiling (ppm)	NIOSH REL Ceiling (mg/m^3)	ACGIH TLV 8-hr TWA (ppm)	ACGIH TLV 8-hr TWA (mg/m^3)	ACGIH TLV STEL (ppm)	ACGIH TLV STEL (mg/m^3)	ACGIH TLV Ceiling (ppm)	ACGIH TLV Ceiling (mg/m^3)	TOTAL
Carbazole	N/A	86-74-8	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**2**
Carbon Black	Furnace Black	1333-86-4	N/A	3.5	N/A	N/A	N/A	N/A	N/A	3	N/A	N/A	N/A	N/A	**5**
Carbon Disulfide	N/A	75-15-0	1	3	10	30	N/A	N/A	1	N/A	N/A	N/A	N/A	N/A	**21**
Carbon Tetrachloride	N/A	56-23-5	N/A	N/A	2	12.6	N/A	N/A	5	N/A	10	N/A	N/A	N/A	**27**
Chlorobenzene	N/A	108-90-7	N/A	N/A	N/A	N/A	N/A	N/A	10	N/A	N/A	N/A	N/A	N/A	**13**
Chloroform	Trichloromethane	67-66-3	N/A	N/A	2	9.78	N/A	N/A	10	N/A	N/A	N/A	N/A	N/A	**26**
Chloromethane	Methyl chloride	74-87-3	N/A	N/A	N/A	N/A	N/A	N/A	50	N/A	100	N/A	N/A	N/A	**20**
Chrysene	N/A	218-01-9	N/A	0.1 (cyclohexane extractable fraction)	N/A	N/A	N/A	N/A	N/A	0.2 (coal tar pitch volatiles)	N/A	N/A	N/A	N/A	**10**
Coronene	N/A	191-07-1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**1**
o-Cyanobenzoic acid	2-Cyanobenzoic acid	3839-22-3	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**0**
Cyclohexanamine	Cyclohexylamine	108-91-8	10	40	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**6**
Cyclohexanamine, N-cyclohexyl-	Dicyclohexylamine	101-83-7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**0**
Cyclohexanamine, N-cyclohexyl-N-methyl-	N-Cyclohexyl-N-methylcyclohexanamine	7560-83-0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**0**
Cyclohexane	N/A	110-82-7	300	1050	N/A	N/A	N/A	N/A	100	N/A	N/A	N/A	N/A	N/A	**9**
Cyclohexane, isocyanato	Isocyanatocyclohexane	3173-53-3	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**0**
Cyclohexane, isothiocyanato-	N/A	1122-82-3	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**0**
Cyclohexanone	N/A	108-94-1	25	100	N/A	N/A	N/A	N/A	20	N/A	50	N/A	N/A	N/A	**13**
N-Cyclohexyl-2-benzothiazolesulfenamide (CBS)	N-Cyclohexyl-2-benzothiazolesulfenamide	95-33-0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**0**
n-Cyclohexyl-formamide	N-Cyclohexylformamide, Formamide, N-cyclohexyl	766-93-8	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**0**
Cycloninasiloxane, octadecamethyl-	Octadecamethylcyclononasiloxane	556-71-8	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**0**
Cyclopenta[cd]pyrene	N/A	27208-37-3	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**1**
4H-cyclopenta[def]phenanthren-4-one	4H-Cyclopenta(def)phenanthren-4-one	5737-13-3	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**0**
4H-cyclopenta[def]-phenanthrene	4-H-Cyclopenta(d,e,f)phenanthrene	203-64-5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**0**
Cyclopentane, methyl-	Methylcyclopentane	96-37-7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**1**
Decane	N/A	124-18-5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**0**
Diazoaminobenzenes	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**0**
Dibenzo(a,h) anthracene	Dibenz(a,h)anthracene	53-70-3	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**5**
Dibenzofurane	Dibenzofuran	132-64-9	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**2**
Dibenzo(ae)pyrene	Naphtho(1,2,3,4-def)chrysene	192-65-4	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**4**
Dibenzo(ai)pyrene	Dibenzo[a,i]pyrene	189-55-9	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**5**
Dibenzo(ah)pyrene	Dibenzo[a,h]pyrene	189-64-0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**5**
Dibenzothiophene	N/A	132-65-0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**1**
Dibutyl phthalate	N/A	84-74-2	N/A	5	N/A	N/A	N/A	N/A	N/A	5	N/A	N/A	N/A	N/A	**9**
1,4-Dichlorobenzene	p-dichlorobenzene	106-46-7	N/A	N/A	N/A	N/A	N/A	N/A	10	N/A	N/A	N/A	N/A	N/A	**20**
Dichlorodifluoromethane	Freon 12	75-71-8	1000	4950	N/A	N/A	N/A	N/A	1000	N/A	N/A	N/A	N/A	N/A	**14**
1,2-Dichloroethane	Ethylene dichloride	107-06-2	1	4	2	8	N/A	N/A	10	N/A	N/A	N/A	N/A	N/A	**26**
cis-1,2-Dichloroethene	(Z)-1,2-Dichloroethylene	156-59-2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**6**
1,2-Dichloropropane	N/A	78-87-5	N/A	N/A	N/A	N/A	N/A	N/A	10	N/A	N/A	N/A	N/A	N/A	**16**
N,N-Dicyclohexyl-2-benzothiazolesulfenamide (DCBS)	N,N-Dicyclohexyl-2-benzothiazolesulfenamide	4979-32-2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**0**
Dicyclohexylphthalate (DCHP)	Dicyclohexyl phthalate	84-61-7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**0**
1,3-Dicyclohexylurea	N,N'-Dicyclohexylurea	2387-23-7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**0**
Diethenylbenzene	Divinylbenzene	1321-74-0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**0**
Di(2-ethylhexyl) adipate	Hexanedioic acid, bis(2-ehtylhexyl); Bis(2-ethylhexyl)hexanedioic acid	103-23-1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**5**
Diethyl phthalate	N/A	84-66-2	N/A	5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**8**
Diethylthiourea (DETU)	N,N'-Diethylthiourea	105-55-5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**1**
Dihydrocyclopentapyrene	2,3-Acepyrene	25732-74-5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**1**
Diisobutyl phthalate	N/A	84-69-5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**0**
Diisodecylphthalate	bis(8-Methylnonyl) phthalate	89-16-7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**1**
Diisononyl phthalate	DINP	28553-12-0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**1**
9,l0-Dimethyl-1,2-Benzanthracene	7,12-Dimethylbenz(a)anthracene	57-97-6	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**3**
(N-1,3-dimethyl-butyl)-N'- phenyl-p-phenylenediamine (6PPD)	N-(1,3-Dimethylbutyl)-N'-phenyl-p-phenylenediamine	793-24-8	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**0**
Dimethyldiphenylthiuram disulfide (MPTD)	Dimethyldiphenylthiuram disulfide	53880-86-7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**0**
2,6-Dimethylnaphthalene	N/A	581-42-0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**0**
2,4-Dimethylphenol	N/A	105-67-9	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**3**
Dimethyl phthalate	N/A	131-11-3	N/A	5	N/A	N/A	N/A	N/A	N/A	5	N/A	N/A	N/A	N/A	**5**
Dinitroarenes	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**0**
Di-n-octyl phthalate	Dioctyl phthalate	117-84-0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**6**
Di-ortho-tolylguanidine	N/A	97-39-2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**0**

Chemical Constituent[a]	Synonym[b]	CAS Number[c]	NIOSH REL[10, 12] 10-hr TWA (ppm)	NIOSH REL 10-hr TWA (mg/m^3)	NIOSH REL STEL (ppm)	NIOSH REL STEL (mg/m^3)	NIOSH REL Ceiling (ppm)	NIOSH REL Ceiling (mg/m^3)	ACGIH TLV 8-hr TWA (ppm)	ACGIH TLV 8-hr TWA (mg/m^3)	ACGIH TLV STEL (ppm)	ACGIH TLV STEL (mg/m^3)	ACGIH TLV Ceiling (ppm)	ACGIH TLV Ceiling (mg/m^3)	TOTAL
Dipentamethylenethiuramtetrasulfide (DPTT)	Bis(pentamethylenethiuram)tetrasulfide	120-54-7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**0**
Diphenylamine	N/A	122-39-4	N/A	10	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**4**
N,N'-Diphenylguanidine (DPG)	1,3-Diphenylguanidine	102-06-7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**0**
N,N'-Diphenyl-p-phenylenediamine (DPPD)	N,N'-Diphenyl-p-phenylenediamine	74-31-7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**0**
Disulfides	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**0**
Di-(2-ethyl)hexylphosphorylpolysulfide (SDT)	Bis-(ethylhexylthiophosphoryl) polysulfide	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**0**
3,5-Di-tert-Butyl-4-hydroxybenzaldehyde	N/A	1620-98-0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**0**
2,2'-Dithiobis(benzothiazole)	2,2'-Dithiobisbenzothiazole	120-78-5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**0**
Dithiocarbamates	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**0**
Dithiomorpholine (DTDM)	4,4'-Dithiodimorpholine	103-34-4	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**0**
Dithiophosphates	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**0**
N,N`-Ditolyl-p-phenylenediamine (DTPD)	N,N'-Ditolyl-p-phenylenediamine	27417-40-9	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**0**
Docosanoic acid	N/A	112-85-6	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**0**
Dodecanoic acid	N/A	143-07-7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**0**
Dotriacontane	N/A	544-85-4	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**0**
Drometrizol	2-(2H-Benzotriazol-2-yl)-4-methylphenol	2440-22-4	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**0**
Eicosane	N/A	112-95-8	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**0**
Erucylamide	Erucamide	112-84-5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**0**
Esters	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**0**
Ethanol, 2-butoxy-	2-Butoxyethanol	111-76-2	5	24	N/A	N/A	N/A	N/A	20	N/A	N/A	N/A	N/A	N/A	**19**
Ethanol, 1-(2-butoxyethoxy)	1-(2-Butoxyethoxy)ethanol	54446-78-5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**0**
Ethanone, 1,1'-(1,3-phenylene)bis-	Benzene-1,3-bis(acetyl)	6781-42-6	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**0**
Ethanone, 1,1'-(1,4-phenylene)bis-	1,1-(1,4-Phenylene)bis-ethanone	1009-61-6	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**0**
Ethanone, 1-[4-(1-methylethenyl) phenyl]-	1-[4-(1-Methylethenyl)phenyl]ethanone	5359-04-6	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**0**
Ethyl Acetate	N/A	141-78-6	400	1400	N/A	N/A	N/A	N/A	400	N/A	N/A	N/A	N/A	N/A	**12**
Ethyl benzene	Ethylbenzene	100-41-4	100	435	125	545	N/A	N/A	20	N/A	N/A	N/A	N/A	N/A	**26**
Ethyl benzene aldehyde	Benzaldehyde, 2-ethyl-	22927-13-5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**0**
Ethylene thiourea (Ethylene thiourea)	N/A	96-45-7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**6**
2-Ethyl-1-hexanol	N/A	104-76-7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**0**
1-Ethyl-4-Methyl Benzene	4-Ethyltoluene	622-96-8	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**0**
Fluoranthene	N/A	206-44-0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**6**
Fluorene	N/A	86-73-7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**5**
Formaldehyde	N/A	50-00-0	0.016	N/A	N/A	N/A	0.1	N/A	N/A	N/A	N/A	N/A	0.3	N/A	**21**
Furan, 2-methyl	2-Methylfuran	534-22-5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**0**
2(3H)-Furanone,dihydro-4-hydroxy-	Dihydro-4-hydroxy-2(3H)-furanone; beta-Hydroxybutyrolactone	5469-16-9	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**0**
Guanidines	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**0**
Halocarbon 11	Trichlorofluoromethane, Freon 11	75-69-4	N/A	N/A	N/A	N/A	1000	5600	N/A	N/A	N/A	N/A	1000	N/A	**10**
Hemeicosane [c]	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**0**
Heptadecane	N/A	629-78-7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**0**
Heptane	N/A	142-82-5	85	350	N/A	N/A	440	1800	400	N/A	500	N/A	N/A	N/A	**13**
Heptanonitrile	Heptanenitrile	629-08-3	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**0**
Hexacosane	N/A	630-01-3	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**0**
Hexadecane	N/A	544-76-3	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**0**
Hexa(methoxymethyl)melamine	N,N,N',N',N'',N''-Hexakis(methoxy methyl)-1,3,5-triazine-2,4,6-triamine	3089-11-0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**0**
Hexamethylenetetramine	Methenamine	100-97-0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**0**
Hexane	n-Hexane	110-54-3	50	180	N/A	N/A	N/A	N/A	50	N/A	N/A	N/A	N/A	N/A	**15**
Hexanedioic acid, methyl ester	Methyl hexanedioate	627-91-8	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**0**
Hexanoic acid, 2-ethyl-	2-Ethylhexanoic acid	149-57-5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**0**
Hydrocarbon (olefin/aromatic)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**0**
7-Hydroxybenzo[f]flavone	7-Hydroxy-3-phenyl-1H-naphtho[2,1-b] pyran-1-one	86247-95-2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**0**
1-Hydroxypyrene	N/A	5315-79-7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**0**
Indeno[l,2,3-cd]pyrene	o-Phenylenepyrene	193-39-5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**5**
1H-isoindole-1,3 (2H)-dione	Phthalimide	85-41-6	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**0**
iso-nonylphenol	3-Nonylphenol	11066-49-2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**0**
Isophorone	N/A	78-59-1	4	23	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	5	N/A	**15**
Isopropyl Alcohol	2-Propanol, Isopropanol	67-63-0	400	980	500	1225	N/A	N/A	200	N/A	400	N/A	N/A	N/A	**19**
Isopropylbenzene	Cumene	98-82-8	50	245	N/A	N/A	N/A	N/A	50	N/A	N/A	N/A	N/A	N/A	**16**
Isopropyltoluene	1-Methyl-2-(propan-2-yl)benzene	527-84-4	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**0**
Ketones	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**0**

Chemical Constituent[a]	Synonym[b]	CAS Number[c]	NIOSH REL[10, 12] 10-hr TWA (ppm)	NIOSH REL 10-hr TWA (mg/m^3)	NIOSH REL STEL (ppm)	NIOSH REL STEL (mg/m^3)	NIOSH REL Ceiling (ppm)	NIOSH REL Ceiling (mg/m^3)	ACGIH TLV 8-hr TWA (ppm)	ACGIH TLV 8-hr TWA (mg/m^3)	ACGIH TLV STEL (ppm)	ACGIH TLV STEL (mg/m^3)	ACGIH TLV Ceiling (ppm)	ACGIH TLV Ceiling (mg/m^3)	TOTAL
Latex protein	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**0**
Limonene	N/A	138-86-3	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**1**
MEK	Methyl ethyl ketone	78-93-3	200	590	300	885	N/A	N/A	200	N/A	300	N/A	N/A	N/A	**17**
2-Mercaptobenzothiazole	N/A	149-30-4	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**1**
Methane, diethoxy-cyclohexane	Diethoxycyclohexanemethane; Bis(cyclohexyloxy)methane	1453-21-0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**0**
Methyl Alcohol	Methanol	67-56-1	200	260	250	325	N/A	N/A	200	N/A	250	N/A	N/A	N/A	**19**
2-Methylanthracene	N/A	613-12-7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**0**
2-Methyl-Butane	2-Methylbutane	78-78-4	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**0**
2,2-Methylene-bis-(4-methyl-6-tert-butylphenol) (BPH)	N/A	119-47-1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**0**
Methylene Chloride	Dichloromethane	75-09-2	N/A	N/A	N/A	N/A	N/A	N/A	50	N/A	N/A	N/A	N/A	N/A	**23**
5-Methyl-2-hexanone	Methyl isoamyl ketone	110-12-3	50	240	N/A	N/A	N/A	N/A	20	N/A	50	N/A	N/A	N/A	**8**
1-Methylnaphthalene	N/A	90-12-0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**2**
2-Methylnaphthalene	N/A	91-57-6	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**3**
3-Methyl-Pentane	3-Methylpentane	96-14-0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**0**
4-Methyl-2-pentanone	MIBK, Methyl isobutyl ketone	108-10-1	50	205	75	300	N/A	N/A	20	N/A	75	N/A	N/A	N/A	**16**
1-Methylphenanthrene	1-Methyl phenanthrene	832-69-9	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**1**
2-Methylphenanthrene	N/A	2531-84-2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**0**
3-Methylphenanthrene	N/A	832-71-3	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**0**
9-Methylphenanthrene	N/A	883-20-5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**0**
2-Methylphenol	o-Cresol	95-48-7	2.3	10	N/A	N/A	N/A	N/A	N/A	20	N/A	N/A	N/A	N/A	**11**
4-Methylphenol	p-Cresol	106-44-5	2.3	10	N/A	N/A	N/A	N/A	N/A	20	N/A	N/A	N/A	N/A	**11**
MES (special purified aromatic oil)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**0**
2-(4-morpholino)benzothiazole	2-morpholinothio benzothiazole (MBS); Morpholinothio-benzothiazole; N-Oxydiethylenebenzothiazole-2-sulfenamide	102-77-2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**0**
2-Morpholinodithiobenzothiazole (MBSS)	2-(Morpholin-4-yldithio)-1,3-benzothiazole	95-32-9	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**0**
Naphthalene	N/A	91-20-3	10	50	15	75	N/A	N/A	10	N/A	15	N/A	N/A	N/A	**21**
Naphthalene, 2-(bromomethyl)-	2-Bromomethylnaphthalene	939-26-4	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**0**
Naphthalic Anhydride	1H,3H-Naphtho(1,8-cd)pyran-1,3-dione	81-84-5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**0**
Napthenic oil	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**0**
Nitro compound (isomer of major peak)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**0**
Nitro compound (nitro-ether derivative)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**0**
Nitrogen containing substances	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**0**
Nitrosodibutylamine (n-)	N-Nitrosodibutylamine	924-16-3	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**8**
Nitrosodiethylamine (n-)	N-Nitrosodiethylamine	55-18-5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**9**
Nitrosodimethylamine (n-)	N-Nitrosodimethylamine	62-75-9	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**11**
n-Nitrosodiphenylamine	N-Nitrosodiphenylamine	86-30-6	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**7**
Nitrosodipropylamine (n-)	N-Nitrosodipropylamine	621-64-7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**8**
Nitrosomorpholine (n-)	N-Nitrosomorpholine	59-89-2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**4**
Nitrosopiperidine (n-)	N-Nitrosopiperidine	100-75-4	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**4**
Nitrosopyrrolidine (n-)	N-Nitrosopyrrolidine	930-55-2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**9**
Nonadecane	N/A	629-92-5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**0**
Nonanale	Nonanal	124-19-6	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**0**
Nonane	N/A	111-84-2	200	1050	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**5**
4-n-nonylphenol	4-Nonylphenol	104-40-5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**0**
Octadecanoic acid, methyl ester	Methyl stearate	112-61-8	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**0**
Octane	N/A	111-65-9	75	350	N/A	N/A	385	1800	300	N/A	N/A	N/A	N/A	N/A	**11**
4-t-octylphenol	4-(1,1,3,3-Tetramethylbutyl)phenol, 4-tert-(octyl)-phenol	140-66-9	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**0**
Optadecane	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**0**
Organic thiola and sulfides	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**0**
Orthocarbonate - Carboxy compound)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**0**
N-Oxydiethylenedithiocarbamyl-N`-oxydiethylenesulfenamide (OTOS)	N/A	13752-51-7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**0**
PAHs	Polycyclic aromatic hydrocarbons	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**0**
Parrafinic oils	Mineral oil	8012-95-1	N/A	5	N/A	10	N/A	N/A	N/A	5	N/A	N/A	N/A	N/A	**7**
PCB sum	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**7**
PCDD/F sum	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**2**
Pentacosane	N/A	629-99-2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**0**
Pentane	N/A	109-66-0	120	350	N/A	N/A	610	1800	1000	N/A	N/A	N/A	N/A	N/A	**11**
Perylene	N/A	198-55-0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**1**
Petroleum Naphtha	Naphtha	8030-30-6	100	400	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**8**
Phenalone	Phenalen-1-one	548-39-0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**0**

Chemical Constituent[a]	Synonym[b]	CAS Number[c]	NIOSH REL[10, 12] 10-hr TWA (ppm)	NIOSH REL 10-hr TWA (mg/m^3)	NIOSH REL STEL (ppm)	NIOSH REL STEL (mg/m^3)	NIOSH REL Ceiling (ppm)	NIOSH REL Ceiling (mg/m^3)	ACGIH TLV 8-hr TWA (ppm)	ACGIH TLV 8-hr TWA (mg/m^3)	ACGIH TLV STEL (ppm)	ACGIH TLV STEL (mg/m^3)	ACGIH TLV Ceiling (ppm)	ACGIH TLV Ceiling (mg/m^3)	TOTAL
Phenanthrene	N/A	85-01-8	N/A	0.1 (cyclohexane extractable fraction)	N/A	N/A	N/A	N/A	N/A	0.2 (coal tar pitch volatiles)	N/A	N/A	N/A	N/A	**6**
1-Phenanthrenecarboxylic acid, 1,2,3,4,4	1,2,3,4,4-1-Phenanthrene carboxylic acid; Dehydroabietic acid	1740-19-8	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**0**
Phenol	2,4-Di-tert-butylphenol	108-95-2	5	19	N/A	N/A	15.6	60	5	N/A	N/A	N/A	N/A	N/A	**16**
Phenolics	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**0**
Phenol, 2,4-bis(1,1-dimethylethyl)-	N/A	96-76-4	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**0**
Phenol, 2,4-bis(1-methyl-1-phenylethyl)-	2,4-Bis(1-methyl-1-phenylethyl)phenol	2772-45-4	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**0**
Phenol, m-tert-butyl-	3-tert-Butylphenol	585-34-2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**0**
Phenylbenzimidazole	2-Phenylbenzimidazole	716-79-0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**0**
p-Phenylenediamines	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**0**
Phenylenediamines	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**0**
2-(1-phenylethyl)-phenol	2-(1-Phenylethyl)phenol	26857-99-8	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**0**
3-Phenyl-2-propenal	3-Phenylprop-2-enal	104-55-2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**0**
Phthalates	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**0**
PM 2.5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**0**
PM 10	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**0**
Poly- and di-nitrobenzenes	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**0**
Poly-p-dinitrosobenzene	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**0**
Propene	1-Propene; propylene	115-07-1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**2**
Propylbenzene	N/A	103-65-1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**0**
Pyrazole	N/A	288-13-1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**0**
Pyrene	N/A	129-00-0	N/A	0.1 (cyclohexane extractable fraction)	N/A	N/A	N/A	N/A	N/A	0.2 (coal tar pitch volatiles)	N/A	N/A	N/A	N/A	**9**
Pyrimidine, 2-(4-pentylphenyl)-5-propyl-	N/A	94320-32-8	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**0**
2-Pyrrolidinone. 1-methyl-	N-Methyl-2-pyrrolidone	872-50-4	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**2**
Quinones	N/A	106-51-4	0.1	0.4	N/A	N/A	N/A	N/A	0.1	N/A	N/A	N/A	N/A	N/A	**8**
Resorcinol	N/A	108-46-3	10	45	20	90	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**6**
Rethene [c]	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**0**
Siloxanes	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**0**
Styrene	N/A	100-42-5	50	215	100	425	N/A	N/A	20	N/A	40	N/A	N/A	N/A	**22**
Styrene oligomers	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**0**
Substituted p-Phenylenediamines	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**0**
Sulfur containing organics	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**0**
Sulfur Donors	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**0**
Sulphenamides	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**0**
TDAE (special purified aromatic oil)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**0**
Tertbutylacetophenone	3,3-dimethyl-1-phenylbutan-1-one	31366-07-1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**0**
N-tert-Butyl-2-benzothiazolesulf enamide (TBBS)	N/A	95-31-8	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**0**
4-tert butylphenol	4-tert-Butylphenol	98-54-4	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**0**
Tetraalkylthiuram disulfides	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**0**
Tetrabenzylthiuram disulfide (TBZTD)	N/A	10591-85-2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**0**
Tetrabutylthiuram disulfide (TBTD)	N/A	1634-02-2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**0**
Tetrachloroethene	Tetrachloroethylene; perchloroethylene	127-18-4	N/A	N/A	N/A	N/A	N/A	N/A	25	N/A	100	N/A	N/A	N/A	**29**
Tetracosane	N/A	646-31-1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**0**
Tetraethylthiuram disulfide	Disulfiram	97-77-8	N/A	2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**2**
Tetrahydrofuran	N/A	109-99-9	200	590	250	735	N/A	N/A	50	N/A	100	N/A	N/A	N/A	**14**
Tetramethylthiuram disulfide	Thiram	137-26-8	N/A	5	N/A	N/A	N/A	N/A	N/A	0.05	N/A	N/A	N/A	N/A	**7**
Tetramethylthiuram monosulfide	N/A	97-74-5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**0**
Thiazoles	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**0**
Thioureas	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**2**
Thiurams	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**0**
Thiuram sulfides	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**0**
Toluene	N/A	108-88-3	100	375	150	560	N/A	N/A	20	N/A	N/A	N/A	N/A	N/A	**25**
Total petroleum hydrocarbons	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**0**
Trans trans-muconic acid	(E,E)-Muconic acid	3588-17-8	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**0**
Trimethyl-1,2-dihydroquinoline (TMDQ)	1,2-Dihydro-2,2,4-trimethylquinoline, polymer	26780-96-1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**0**
1,1,1-Trichloroethane	N/A	71-55-6	N/A	N/A	N/A	N/A	350	1900	350	N/A	450	N/A	N/A	N/A	**19**
Trichloroethylene	N/A	79-01-6	N/A	N/A	N/A	N/A	N/A	N/A	10	N/A	25	N/A	N/A	N/A	**23**
1,1,2-Trichloro-1,2,2-trifluoroethane	N/A	76-13-1	1000	7600	1250	9500	N/A	N/A	1000	N/A	1250	N/A	N/A	N/A	**17**
Trichloro-trifluoroethane	1,1,1-Trichloro-2,2,2-trifluoroethane	354-58-5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**0**
Tricosane	N/A	638-67-5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**0**
1,2,3-Trimethyl benzene	1,2,3-Trimethylbenzene	526-73-8	25	125	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**4**
1,2,4-Trimethyl benzene	1,2,4-Trimethylbenzene	95-63-6	25	125	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**4**

	Chemical Constituent[a]	Synonym[b]	CAS Number[c]	NIOSH REL[10, 12] 10-hr TWA (ppm)	NIOSH REL 10-hr TWA (mg/m^3)	NIOSH REL STEL (ppm)	NIOSH REL STEL (mg/m^3)	NIOSH REL Ceiling (ppm)	NIOSH REL Ceiling (mg/m^3)	ACGIH TLV 8-hr TWA (ppm)	ACGIH TLV 8-hr TWA (mg/m^3)	ACGIH TLV STEL (ppm)	ACGIH TLV STEL (mg/m^3)	ACGIH TLV Ceiling (ppm)	ACGIH TLV Ceiling (mg/m^3)	TOTAL
	1,3,5-Trimethyl benzene	1,3,5-Trimethylbenzene	108-67-8	25	125	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**3**
	2,2,4-Trimethyl-1,2-dihydroquinoline (TMQ)	1,2-Dihydro-2,2,4-trimethylquinoline, polymer	26780-96-1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**0**
	Vinyl Acetate	N/A	108-05-4	N/A	N/A	N/A	N/A	4	15	N/A	N/A	N/A	N/A	N/A	N/A	**9**
	White gasoline	Natural gasoline	8006-61-9	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**0**
	o-Xylene	N/A	95-47-6	100	435	150	655	N/A	N/A	100	N/A	150	N/A	N/A	N/A	**11**
	Xylenes	N/A	1330-20-7	N/A	N/A	N/A	N/A	N/A	N/A	100	N/A	150	N/A	N/A	N/A	**22**
	Zn-Dibenzyldithiocarbamate (ZBEC)	N/A	136-23-2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**0**
	Zn-Diethyldithiocarbamate (ZDEC)	Zinc diethyldithiocarbamate	14324-55-1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**0**
	Zn-Dimethyldithiocarbamate (ZDMC)	Ziram	137-30-4	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**1**
	Zn-dibutyldithiocarbamate (ZDBC)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**0**
	ZnO	Zinc Oxide	1314-13-2	N/A	5 (fume/dust)	N/A	10 (fume)	N/A	15 (dust)	N/A	5 (fume) 2 (resp. fract.)	N/A	10 (fume, resp. frac.)	N/A	N/A	**8**
TOTALS	**355**	**158**	**290**	**44**	**74**	**18**	**22**	**8**	**12**	**44**	**33**	**21**	**2**	**5**	**0**	**167**
PERCENTS	**100%**	**45%**	**82%**	**12%**	**21%**	**5%**	**6%**	**2%**	**3%**	**12%**	**9%**	**6%**	**1%**	**1%**	**0%**	**47%**

[a] Spelling of analyte names is consistent with the authors' spelling in the original literature.

[b] Synonym names and CAS numbers for chemicals for which the authors provided no CAS number were added based on curation conducted by EPA's National Center for Computation Toxicology. Additional synonyms were added based on chemical names provided in the toxicity resources used.

[c] Chemical name possibly misspelled, but author's spelling was retained. Rethene may be a misspelling of Retene, and Hemeicosane may be a misspelling of Heneicosane; Anathrene may also be a misspelling, but the correct chemical name is not known (cannot be a misspelling of anthracene because the author also provides data for anthracene).

Data Sources:

[1] EPA IRIS (https://cfpub.epa.gov/ncea/iris2/atoz.cfm)

[2] EPA PPRTVs (https://hhpprtv.ornl.gov/quickview/pprtv.php)

[3] EPA HEAST (https://cfpub.epa.gov/ncea/risk/recordisplay.cfm?deid=2877)

[4] ATSDR MRLs (http://www.atsdr.cdc.gov/mrls/pdfs/atsdr_mrls.pdf)

[5] IPCS CICADs (http://www.who.int/ipcs/publications/cicad/cicads_alphabetical/en/)

[6] IARC Monographs (http://monographs.iarc.fr/ENG/Classification/latest_classif.php)

[7] CalEPA PR65 (http://oehha.ca.gov/prop65/pdf/P65safeharborlevels040116.pdf)

[8] CalEPA RELs (http://www.oehha.ca.gov/air/allrels.html)

[9] CalEPA Cancer Values (http://www.oehha.ca.gov/air/hot_spots/pdf/CPFs042909.pdf)

[10] OSHA, CalOSHA, NIOSH, ACGIH (Z1-3) (https://www.osha.gov/dsg/annotated-pels/)

[11] CalOSHA (http://www.dir.ca.gov/title8/ac1.pdf)

[12] NIOSH (https://www.cdc.gov/niosh/npg/npgsyn-a.html)

Abbreviations:

ACGIH = American Council of Government Industrial Hygienists; **ATSDR** = Agency for Toxic Substance and Disease Registry; **CalEPA PR65** = California Proposition 65; **CalOSHA** = California Occupational Safety and Health Administration; **CAS** = Chemical Abstract Service; **CICAD** = Concise International Chemical Assessment Documents; **Conc.** = Concentration; **Dr. Water** = Drinking Water; **EPA** = Environmental Protection Agency; **HEAST** = Health Effects Assessment Summary Tables; **IARC** = International Agency for Research on Cancer; **IHL** = Inhalable; **Inhal.** = Inhalation; **Inorg. cmpds.** = Inorganic compounds; **Insol.** = Insoluble; **Inter.** = Intermediate; **IPCS** = International Programme on Chemical Safety; **IRIS** = Integrated Risk Information System; **MADL** = Maximum Allowable Dose Levels; **Monogr.** = Monograph; **MRL** = Minimal Risk Level; **NIOSH** = National Institute for Occupational Safety and Health; **NSRL** = No Significant Risk Level; **OSHA** = Occupational Safety and Health Administration; **Partic.** = Particulates; **PEL** = Permissible Exposure Limit; **PPRTV** = Provisional Peer Reviewed Toxicity Values for Superfund; **REL** = Recommended Exposure Limit; **Resp.** = Respirable; **RfC** = Reference Concentration; **RfD** = Reference Dose; **SF** = Slope Factor; **Sol.** = Soluble; **STEL** = Short Term Exposure Limit; **TLV** = Threshold Limit Value; **TWA** = Time Weighted Average; **UR** = Unit Risk

EPA IRIS Cancer Classifications:

A = Human Carcinogen; **B1** = Probable human carcinogen - based on limited evidence of carcinogenicity in humans; **B2** = Probable human carcinogen - based on sufficient evidence of carcinogenicity in animals; **C** = Possible human carcinogen; **D** = Not classifiable as to human carcinogenicity; **E** = Evidence of non carcinogenicity in humans

IARC Cancer Class:

Group 1 = Carcinogenic to humans; **Group 2A** = Probably carcinogenic to humans; **Group 2B** = Possibly carcinogenic to humans; **Group 3** = Not classifiable as to its carcinogenicity to humans; **Group 4** = Probably not carcinogenic to humans

Appendix V
Summary of the Tire Crumb Rubber Characterization Peer Review and Responses

V.1 Introduction

An independent letter peer review was conducted in May 2018 for the draft report detailing specific research activities under the *Federal Research Action Plan on Recycled Tire Crumb Used on Playing Fields and Playgrounds* developed by EPA and the Centers for Disease Control and Prevention/Agency for Toxic Substances and Disease Registry (CDC/ATSDR). Eastern Research Group, Inc. (ERG), a contractor to EPA, independently selected the external peer reviewers and conducted this external peer review. This appendix includes a description of the peer review process and a summary of key reviewer recommendations and responses relevant to the Part 1 report on tire crumb rubber characterization. A response-to-peer review comments document will be released, at a later date, along with the final report - Part 2 - detailing the exposure characterization research activities.

V.2 Peer Review Process

For this peer review, ERG identified, contacted, and screened qualified experts, and then proposed a pool of 12 candidate reviewers who had no conflicts of interest (COI) in performing the review and who collectively met the following technical selection criteria provided by EPA:

- Expertise in human exposure assessment, including
  - Characterization of chemical constituents
  - Human exposures associated with synthetic turf fields and/or crumb rubber infill
- Expertise in human exposure modeling, including
  - Characterization of human activity information through questionnaires and/or videography for exposure model development and application
- Expertise in analytical chemistry, including
  - Analysis of metals, volatile organic compounds (VOCs)/semivolatile organic compounds (SVOCs) in rubber and/or environmental media
  - Product emissions testing
  - Bioaccessibility/bioavailability measurements for chemicals in solid media
- Expertise in environmental microbiology

EPA verified that the experts in the candidate pool were appropriately qualified. ERG then independently selected seven reviewers from the pool who collectively best met the selection criteria and could meet the review schedule.

ERG provided reviewers with instructions, the draft report for review, and the charge to reviewers prepared by EPA and CDC/ATSDR. Reviewers worked independently (e.g., without contact with other reviewers, colleagues, the public, EPA or CDC/ATSDR) to prepare written comments in response to the charge questions. Reviewers completed their reviews and submitted written comments to ERG. ERG compiled the comments and forwarded to EPA. ERG, EPA and CDC/ATSDR checked the comments to ensure that reviewers had responded clearly to all charge questions. EPA and CDC/ATSDR indicated that no clarifications were needed on the reviewers' comments.

V.3 Summarized Comments and Responses

EPA and CDC/ATSDR examined all review comments and identified several common themes on the tire crumb rubber characterization elements of the report. EPA and CDC/ATSDR then developed summary responses describing how the comments were considered and addressed. These comment and response summaries are described below.

In general, the peer reviewers found that the findings and conclusions were supported by the results of the tire crumb rubber characterization components of the report. ***No fundamental flaws were identified that would preclude proceeding with dissemination of results and findings in a public report***. The reviewers provided numerous substantial recommendations for improving the clarity, conciseness, and communication of research findings. Reviewers also provided a number of technical questions and comments for consideration; as a result, the authors made corrections where needed and clarified technical approaches and results. In some cases, reviewers made well-reasoned comments and recommendations that were beyond the scope of this research or would require additional time and effort not feasible. Overall, the peer reviewers provided valuable feedback that was used to revise the report.

Regarding the Executive Summary, reviewers provided three types of recommendations. First, reviewers suggested that high-level research findings and conclusions be more clearly formulated and highlighted, using language accessible to the general public where possible. In response, plain language summaries of key results and findings were prepared and highlighted in callout boxes throughout the executive summary. Second, reviewers recommended providing additional information and highlighting additional results from the tire crumb rubber characterization, including the toxicology reference information. Therefore, the Executive Summary was expanded to include additional results and findings from the tire crumb rubber characterization and a short section on the toxicity reference information gathering and results. Finally, some reviewers recommended providing more detailed information on specific chemicals of interest and more specific measurement results, in support of the key findings. However, the authors elected not to include measurement results for a range of specific chemicals or chemical groups in the Executive Summary as this would greatly expand the size of the summary and distract from highlighting key results and findings. Instead, Section 2 was used to provide summaries for detailed information and results from across the entire study.

Regarding the organization and presentation of the report, some reviewers recommended providing schematic figures to summarize and explain the study's approaches, methodology and findings, given different types and complexities of the research activities. Several actions were taken to address these comments. A schematic overview figure was added to the Executive Summary and to the beginning of the methods section, Section 3, to describe the tire crumb characterization research activities (Figure ES-1 and Figure 3-1). In Section 2, a table describing key research topic areas and specific research activities was moved to the beginning of the section, and this overview table was also provided at the beginning of the detailed results section, Section 4, to refresh readers' understanding about the scope of tire crumb characterization results (Table 2-1 and Table 4-1). In addition, side-bar text boxes were developed and included in both the Executive Summary and Section 2 to highlight key results and findings in plain language. Finally, the entire report was thoroughly edited by an experienced technical editor to improve readability, ensure technical conformance, and to ensure 508 compliance.

- Reviewers also provided specific comments to help improve the report's organization and presentation. In response to these comments, Sections 1 and 2 were re-organized and revised substantially to improve presentation and clarity. In addition, a new conclusions sub-section was added at the end of Section 2.

- Many tables and figures received specific recommendations and were subsequently revised. For example, the comparison tables in Section 2 (Tables 2-2, 2-3, 2-4, and 2-5) were updated to group the recycling plant, indoor field, and outdoor field study results together. A table was added in Section 4 (Table 4-23) to describe the characteristics for each individual field. All figures showing the within- and between-plant and field results (in Section 4.9.2) were adjusted so that the recycling plant and field figures had the same y-axis scales. All scatter-plot and box-plot figures (for example, Figures 4-14, 4-21, 4-27, 4-37, 4-43 and 4-47) showing chemical analysis results comparisons throughout the Section were revised to improve the x-axis and y-axis labels. Figures in Section 4.10.3 showing results for different age groups for recycling plants, indoor fields and outdoor fields were substantially revised to improve clarity.

Regarding the technical approaches, methods and research results, reviewers provided a number of specific technical comments and questions. Several examples are described here, along with how they were addressed. Other technical review comments were also considered and addressed, where appropriate, through report revision.

- A reviewer raised an important question about the ***adequacy of the method used to extract SVOCs from tire crumb rubber***. In this study, a simple vortex solvent extraction method was applied rather than a more vigorous method such as soxhlet or accelerated solvent extraction. In response, more information was provided in the report regarding the preliminary testing performed in support of this method and the potential benefits including speed, lower processing losses of analytes and keeping the extracts relatively clean to avoid analytical system contamination. The response also acknowledges that this method probably does not exhaustively extract all SVOCs in the material but may provide a good representation about what is potentially available for exposure. It was also noted that the SVOC measurement results in this study compare well with similar results to those in other studies; for a few chemicals, concentrations were even higher compared to measurements in other studies where more vigorous extraction methods were used.

- Reviewers raised several questions regarding the approach and interpretation for the ***dynamic emissions testing*** for VOCs and SVOCs. For example, how the 60 °C test condition was selected and whether it adequately represents 'upper end' temperature conditions. In response, more information was provided in Section 2 to better describe the current information available about tire crumb temperatures on fields, and to acknowledge the uncertainty as a potential limitation in whether this best represents upper end conditions. Reviewers also commented on observations and interpretation of emission results that may show some chemicals having higher intrinsic levels in the crumb rubber versus chemicals that may have higher levels at the surface, potentially as a result of atmospheric absorption. More discussion was added to the limitations section in Section 2, and the discussion of results in Section 4. The discussion acknowledges the need for additional testing to better understand these dynamic results.

- Questions were also raised about ***adjusting emission results for chamber background levels*** and the resulting creation of some less-than-zero measurement results. As a result of these questions, the chemical emission results were reviewed and decisions were made to remove the results for several SVOCs most affected by the relatively high and variable amounts found in chamber background samples. Additional text was also added to the report and tables regarding the presence of some remaining less-than-zero results.

- Reviewers also asked about ***the implications of the results for human exposure and suggested applying the emission results towards the prediction of air concentrations at fields***. While there is interest in such estimations, there remains considerable uncertainty regarding the many factors associated in translating these emission results to air concentration predictions, and the effort to do so was outside the current study scope.

- Reviewers commented on the challenges for ***interpreting the microbial measurement*** results given that no other synthetic turf field or tire crumb rubber studies have reported results based on genetic analyses. In several sections, new information was included to compare and contrast the several smaller synthetic turf field and natural grass studies in the literature based on bacterial culture methods with the genetic results from this study. In addition, information on the presence and levels of bacteria in other human environments (particularly those obtained through quantitative polymerase chain reaction or qPCR) was cited to better frame the results for tire crumb rubber on synthetic turf fields in this study.

- Some reviewers suggested that ***additional toxicological data are available*** in the literature for chemicals associated with tire crumb rubber or in databases other than the 11 toxicological reference data sets examined as part of this work. While additional toxicity data may be available for some chemicals, searching the literature, curating the information, and reporting the results in a way that is useful for potential assessments was beyond the scope of work of these research activities.

Regarding recommendations for future research, reviewers recommended conducting additional work to further identify and confirm chemicals tentatively identified in this study and additional work to further develop and apply approaches for 'whole material' toxicity testing for tire crumb rubber. These recommendations for future research have been included in Section 2.5. Some comments noted that future research should also include assessing environmental impacts of synthetic turf fields with tire crumb rubber infill. While this may be an important topic of interest or concern, the focus of this research is on human exposure, so environmental impacts were not included as a recommendation for future research in this report.

Finally, several reviewers ***recommended extending this research effort to risk evaluation and to communicate risk information to the public***. It is important to note that the study activities completed as part of this multi-agency research effort were not designed, and are not sufficient by themselves, to directly answer questions about potential health risks. We recognize that communities, parents, and state and local officials are concerned about tire crumb used in synthetic turf fields. Risk is a function of both hazard (toxicity) and exposure; therefore, understanding what is present in the material (Part 1 of the report, describing tire crumb rubber characterization) and how individuals are potentially exposed (Part 2 of the report, describing exposure characterization, to be released at a future date) is critical to understanding potential risk. While this short-term study will not provide all the answers, characterizing the chemicals in recycled tire crumb rubber and identifying the ways in which people may be exposed to those chemicals based on their activities on synthetic turf fields, will contribute to future risk assessments.

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