Calvert City, Kentucky
Volatile Organic Compound (VOC)
Air Quality Risk Assessment

Prepared by:

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Region 4
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KEY MESSAGES

- The U.S. Environmental Protection Agency and Kentucky Department of Environmental Protection, Division for Air Quality (KDAQ) are working together to protect public health in Calvert City, KY.
- The EPA and KDAQ completed a monitoring study for toxic air pollution near the Calvert City Industrial Complex that focused on volatile organic compounds (VOCs), including ethylene dichloride (EDC, also known as 1,2-dichlorethane). VOCs are a group of many chemicals that evaporate easily and often have an odor. VOCs are used in industrial processes and in common household products. Exposure to certain VOCs can cause harmful health effects, including cancer.
- The air monitoring study found elevated levels of VOCs. The levels identified at the Calvert City air monitoring sites are estimated to result in elevated chronic cancer risk over a 70-year lifetime of continuous exposure.
- The EPA and KDAQ are taking steps to protect public health while continuing air monitoring for EDC and other VOCs at the three Calvert City air monitoring sites.
- The air monitoring study measured VOCs at each of three Calvert City monitoring sites and a background site between October 2020 and December 2021. None of the VOCs measured were at levels that would be expected to result in non-cancer or short-term health problems. The highest lifetime cancer risk was found at the LWD site, which is close to VOC sources at the industrial complex. Lower risks were found at the two other sites. All three sites were above the target cancer risk level referenced by the KDAQ to determine if air emissions reductions are needed.
- EDC was found to be the chemical with the highest estimated risk at each monitoring site. EDC is a man-made chemical that is not found naturally in the environment. It is primarily used in industrial processes, such as in the production of vinyl chloride, polyvinyl chloride (PVC), solvents, and other chemicals. Exposure to EDC in the air over long periods of time can pose an increased risk of cancer and other negative health effects to the liver and kidneys.
- According to the EPA's 2020 National Emissions Inventory (NEI) there are three facilities in the Marshall County, KY, area that emitted EDC in 2020 (the most recent inventory year). The majority (96%) of reported EDC emissions in Calvert City are from the Westlake Vinyls, Inc. facility, which is the largest single source of EDC air emissions in the United States according to the 2020 NEI.
- The EPA is supporting the KDAQ in developing short-and long-term strategies to reduce EDC exposure in Calvert City, including working with Westlake Vinyls and potentially other facilities to explore voluntary actions to reduce EDC emissions. The EPA has also proposed revisions to air emissions rules for the Synthetic Organic Chemical Manufacturing Industry . Westlake Vinyls and other similar chemical plants are subject to these rules.
- The KDAQ is continuing air monitoring for EDC and other VOCs at the three Calvert City sites and will work with the EPA to assess any changes or trends in the air pollution concentrations.

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EXECUTIVE SUMMARY

This document reports on ambient air toxics monitoring and the resulting human health risk assessment from three monitors in Calvert City, KY and a background monitor located at Grayson Lake State Park in Carter County, KY. The purpose of this study was to determine if residents of the area around Calvert City Industrial Complex (CCIC) were being exposed to airborne concentrations of toxic air pollutants via the inhalation route of exposure that may pose risks to human health. Air samples were obtained during October 2020 to December 2021 at sites surrounding CCIC. Volatile organic compounds (VOCs) were identified as chemicals of potential concern (COPC) based on previous sample screening performed during 2011-2017. Standard risk assessment procedures and exposure factors were applied to assess the risk from exposure to outdoor ambient VOCs near CCIC. Other potential pollutants such as carbonyls, metals, and polyaromatic hydrocarbons (PAHs) and potential risks associated with worker exposures were not assessed in this risk assessment.

The Kentucky Division for Air Quality (KDAQ) and EPA worked together to establish air monitoring stations at Calvert City Elementary School, Johnson-Riley Road, and LWD. The existing Grayson Lake National Air Toxics Trends Station (NATTS) in Carter County, KY is at a rural state park and was used as a comparison background site. Air samples were collected at the four sites from October 2020 to December 2021 and analyzed for VOCs. Over 60 24-hour samples were collected on a 1-in-6-day schedule at each location. Data completeness at each site was above the 75% project goal (KDAQ, Calvert City Special Study. Final Report. Kentucky Energy and Environmental Cabinet, Department for Environmental Protection, Division of Air Quality, Frankfort, KY. , 2022) . Collocated quality assurance (QA) samples were collected at the LWD site on a 1-in-12-day schedule. The sampling and laboratory analysis process was subject to the quality assurance/quality control procedures in the study's Quality Assurance Project Plan (QAPP). Sample results were evaluated and additional COPCs were identified.

To be a COPC at a monitoring site, a chemical had to be detected in greater than 10% of the samples collected at that monitoring location. All samples from the monitors in the network included analysis for VOCs. A portion of the VOCs were selected as COPCs at every monitoring location.

Only inhalation exposures were evaluated with risks calculated for each specific monitoring location for individuals that may reside near each of the monitoring areas. Both chronic (cancer and noncancer) and acute/short-term (noncancer) inhalation exposures were estimated for individuals residing near the four monitoring locations. The chronic exposure assessment assumed an individual is exposed to the identified COPCs continuously for 24 hours per day over a 70-year period. The 95% Upper Confidence Level

(95UCL) of the arithmetic mean of the chemical concentration in air at a given monitor was used as the exposure concentration for an individual. The 95UCL is a value that, 95% of the time, equals or exceeds the true average concentration. The 95UCL is typically used as a conservative estimate of the true average concentration. Potential risk at each monitoring site was calculated by combining the 95UCL concentrations of each COPC identified in the analysis with toxicity data for the pollutants. The cumulative cancer risks were calculated by combining the cancer risks for all COPCs. For the chronic risk assessment, a distinction is made between the potential risk of developing cancer and the potential for non-cancer health effects.

The risk estimates provided here are based on approximately 13 months of VOC HAP monitoring data collected at four monitoring sites. The monitors were sited at specific locations due to the past elevated historical EDC concentrations and based on modeling of the current EDC and vinyl chloride sources in the area. For the purpose of this assessment, it was assumed that VOC HAP concentrations measured at the monitors would be stable for daily exposure over many years.

The results of the cancer risk assessment, with the assumption of a lifetime of continuous exposure, at each monitoring location are as follows:

a) Calvert City Elementary School had a total or “cumulative” risk of $6x10^{-5}$ (60 potential additional cancer cases in 1,000,000 exposed people)
b) Johnson-Riley Road had a total or “cumulative” risk of $1x10^{-4}$ (100 potential additional cancer cases in 1,000,000 exposed people),
c) LWD had a total or “cumulative” risk of $1x10^{-3}$ (1,000 potential additional cancer cases in 1,000,000 exposed people),
d) Grayson Lake monitoring site had a total or “cumulative” risk of $1x10^{-5}$ (10 potential additional cancer cases in 1,000,000 exposed people), respectively.

Due to measurement uncertainties in the ethylene oxide (EtO) and acrolein monitoring data discussed in this document, these chemicals were excluded from the risk assessment. Acetonitrile data from the Grayson Lake site was also excluded due to sample contamination, as discussed later in the document.

Under the Clean Air Act (CAA), EPA generally strives to protect the greatest number of persons possible to an individual lifetime risk level no higher than 1×10^{-6} (one in one million) and limiting to no higher than approximately 1×10^{-4} (one hundred in one million) as the estimated risk that a person living near a source would have if exposed to the maximum pollutant concentrations for 70 years. While this assessment is not a regulatory action under the CAA, it is reasonable to compare the risk estimates to this acceptability range to determine if further action to characterize or reduce risk is warranted. Cancer

risks calculated at the Grayson Lake background site and the Calvert City Elementary site fell at 10 in a million and 60 in a million respectively, while the calculated risk was 1,000 in a million at the LWD monitoring site, which is closest to major industrial facilities. The calculated risk at the Johnson Riley Rd. site was equal to 100 in a million. Ethylene dichloride (EDC, also known as 1-2-dichloroethane) was the leading driver of carcinogenic risk at all the Calvert City, KY sites. A summary of the air toxics cancer risk at each monitoring site is shown in Table E – 1 and Figure E - 1 below.

EPA reviewed more recent EDC monitoring data collected by KDAQ at the Calvert City sites from January 2022 – June 2023 that were collected after the data used in this risk assessment and determined that the more recent ambient concentrations at all three sites have a similar distribution to those observed in the dataset evaluated in this risk assessment.

Table E - 1: Calvert City, KY Cumulative Chronic Cancer Risks by Monitoring Site

Site	Chronic Cancer Risk	Approx. Distance to Nearest Facility in the CCIC
LWD	1,000 in 1 million (1 x 10^{-3})	200 m
Johnson-Riley Rd	100 in 1 million (1 x 10^{-4})	200 m
Calvert City Elementary	60 in 1 million (6 x 10^{-5})	1.5 km
Background (Grayson Lake, KY)	10 in 1 million (1 x 10^{-5})	N/A

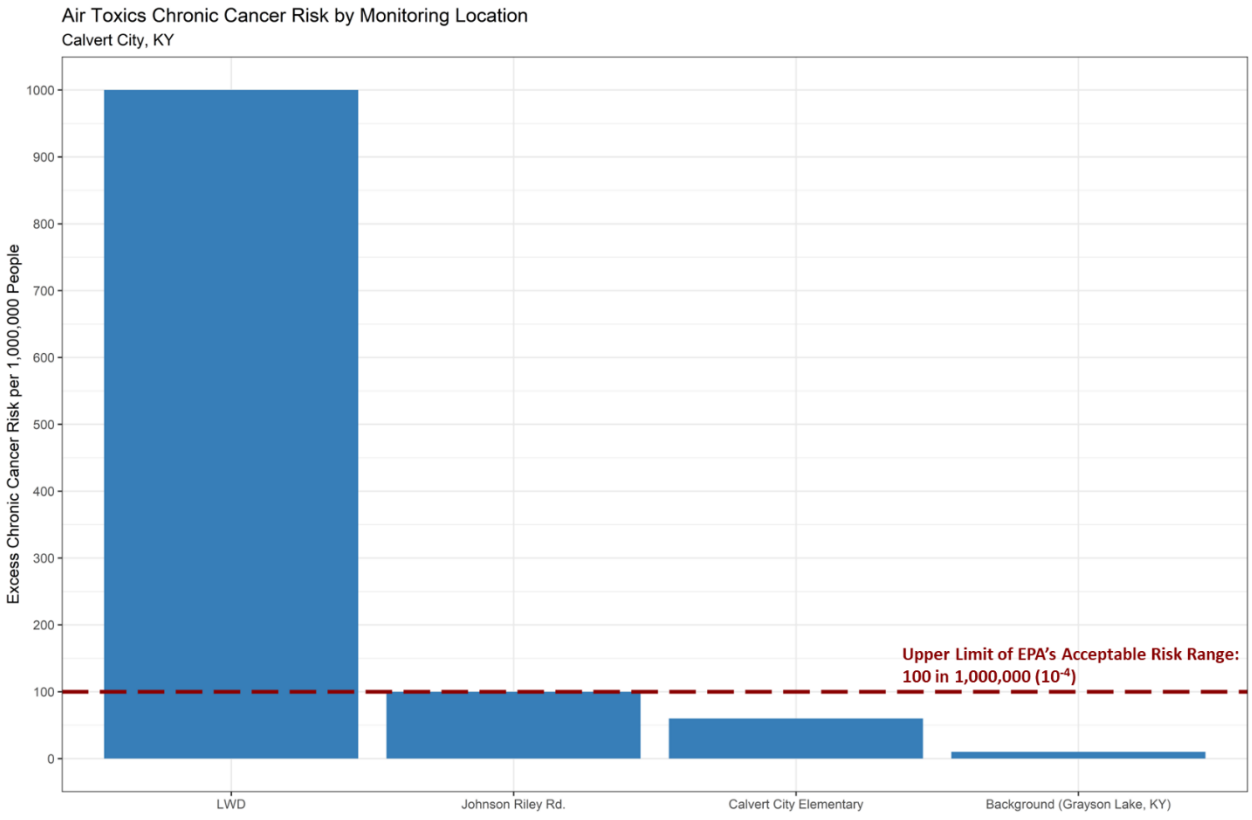

Figure E - 1: Air Toxics Chronic Cancer Risk by Monitoring Location

Long-term non-cancer health hazards are evaluated in a two-step process. First, a Hazard Quotient (HQ) is calculated by comparing the 95UCL concentrations to a reference dose considered to be a safe level of exposure. The HQs for COPCs are summed to determine the Hazard Index (HI) at a monitoring site. A HI of less than or equal to 1 is an indication that the cumulative impact of all of the COPCs at a given monitoring site is not likely to result in adverse, non-carcinogen health impacts. For monitoring sites where the HI exceeds 1, a second analysis is conducted to better assess the impact of COPCs on specific organs or systems (a Target Organ Specific Hazard Index, or TOSHI, analysis). The TOSHI is determined by summing each HQ for COPCs that affect the same target organ/system or have the same mechanism of action. A TOSHI value of less than or equal to 1 is an indication that the cumulative impact of all of the COPCs to the same toxicological endpoint or mechanism of action at a given monitoring site is not likely to result in adverse, non-carcinogen health impacts.

In this study, none of the monitoring sites had an HI that exceeded 1. The two contributors that contributed to the chronic non-cancer HI of 0.04 at the LWD monitoring site were chloroform (53%) and bromomethane (47%). The Calvert City Elementary, Johnson-Riley, and Grayson-Lake monitoring locations did not have any chronic non-cancer contributors.

Potential health effects from acute, or short-term, exposures were also evaluated. Acute exposures last a few minutes to one day. The acute exposure analysis consisted of comparing the maximum concentration of chemicals that were detected at least once to health-based comparison values. The individual sample results of this analysis indicated that none of the chemicals exceeded its acute comparison value in any of the samples at any monitoring site. This indicates that there are not any potential short-term health hazards resulting from elevated levels of VOCs at the sites at the time of sampling.

In general, the three monitors collected data that indicate higher concentrations of certain VOC air toxics in areas closer to the CCIC. A summary table of the air toxics risk results is provided in Table E - 2 below.

Calvert City Air Toxics Risk Summary

Table E - 2: Calvert City Air Toxics Risk Summary

Monitoring Site/Community	Chronic Cancer Risk		Chronic Non-Cancer Hazard		Acute Hazard
	Total Risk	Risk Drivers and % Contributions to Total Risk	Hazard Index	Hazard Drivers and % Contributions to Hazard Index	
Calvert City Elementary	$6.00x10^{-5}$	Ethylene dichloride (80.77%), Carbon tetrachloride (5.52%), Benzene (5.37%), 1,1,2-Trichloroethane (2.85%), Vinyl Chloride (2.57%), 1,3-Butadiene (2.24%), Ethylbenzene (0.41%), 1,1-Dichloroethane (0.28%)	None	None	None
Johnson-Riley Road	$1.00x10^{-4}$	Ethylene dichloride (61.15%), Vinyl chloride (27.25%), Benzene (3.38%), Carbon tetrachloride (2.79%), 1,1-Dichloroethane (2.45%), 1,1,2-Trichloroethane (1.95%), 1,3-Butadiene (1.04%)	None	None	None
LWD	$1.00x10^{-3}$	Ethylene dichloride (91.84%), Chloroprene (4.53%), 1,1,2-Trichloroethane (1.48%), Vinyl chloride (0.94%), Carbon tetrachloride (0.52%), Benzene (0.31%), 1,1-Dichloroethane (0.22%), 1,3-Butadiene (0.13%), Trichloroethylene (0.03%)	0.04	Chloroform (53%), Bromomethane (47%)	None
Grayson Lake (Background)	$1.00x10^{-5}$	Carbon tetrachloride (31.09%), Benzene (29.70%), Ethylene dichloride (17.45%), 1,3-Butadiene (11.39%), Hexachlorobutadiene (10.36%)	None	None	None

Study Purpose: The purpose of this monitoring study was to determine if residents in the vicinity of the CCIC are potentially being exposed to VOC concentrations in ambient air and the risks that those exposures may pose. Using the data collected during the October 2020 to December 2021 special study of VOCs at the Calvert City Elementary, Johnson-Riley Road, and LWD monitors, a risk assessment was conducted to inform the need for subsequent steps such as pursuing risk reduction activities where data show levels that exceed 100 in a million lifetime cancer risk. The 2020 population in Calvert City, KY was 2,525 and split among males (1,095) and females (1,430). The majority (45%) age group was between 20-54 years of age while 26% of the population were <19 years of age. The racial makeup of the Calvert City was 98% white, 0.3 % black, and less than 1% of the

remaining population spread among several groups (American Indian, Asian, and other races). The median income in Calvert City was $55,938.

Exposure Analysis: Chronic exposure was evaluated using the median, average, and 95UCL on the arithmetic mean concentrations of the 1-year special study data as estimates of long–term exposure for each COPC. The use of the 95UCL of the arithmetic mean as the exposure concentration (EC) for inhalation risk reflects a conservative estimate of chronic (long-term) exposure when limited data are available (such as a one-year monitoring study). The EC for each COPC was calculated based on the distribution of each chemical's sampling data using ProUCL version 5.1.00. Additionally, short-term exposure was analyzed by comparing the maximum concentration detected during the year for each COPC to all short-term toxicological exposure concentrations for the chemical.

Toxicity Analysis: The toxicity values used for this study are listed in EPA Office of Air Quality, Planning, and Standards' (OAQPS') Toxicity Tables for Chronic and Acute Exposure (USEPA, Dose Response Assessment Tables, Office of Air Quality, Planning and Standards, Table 1 and Table 2, see:, 2021). The OAQPS toxicity values are compiled and prioritized from many sources including the EPA, the Agency for Toxic Substances and Disease Registry (ATSDR), the State of California, and other government bodies, and were used in this study to represent the toxicity of the COPCs. Toxicity values for chronic (long term) or acute (one-time or short duration) exposures were applied. Cancer risk and non-cancer hazards were assessed. When chemicals lacked specific toxicity information, surrogate values were adopted and carried through the assessment for risk screening purposes.

Risk Characterization: The risk characterization for chronic exposures was conducted by combining the relevant toxicity criteria with the ECs estimated from the October 2020 – December 2021 monitoring data. The ECs used to estimate potential cancer risks and chronic noncancer hazards were the 95UCL of the arithmetic mean to account for the use of limited monitoring data (1 year) to represent lifetime exposures (70 years). ATSDR's acute (1- to 14-day) minimal risk levels (from OAQPS's Table 2, (USEPA, Dose Response Assessment Tables, Office of Air Quality, Planning and Standards, Table 1 and Table 2, see:, 2021)) were compared to maximum concentrations detected at the monitoring site to assess the potential for acute effects.

Risk Findings: EDC was the main chronic cancer risk driver and COPC at each Calvert City monitoring site. The main chronic cancer risk driver at the Grayson Lake background site was carbon tetrachloride. The site-specific risk are as follows:

Calvert City Elementary School

EDC levels across all sampling events at the Calvert City Elementary School site ranged from 0.0283 µg/m^3 to 11.21 µg/m^3 and were detected in 96% of the valid

samples. The ProUCL 95UCL for EDC was 2.009 µg/m^3 based on a lognormal distribution. The corresponding estimated cancer risk at the monitoring location was $5x10^{-5}$ (50 in one million; rounded to one significant figure per EPA guidance; (USEPA, Air Toxics Risk Assessment Reference Library, Office of Air Quality Planning and Standards, EPA-453-K-04-001A, see: , 2004) .The other carcinogenic chemicals associated with the study were all in the 10^{-6} risk range or lower. Thus, EDC represented 80.77% of the risks. The cumulative risk at the Calvert City Elementary School monitoring site was $6x10^{-5}$ (60 in one million; rounded to one significant figure per EPA guidance; (USEPA, Air Toxics Risk Assessment Reference Library, Office of Air Quality Planning and Standards, EPA-453-K-04-001A, see: , 2004).

There were no non-cancer health effects associated with the COPCs. A comparison of each chemical's maximum concentration in any 24-hour sample to its corresponding acute benchmark (where available) indicated that acute effects are not expected.

Johnson-Riley Road

EDC levels across all sampling events at the Johnson-Riley Road site ranged from 0.0591 µg/m^3 to 15.42 µg/m^3 and were detected in 93% of the valid samples. The ProUCL 95UCL for EDC was 2.705 µg/m^3 based on a lognormal distribution. The corresponding estimated cancer risk at the monitoring location was $7x10^{-5}$ (70 in one million; rounded to one significant figure per EPA guidance; (USEPA, Air Toxics Risk Assessment Reference Library, Office of Air Quality Planning and Standards, EPA-453-K-04-001A, see: , 2004)). Vinyl chloride was the next highest cancer risk driver with levels ranging from 0.0036 µg/m^3 to 13.75 µg/m^3 and were detected in 88% of the valid samples. The ProUCL 95UCL for vinyl chloride was 3.561 µg/m^3 based on a lognormal distribution and the corresponding estimated cancer risk at the monitoring location was $3x10^{-5}$ (30 in a million; rounded to one significant figure per EPA guidance; (USEPA, Air Toxics Risk Assessment Reference Library, Office of Air Quality Planning and Standards, EPA-453-K-04-001A, see: , 2004)). The other carcinogenic chemicals associated with the study were all in the 10^{-6} risk range or lower. Thus, EDC and vinyl chloride represented 61.15% and 27.25% of the risks, respectively. The cumulative risk at the Johnson-Riley Road monitoring site was $1x10^{-4}$ (100 in one million; rounded to one significant figure per EPA guidance; (USEPA, Air Toxics Risk Assessment Reference Library, Office of Air Quality Planning and Standards, EPA-453-K-04-001A, see: , 2004)).

There were no non-cancer health effects associated with the COPCs. A comparison of each chemical's maximum concentration in any 24-hour sample to its corresponding acute benchmark (where available) indicated that acute effects are not expected.

LWD

EDC levels ranged from 0.0429 µg/m^3 to 221.0 µg/m^3 and were detected in 99% of the valid samples. The ProUCL 95UCL for EDC was 45.24 µg/m^3 based on a lognormal distribution. The corresponding estimated cancer risk at the monitoring location was 1x10^{-3} (1000 in one million; rounded to one significant figure per EPA guidance; (USEPA, Air Toxics Risk Assessment Reference Library, Office of Air Quality Planning and Standards, EPA-453-K-04-001A, see: , 2004)). Chloroprene had the second highest chronic cancer risk at the monitor. Chloroprene levels ranged from 0.0065 µg/m^3 to 0.5667 µg/m^3 and were detected in 29% of the valid samples. The ProUCL 95UCL for chloroprene was 0.121 µg/m^3 based on a lognormal distribution and the corresponding estimated cancer risk at the monitoring location was 6x10^{-5} (60 in a million; rounded to one significant figure per EPA guidance; (USEPA, Air Toxics Risk Assessment Reference Library, Office of Air Quality Planning and Standards, EPA-453-K-04-001A, see: , 2004)). 1,1,2-Trichloroethane had the third highest chronic cancer risk at the monitor. 1,1,2-Trichloroethane levels ranged from 0.0115 µg/m^3 to 10.61 µg/m^3 and were detected in 75% of the valid samples. The ProUCL 95UCL for 1,1,2-Trichloroethane was 1.181 µg/m^3 based on a lognormal distribution and the corresponding estimated cancer risk at the monitoring location was 2x10^{-5} (20 in a million; rounded to one significant figure per EPA guidance; (USEPA, Air Toxics Risk Assessment Reference Library, Office of Air Quality Planning and Standards, EPA-453-K-04-001A, see: , 2004)). Vinyl chloride had the fourth highest chronic cancer risk at the monitor. Vinyl chloride levels ranged from 0.0033 µg/m^3 to 8.230 µg/m^3 and were detected in 95% of the valid samples. The ProUCL 95UCL was 1.364 µg/m^3 based on a lognormal distribution and the corresponding estimated cancer risk at the monitoring location was 1x10^{-5} (10 in a million; rounded to one significant figure per EPA guidance; (USEPA, Air Toxics Risk Assessment Reference Library, Office of Air Quality Planning and Standards, EPA-453-K-04-001A, see: , 2004)). The other carcinogenic chemicals associated with the study were all in the 10^{-6} risk range or lower. Thus, EDC, chloroprene,1,1,2-Trichloroethane, and vinyl chloride represented 91.84%, 4.53%, 1.48%, and 0.94% of the risks, respectively. The cumulative risk at the LWD monitoring site was 1x10^{-3} (1000 in one million; rounded to one significant figure per EPA guidance; (USEPA, Air Toxics Risk Assessment Reference Library, Office of Air Quality Planning and Standards, EPA-453-K-04-001A, see: , 2004)).

Non-cancer health effects associated with the COPCs together approximate a 0.04 HI (rounded to one significant figure per EPA guidance – (USEPA, Air Toxics Risk Assessment Reference Library, Office of Air Quality Planning and Standards, EPA-453-K-04-001A, see: , 2004)). The highest HQ of 0.02 was associated with chloroform, followed by bromomethane with an HQ of 0.02 (note that an HI equal to or less than 1 indicates that noncancer effects are not likely to occur). A comparison of each chemical's maximum concentration in any 24-hour sample to its corresponding acute benchmark (where available) indicated that acute effects are not expected from levels measured in the study.

Grayson Lake

Carbon tetrachloride levels ranged from 0.0723 µg/m^3 to 0.654 µg/m^3 and were detected in 100% of the valid samples. The ProUCL 95UCL for carbon tetrachloride was 0.528 µg/m^3 based on a lognormal distribution and the corresponding estimated cancer risk at the monitoring location was $3x10^{-6}$ (3 in one million; rounded to one significant figure per EPA guidance; (USEPA, Air Toxics Risk Assessment Reference Library, Office of Air Quality Planning and Standards, EPA-453-K-04-001A, see: , 2004)). All COPCs measured at this site were all in the 10^{-6} risk range or lower. The cumulative risk at the Grayson Lake (background) monitoring site was $1x10^{-5}$ (10 in one million; rounded to one significant figure per EPA guidance; (USEPA, Air Toxics Risk Assessment Reference Library, Office of Air Quality Planning and Standards, EPA-453-K-04-001A, see: , 2004)).

There were no non-cancer health effects associated with the COPCs. A comparison of each chemical's maximum concentration in any 24-hour sample to its corresponding acute benchmark (where available) indicated that acute effects are not expected.

There are a number of uncertainties associated with this analysis that should be considered when making risk management decisions such as:

- the use of one year's worth of monitoring data to represent a lifetime of exposure;
- the time residents spend in the immediate vicinity of the monitor (the assessment assumes around the clock exposure for a full lifetime);
- the proportion of measured pollutants that may come from potential sources in the area; and
- potential exposure concentrations may be higher when in closer proximity to an emission source and, conversely, lower in other areas than those measured at the Calvert City monitors (samples were only collected at three monitoring sites);

The Uncertainty Section of this risk assessment discusses these and other uncertainties in more detail.

Next Steps:

Considering that the highest risks in the study were driven by EDC, EPA Region 4 is working to identify and explore options for reducing EDC emissions in the area. EDC is a HAP regulated under the Clean Air Act (CAA). Generally, large industrial sources of HAPs (and some small sources) are regulated under Section 112 of the CAA. A review of the available emissions inventory data identified that Westlake Vinyls, Inc., a chemical facility in the CCIC, is the largest emitter of EDC in the U.S. according to the 2020 National Emissions Inventory

(NEI). The air dispersion modeling conducted by EPA prior to the monitoring study to assist in selecting the monitoring sites also predicted elevated ambient concentrations of EDC, which are primarily attributable to the reported EDC emissions from Westlake Vinyls, Inc. Figure E - 2 below shows the EDC concentrations measured in this monitoring study (from October 2020 – December 2021), compared to the historical concentration trends at monitoring sites with similar objectives. Data collected prior to 2020 were not collected under an EPA approved QAPP and were not used in this assessment, but these historical data provide additional weight of evidence that the EDC concentrations in the Calvert City area have been elevated for several years, and that the monitoring sites in the area consistently measure among the highest EDC concentrations across all ambient VOC monitoring sites in the country.

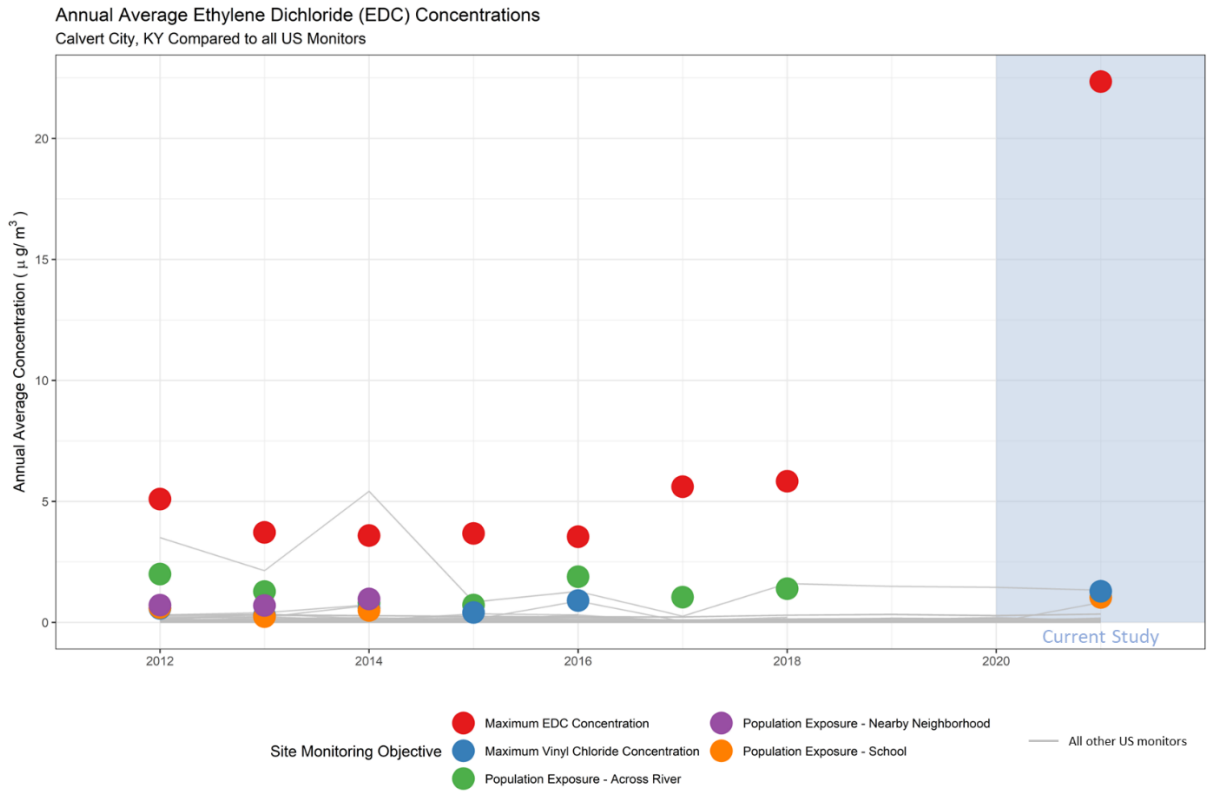

Figure E - 2: Annual average trend of ethylene dichloride concentrations: Calvert City, KY compared to all US monitors in AQS

EPA will work with the Kentucky Department for Environmental Protection (KDEP), Division for Air Quality (KDAQ) to determine the appropriate steps to reduce EDC emissions in the area, with the goal of lowering the ambient concentrations. KDAQ is continuing to operate the three air toxics monitoring sites in the Calvert City area, with funding support from EPA.

Recently, EPA proposed new rules for the Synthetic Organic Chemical Manufacturing Industry (also known as the "HON" rules)[1]. Under this proposal, fenceline monitoring would be required at certain HON sources for six specific HAPs, including ethylene dichloride (EDC), which is the main risk driver discussed in this Risk Assessment for Calvert City. Westlake Vinyls is an affected HON source and reports the most EDC emissions of all sources in both Calvert City and the country. The proposed HON rule's fenceline monitoring includes requirements to identify emission sources and make repairs if monitored fenceline concentrations are higher than an action level previously determined in the rules by emissions modeling. EPA explained in its proposal that these rules, if finalized, will serve as a backstop to help ensure that emissions of EDC and the other five specific HAP at applicable sources will not be greater than expected from compliance with its proposed emission standards. The proposed HON rule would also require that fenceline monitoring data be reported and made available through a public EPA database. The public comment period for the HON rules recently closed, and EPA is evaluating the voluminous comments it received, including comments on the proposed fenceline monitoring program. EPA is required by a court order to sign the final HON rules by March 29, 2024.[2]

EPA and KDEP are planning strategies for mitigating the elevated chronic risks identified in this monitoring study and risk assessment. KDEP identified applicable regulatory provisions relating to air emissions that have been determined to result in impacts above target risk levels established by the Commonwealth. See Section 7.4 for a detailed discussion of next steps.

[1] HON Rule Proposal 88 FR 25080 - 25205, April 25, 2023

[2] More information on the HON Rule Proposal can be found at EPA's HON webpage: https://www.epa.gov/stationary-sources-air-pollution/synthetic-organic-chemical-manufacturing-industry-organic-national

1 INTRODUCTION

1.1 Calvert City Industrial Complex

The CCIC is located in Marshall County in Western Kentucky on the Tennessee River, just downstream of the Kentucky Dam and north of Calvert City (population 2,525). The largest city in the region is Paducah (population 26,278), approximately 13 miles due west of the CCIC.

The first manufacturing facilities in the industrial complex were built in the 1950s to take advantage of the availability of barge and rail transport facilities and the electric generating capacity of the Tennessee Valley Authority (TVA). The primary activity of CCIC facilities is chemical manufacturing. Ownership of the individual facilities has changed periodically over the last 50 years. Current, major operating facilities in CCIC include: Air Products and Chemicals, Inc., Arkema, Inc., Carbide Industries, Celanese Ltd., Cymtech, LLC, Evonik Corp., ICT, ISP Corp., Lubrizol Advanced Materials, Inc., Wacker Chemical Corp., and Westlake Chemical Corporation (two facilities: Westlake PVC and Westlake Vinyls). CCIC is the largest industrial complex in the County and is also the only major manufacturing complex within a 15-mile radius of Calvert City based on Toxic Release Inventory (TRI) data.

Due to the nature of the industrial activities at the CCIC, various volatile organic chemicals (VOCs) have been released over the years, either through permitted air pollution emissions, spillage (accidental or intentional), or through leaks resulting from maintenance or operational problems.

1.2 Calvert City, KY Demographic Analysis

According to the 2020 estimate for the United States Census Bureau, the number of people in Calvert City, KY was 2,525 (Table 1.2). The ratio of men to women in Calvert City is approximately equal to 1,095 men and an estimated female population of 1,430. The median age of people living in Calvert City was 39.2 years. The number of people under the age of 5 was 91. As for ages 5-19, there were 573 (22 percent of the total population [2,525]). As for the seniors in the community, there were 142 individuals at ages 60-64 and 167 persons at ages 65-74. The estimated white population in Calvert City was 2,386, which is 98% of the total population. The estimated Black/African American population was 8, which is 0.3% of Calvert City's total population. At the last survey, the total Asian population in the city was 18, while the American Indian/Alaska Native population totaled 2 and persons who identified as other race were 14.

As of 2020, the number of children in elementary school totaled 298, while 245 students attended high school. Also note that 17 individuals were

attending undergraduate college, while 313 white individuals graduated from college in 2020. No other races graduated from college in 2020. The median household income in Calvert City was $ 55,938 (the mean household income was $ 78,222). The median family income in Calvert City was $69,260 while the mean family income was $93,552.

Persons living in poverty in Calvert City were estimated at 10.2% compared to the United States poverty level of 12.8% (U.S. Census, 2021).

1.3 Previous Air Monitoring

Prior to initiating the current study, EPA Region 4 conducted a risk screening analysis on air toxics data previously collected by KDAQ near the CCIC. The data was obtained from the AQS database and encompassed VOC monitoring conducted from 2011-2017. The analysis indicated potentially elevated cancer risks and non-cancer hazards due to a recurring set of chemicals. The screening results predicted a total maximum cancer risk of 6.0×10^{-3}, or a maximum of 6,000 additional cancers per one million persons with exposure at chronic levels for a lifetime at the maximum screened site. The screening analysis indicated elevated cancer risk at all five of the locations where samples were collected in Calvert City and the surrounding area. The majority of the elevated cancer risk screening results were due to elevated levels of EDC and vinyl chloride. The screening results also indicated elevated cancer risk from 1,3-butadiene, acrylonitrile, and benzene.

Trends analysis conducted by EPA Region 4 showed an increased cancer risk trend for several chemicals during 2011-2017. A non-cancer hazard screening conducted by EPA Region 4 on 2011-2017 data showed a total maximum non-cancer health effect HQ of 10.7, or concentrations 10.7 times higher than the reference level. The majority of the elevated non-cancer hazard screening results were due to elevated levels of 1,3-butadiene. However, site selection for this study was based on modeling of EDC and vinyl chloride emissions from nearby major sources because these two chemicals were responsible for the majority of the elevated cancer risk in the screening results.

1.4 VOC Emissions Sources in the Area

To evaluate air pollutant emissions in the area, VOC emissions data for EDC and vinyl chloride were obtained from EPA's 2020 National Emissions Inventory (NEI) (USEPA, 2017 National Emissions Inventory, January 2021 version. Data and documentation available at, 2020), which is the most recent complete national inventory. These two chemicals were selected because EDC was the main chronic cancer risk driver and COPC at each Calvert City air monitoring site, and vinyl chloride was a secondary risk driver at one site. Yearly historical emissions

from 2011-2020 of EDC and vinyl chloride were also obtained from the KDAQ emissions inventory in EPA's emissions inventory system gateway (KDAQ, Kentucky Division for Air Quality – Emissions Inventory. 2011 – 2020 air emissions data reported to and retrieved from the US EPA Emissions Inventory System (EIS) Gateway: , 2020).

Figure 1-1 shows all facilities that emitted above 5 tons per year of EDC in the US, according to the 2020 NEI. The only facility in Calvert City, KY above 5 tons per year, Westlake Vinyls Inc. is shown in blue. Figure 1-2 shows all of the facilities in Calvert City, KY with any reported emissions of EDC in the 2020 NEI. The facility labeled "Avient Corporation / Goodrich Corporation" is reported emissions data from the pump and treat groundwater remediation process at the B.F. Goodrich Superfund Site[3] in Calvert City, where EPA is managing ongoing remediation of contaminated soil and groundwater. Figure 1-3 shows the historical trend of EDC and vinyl chloride emissions in the Calvert City area from 2011-2020, according to the KDAQ annual emissions inventories and historical NEI data. The emissions trends of other US facilities from the historical NEI data is shown in grey. Table 1-1 shows the distribution of EDC and vinyl chloride emissions from point and area sources in Marshall County, KY in the 2020 NEI. The majority (>99%) of emissions of both chemicals were from point sources (i.e. from large facilities) rather than from area sources such as vehicles and other mobile sources, agricultural sources, fires, and other smaller sources.

[3] B.F. Goodrich Superfund Site Profile, Calvert City, KY. US EPA. https://cumulis.epa.gov/supercpad/SiteProfiles/index.cfm?fuseaction=second.cleanup&id=0401930#bkground

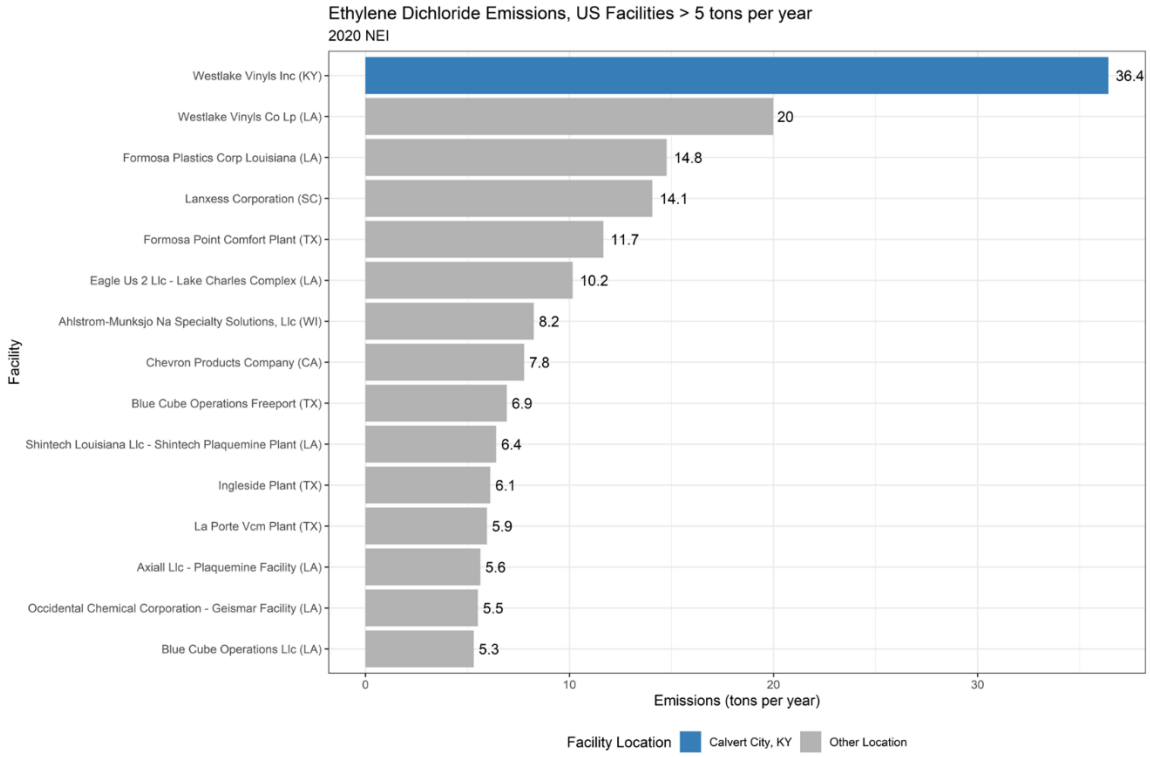

Figure 1-1: Ethylene dichloride emissions at US facilities emitting greater than five tons per year in the 2020 NEI

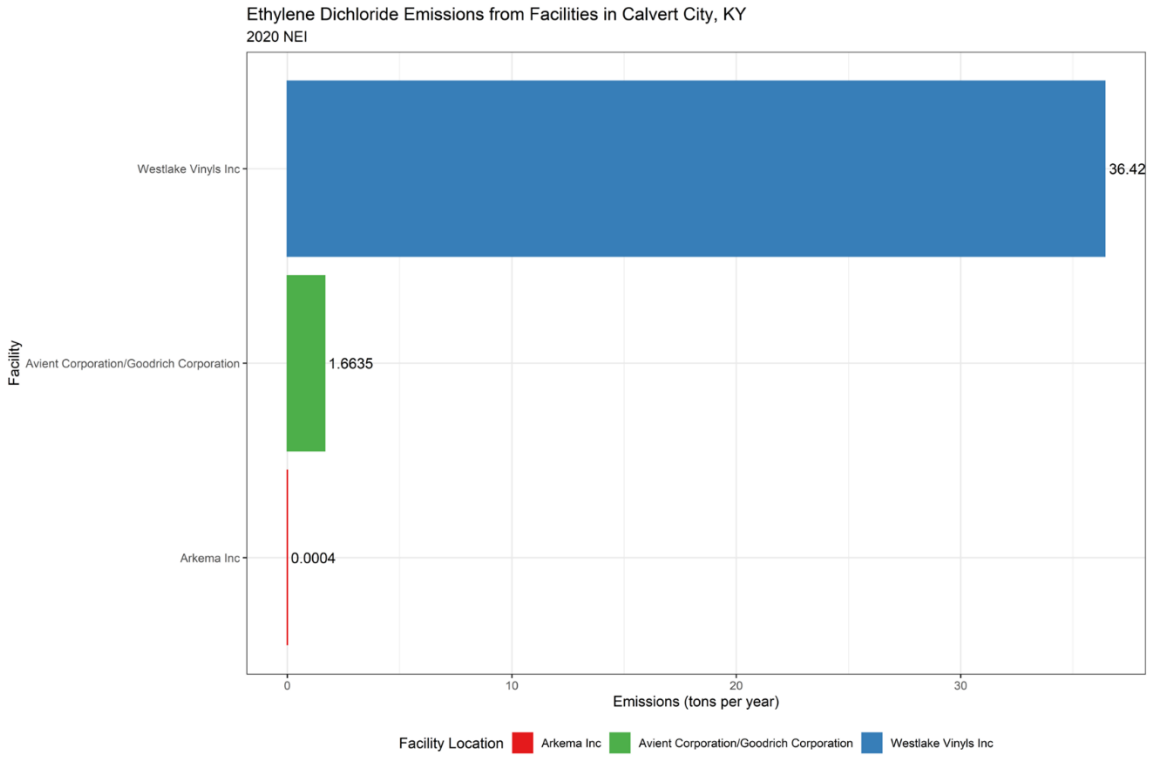

Figure 1-2: Ethylene dichloride emissions from facilities in Calvert City, KY in the 2020 NEI

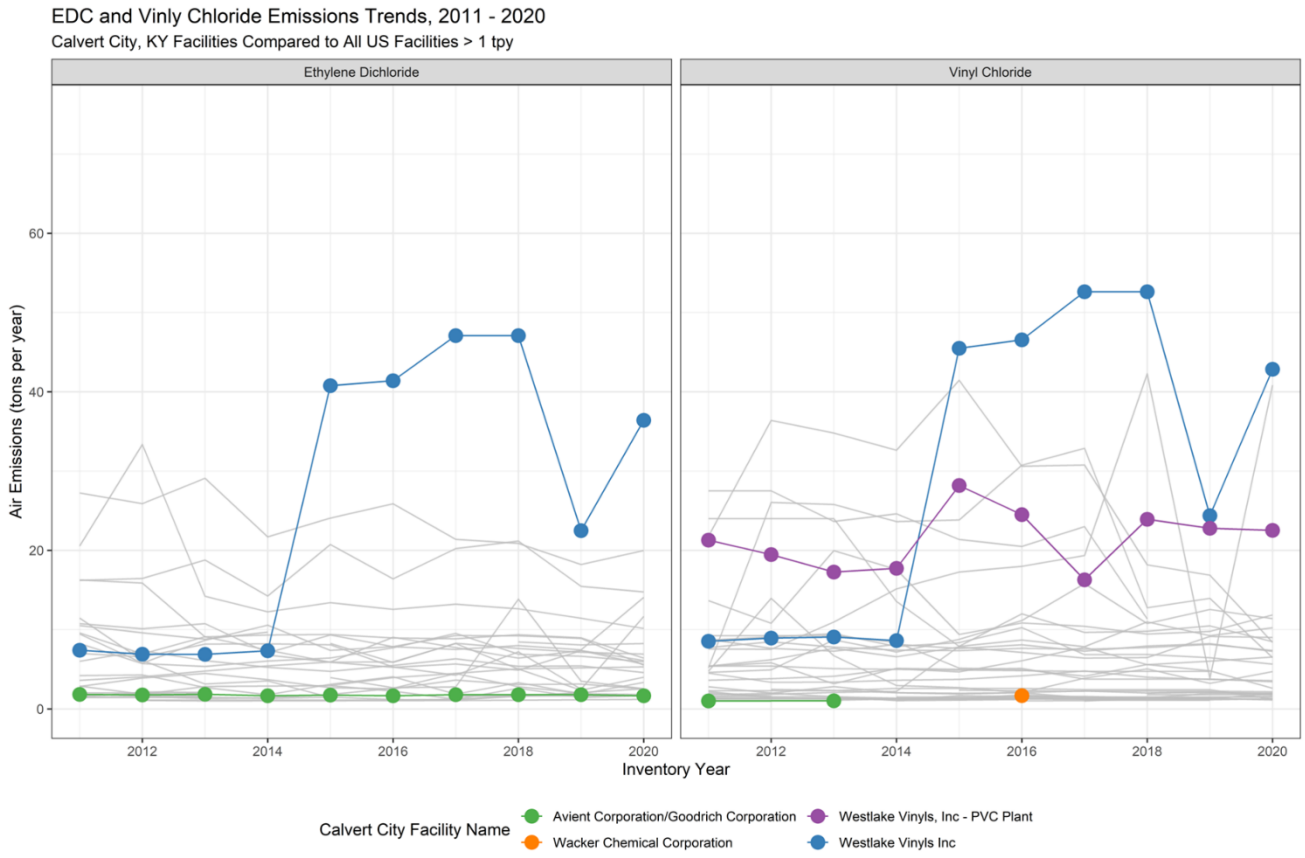

Figure 1-3: Calvert City emissions trends of ethylene dichloride and vinyl chloride from 2011-2020 compared to all US facilities greater than 1 ton per year, according to EPA NEI and KDAQ annual emissions inventories.

Table 1-1: Point and area source emissions of ethylene dichloride and vinyl chloride in Marshall County, KY in the 2017 NEI

Chemical	Point Source Emissions (lbs)	Area Source Emissions (lbs)	Total Emissions (lbs)	Percentage from Point Sources	Percentage from Area Sources
Ethylene Dichloride	76,168.2	3.4	76,171.6	99.99%	0.01%
Vinyl Chloride	132,605.6	0.004	132,605.6	100.00%	0.00%

1.5 Problem Definition and Study Design

The KDAQ has monitored airborne VOC concentrations in the vicinity of the CCIC in some form for most of the last three decades. Based on the EPA risk screening analysis discussed above, the EPA and the KDAQ determined that a

health risk assessment was needed, which required a new study and an EPA-approved QAPP.

As stated in section 2.1, the purpose of this risk assessment is to if the VOC HAP levels measured at the monitoring sites in the vicinity of the CCIC are above 1×10-4 (100 in a million). VOC data obtained from 10/28/2020 to 12/28/2021 was used to evaluate the long-term potential human health impacts via inhalation exposures within approximately 2 kilometers the CCIC.

Detailed information about how the air monitoring study was designed is contained in Section 2. This information is also documented in the KDAQ QAPP for Volatile Organic Compound Monitoring near the Calvert City Industrial Complex contained in Appendix D (KDAQ, Quality Assurance Project Plan for Volatile Organic Compound Monitoring near the Calvert City Industrial Complex. Kentucky Energy and Environment Cabinet, Department for Environmental Protection, Division for Air Quality, Frankfort, KY. , 2021).

1.6 Organization of This Report

The remainder of this report is organized into the following main sections:

- Section 2, **Data Collection and Analysis**, which includes details about the monitoring data used in this assessment including sampling and analysis methods. This section also includes a data quality assessment of the air monitoring data and describes the process of selecting COPCs.

- Section 3, **Exposure Assessment**, wherein the COPCs were further reduced and carried through the remainder of the risk assessment. The risk assessment will focus on chronic (lifetime) exposures and acute (minutes to one day) exposures.

- Section 4, **Toxicity Assessment,** which includes the potential health effects and the dose-response information associated with the COPCs.

- Section 5, **Risk Characterization**, summarizes and discusses the risk assessment results for each COPC detected.

- Section 6, **Uncertainty Analysis**, summarizes important sources of uncertainty in this assessment and their potential impacts on the risk estimates.

- Section 7, **Summary of Findings**, summarizes the conclusions of the risk assessment.

References are provided in Section 8 followed by Section 9, a glossary of important acronyms and terms. The appendices provide supporting detail for the risk assessment including A) monitoring study tables, B) monitoring data, C) ProUCL statistical results, D) chemical-specific health effects, E) Calvert City, KY air monitoring QAPP and F) Calvert City, KY Special Study Final Report. Overall, although extensive, this risk assessment is intended to comply with available guidance (USEPA, Air Toxics Risk Assessment Reference Library, Office of Air Quality Planning and Standards, EPA-453-K-04-001A, see: , 2004) in support of the goals outlined in Section 1.6 herein.

2 DATA COLLECTION, STUDY DESIGN, ANALYSIS, AND SELECTION OF CHEMICALS OF POTENTIAL CONCERN

This section first summarizes the design and analytical methodology for the study. More detailed information on study design can be found in the QAPP, located in Appendix E. This section also includes a data quality assessment of the air monitoring data and describes how the study COPCs were selected.

2.1 Monitoring Study Participants

In 2020, the KDAQ, in conjunction with the US Environmental Protection Agency Region 4 (EPA-R4), developed a QAPP for this study. The monitors were established and operated by KDAQ while all samples were sent to EPA's national contract lab, Eastern Research Group (ERG), for laboratory analysis. Additional information about previous air monitoring and the problem definition and study design are included in Sections 1.3 and 1.5, respectively

2.2 Site Selection and Monitoring Locations

To determine the best potential locations for ambient monitoring sites near the CCIC, KDAQ and EPA utilized air dispersion modeling conducted by EPA Region 4. The modeling was performed with emissions data from 2013-2017 for EDC and vinyl chloride obtained from KDAQ. The modeling was conducted for EDC and vinyl chloride because these two chemicals were responsible for the majority of the elevated cancer risk in the screening results of previous monitoring data. The modeled concentrations at the receptor locations were ranked in order of descending modeled five-year average ambient concentration. The maximum concentration monitoring sites were selected by evaluating the modeling results and looking for suitable monitoring sites near the highest ranked receptors. LWD was selected as the maximum concentration site for EDC, Johnson-Riley was selected as a maximum concentration site for vinyl chloride. An additional monitoring site, Calvert City Elementary, was selected to characterize ambient air toxics concentrations in an area of expected high concentration with the potential for sustained population exposure. The existing NATTS site at Grayson Lake, located in Carter County in northeastern Kentucky, was selected as a background location for comparison.

A map of the CCIC showing the locations of KDAQ's air monitoring sites used during the study and several nearby facilities is shown in Figure 2-1.

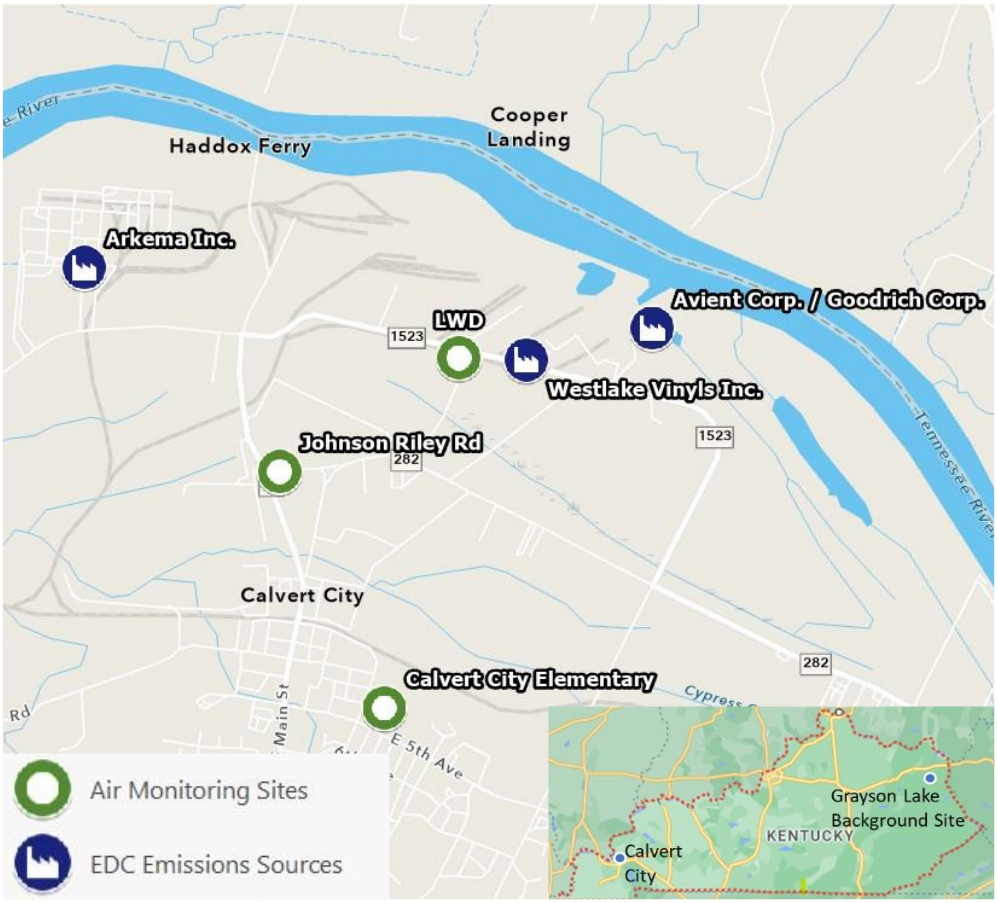

Figure 2-1: Map of Calvert City, KY air monitoring sites and nearby industrial facilities

2.2.1 Monitoring Objectives

The measurement goal of the Calvert City Special Study is to quantify the 24-hour average passive canister sampling concentrations of VOC HAPs in units of micrograms per cubic meter (µg/m^3). The Calvert City Special Study followed EPA Compendium Method TO-15, as applicable, for collecting VOCs. All samples were analyzed for the full suite of Tier I and II NATTS VOCs (USEPA, Technical Assistance Document for the National Air Toxics Trends Stations Program, Revision 4. see: , 2022)). To aid in data interpretation and analysis, collocated hourly meteorological measurements were taken at one of the monitoring sites during the study.

The monitoring objectives of this project were to:

1. Characterize the maximum ambient concentrations of VOC air toxics in the area around the CCIC.
2. Characterize ambient air toxics concentrations in nearby area(s) of potential population exposure.

3. Collect quality-assured air sampling and meteorology data to supplement and confirm the previous monitoring results.

Additional information about the monitoring objectives can be found in the QAPP in Appendix E.

A summary of the monitoring sites for this special study, including monitoring objectives, sampling equipment and sampling schedules are listed in Table 2-1 below.

Table 2-1: Summary of monitoring site information

Calvert City Study: Site & Monitor Summary						
Site/AQS ID/Coordinates	**Objective**	**Sampling Instruments**	**Sampling Media**	**Monitor Type**	**Sampling Schedule**	**Monitor Purpose**
LWD Collocated & Meteorological Site (LWD) 21-157-0021 37.047906, -88.338347	Maximum Expected Ethylene Dichloride* Concentration and Meteorology	Xonteck 911a	6-Liter stainless steel canister	Primary and collocated	Primary-Every 6 days; Collocated-Every 12 days	Characterization of maximum vinyl chloride concentration
		RM Young 05305V	n/a	n/a	Continuous	Characterization of wind speed/direction, representative of entire study area
Johnson-Riley Road (JRR) 21-157-0020 37.041179, -88.351889	Maximum Expected Vinyl Chloride* Concentration	Xonteck 911a	6-Liter stainless steel canister	Primary	Every 6 days	Characterization of maximum EDC concentration
Calvert City Elementary (CCE) 21-157-0018 37.026746, -88.343747	High Air Toxics Concentration in Area of Expected Population Exposure	Xonteck 911a	6-Liter stainless steel canister	Primary	Every 6 days	Characterization of air quality in more heavily populated area
Grayson Lake NATTS (GLKY)* 21-043-0500 38.238972, -82.988084	Comparative Background Concentrations (previously established NATTS site)	ATEC 2200	6-Liter stainless steel canister	Primary and collocated	Primary-Every 6 days; Collocated-6/Year	Background

* The Grayson Lake NATTS site is already operated by KDAQ, and the data collection and reporting are covered under the NATTS QAPP. These data were referenced for comparative background concentrations during the study and data analysis.

2.3 Monitoring Schedule and Analytical Parameters

Monitoring at the four sites was planned to be conducted over a one-year period, from October 2020 to December 2021. To account for potential seasonal variability, the monitoring consisted of collecting samples every sixth day, which would have resulted in approximately sixty sampling events at each location. Samples were collected and handled according to the procedures presented in the QAPP, which is available in Appendix E.

Volatile Organic Compounds (VOCs)

VOCs are organic chemicals that have a high vapor pressure and tend to have low water solubility. They have a high propensity to evaporate and remain airborne. Many VOCs are human-made chemicals that are used in the manufacture of paints, pharmaceuticals, and refrigerants. VOCs are commonly used as industrial solvents, such as trichloroethylene, or are created as by-products, such as chloroform produced as a result of chlorination in water treatment. VOCs (e.g., benzene) are often components of petroleum fuels, hydraulic fluids, paint thinners, and dry-cleaning agents.

2.4 Monitoring Equipment

The monitoring sites consisted of Xonteck 911a and ATEC 2200 samplers to collect ambient air samples in stainless steel canisters. The sampling apparatus was furnished by ERG and KDAQ. All monitoring equipment was operated in accordance with EPA and KDAQ Standard Operating Procedures.

2.5 Air Sample Laboratory Analysis

All the samples were analyzed in the ERG laboratory in Morrisville, NC. Laboratory analyses were performed using EPA-approved methods, as follows:

- Compendium Method TO-15 for the analysis of VOCs air toxics. Samples were analyzed with the gas chromatograph/flame ionization detector/mass selective detector (GC/FID/MSD) using the pre-concentrator and autosamplers. The method is applicable to ambient air, indoor air, landfill gas, and any air samples where VOCs are not present at levels above hundreds of parts per billion by volume (ppbv). A copy of the document detailing this procedure is available at the EPA website at: https://www3.epa.gov/ttnamti1/files/ambient/airtox/to-15r.pdf.

2.6 Analytical Air Sampling Results

Appendix B contains a detailed output of the year-long analytical data (1-in 6-day samples collected from October 24, 2020 through December 30, 2021) for the monitoring sites. Table 2.6-1, Table 2.6-2, Table 2.6-3, and Table 2.6-4

summarizes the list of analytes detected at the Calvert City, Johnson-Riley, LWD, and Grayson Lake sites, respectively. There were 46 chemicals detected during sampling including EDC, vinyl chloride, carbon tetrachloride, benzene, and 1-3 butadiene.

2.7 Detection Limits

All detection limits were reported as MDLs for each chemical contaminant and by each analytical method. The detection limits were determined by the ERG laboratory using 40 CFR, Part 136 Appendix B procedures ((USEPA, Guidelines for Carcinogen Risk Assessment. EPA/630/P-03/001B. Risk Assessment Forum, Washington, DC., 2005)) in accordance with the specifications presented in the NATTS Technical Assistance Document (USEPA, Technical Assistance Document for the National Air Toxics Trends Stations Program, Revision 4. see: , 2022) (USEPA, Graphical Arrays of Chemical-Specific Health Effect Reference Values for Inhalation Exposures [Final Report], EPA/600/R-09/061, , 2009)). By definition, MDLs represent the lowest concentration at which laboratory equipment can reliably quantify concentrations of specific pollutants at a specific confidence level. If a chemical concentration in ambient air did not exceed the method sensitivity (as gauged by the MDL), the analytical method might not differentiate the pollutant from other pollutants in the sample or from the random "noise" inherent in laboratory analyses. While quantifications below the MDL were sometimes reported in the analytical results, the measurement reliability is lower. Therefore, all measurements under the respective MDL were considered non-detects in this study.

All detection limits were reported to AQS by ERG as MDLs per chemical for each sample analyzed. MDLs and corresponding Sample Quantitation Limits (SQLs) are provided in the laboratory data results appendix of this report.

2.8 Air Monitoring Data Quality

2.8.1 Summary of Air Monitoring Data Collected

The monitors at each site collected samples on the same schedule whenever possible. Rigorous data validation and quality assurance/quality control (QA/QC) procedures were implemented for both sample collection and laboratory sample analysis. Information regarding data validation and QA/QC measures can be found the QAPP for this study (Appendix E).

KDAQ began collecting VOC samples on October 24, 2020. The QAPP required one full year of sampling, (12 complete months). Since KDAQ validates data quarterly and elected to continue monitoring after one year, data was available through December 31, 2021 at the point when at least 12 complete months of validated data was available. EPA and KDAQ agreed that the risk assessment

should evaluate all available validated data collected between October 24, 2020, and December 31, 2021. APPENDIX B: Monitoring Data contains the sampling dates on which each valid sample was collected at each monitoring site. From October 24, 2020, to December 30, 2021, monitoring was reported for 61, 58, 65, and 59 sampling dates at Calvert City Elementary, Johnson-Riley Road, LWD, and Grayson Lake, respectively.

The data obtained during the study were sufficient in both quantity and quality to provide a representative sampling of what VOCs are in the ambient air and at what concentrations they exist. Each sample was collected by KDAQ staff and shipped to ERG for analysis using Method EPA TO-15 (AQS method code 149) to identify the targeted pollutants as well as their respective concentrations. A list of monitored/analyzed pollutants and their respective concentrations across the study can be found in APPENDIX A: Monitoring Study Figures and Tables. The data were validated and reported within approximately 45-days after the end of each sampling month. ERG entered all data into Air Quality System (AQS), and the data was validated by KDAQ. The project's sampling plan and quality assurance procedures are outlined in the QAPP, located in Appendix D.

2.8.2 Air Monitoring Data Quality Assessment

In the KDAQ Calvert City Special Study Final Report (KDAQ, Calvert City Special Study. Final Report. Kentucky Energy and Environmental Cabinet, Department for Environmental Protection, Division of Air Quality, Frankfort, KY. , 2022) (KDAQ, Quality Assurance Project Plan for Volatile Organic Compound Monitoring near the Calvert City Industrial Complex. Kentucky Energy and Environment Cabinet, Department for Environmental Protection, Division for Air Quality, Frankfort, KY. , 2021); included in APPENDIX E: Quality Assurance Project Plan), each of the monitoring data quality indicators (DQIs) and data quality objectives (DQOs) defined in the project QAPP were evaluated. The report concluded that "[t]he data collected in support of this Calvert City Special Study was released for use in EPA's risk assessment. The data collected meets the study's data quality objectives, and is of a sufficient quality and quantity to be used in the assessment." A summary of the comparison of the study data to the data quality indicators is included below.

2.8.2.1 Representativeness

According to the QAPP, sampling must occur at a one-in-six day frequency, from midnight to midnight local standard time, over 24 hours ± 1 hour. Due to incorrect run dates from the lab, collocated samples at LWD were initially collected at the required frequency, but not on the same days as the national sampling calendar. EPA and KDAQ decided that while the actual run dates did not affect the sample validity, precision calculations, nor representativeness, collection against the national calendar was preferred since that was specified in the QAPP. Collocated

sampling began on the national schedule starting March 11, 2021. Otherwise, samples were collected against the schedule and sample time requirements stated in the QAPP; thus, data have met the DQI of “Representativeness.” When necessary, makeup samples were collected in accordance with the QAPP.

2.8.2.2 Completeness

According to the QAPP, at least 75% of all data must be reported annually for each monitoring site. A summary of the data completeness for the study period (October 2020 – December 2021) is shown in Table 2-2 below. Each of the monitoring sites exceeded the goal of at least 75% data completeness. As such, the study met the DQI of “Completeness.”

Table 2-2: Data completeness by monitoring site

Month	# Scheduled 1/6 Run Days	# Scheduled 1/12 Run Days	Calvert City Elem. (CCE)		Johnson-Riley Rd. (JRR)		LWD-Primary (LWD-P)		LWD-Collocated (LWD-C)	
			# Valid	% Rec.	# Valid	% Rec.	# Valid	% Rec.	# Valid	% Rec.
Oct-2020*	**2**	**1**	2	100.0	2	100.0	2	100.0	1	100.0
Nov-2020	**5**	**2**	5	100.0	5	100.0	3	60.0	2	100.0
Dec-2020	**5**	**3**	5	100.0	5	100.0	6	120.0	2	66.7
Jan-2021	**5**	**2**	5	100.0	5	100.0	5	100.0	2	100.0
Feb-2021	**5**	**3**	5	100.0	2	40.0	5	100.0	2	66.7
Mar-2021	**5**	**2**	5	100.0	5	100.0	5	100.0	2	100.0
Apr-2021	**5**	**3**	5	100.0	5	100.0	5	100.0	3	100.0
May-2021	**5**	**2**	5	100.0	3	60.0	5	100.0	2	100.0
Jun-2021	**5**	**3**	5	100.0	6	120.0	5	100.0	3	100.0
Jul-2021	**5**	**2**	5	100.0	5	100.0	4	80.0	2	100.0
Aug-2021	**5**	**3**	5	100.0	5	100.0	5	100.0	3	100.0
Sep-2021	**5**	**2**	5	100.0	5	100.0	5	100.0	2	100.0
Oct-2021	**6**	**3**	4	66.7	5	83.3	6	100.0	2	66.7
Nov-2021	**5**	**3**	2	40.0	4	80.0	5	100.0	2	66.7
Dec-2021	**5**	**2**	6	120.0	5	100.0	5	100.0	3	150.0
Total Observations	**73**	**36**	**Total**	**Avg. %**	**Total**	**Avg. %**	**Total**	**Avg. %**	**Total**	**Avg. %**
			69	**95.1**	**67**	**92.2**	**71**	**97.3**	**33**	**94.4**
Completeness - Compared to Total Scheduled Observations			**94.5 %**		**91.8 %**		**97.3 %**		**91.7%**	

* Sampling did not start until October 24, 2020.

*Low data completeness due to equipment malfunction.

2.8.2.3 Precision

For individual collocated sample pairs, relative percent difference (RPD) was used as an estimator of collocated precision, when one or both samples had a concentration greater than five times the method detection limit (MDL). In accordance with the QAPP, sample data were flagged “QX”, an AQS QA qualifier meaning the sample does not meet QC criteria, when collocated precision was more than 25% RPD. Measurement precision was also evaluated by performing the same calculations using the laboratory replicate data. Collocated samples are two samples collected side by side in the field and provides an estimate of the precision of the entire field sampling and laboratory analysis system. Replicate samples are a single sample that is analyzed twice in the laboratory and provides an estimate of the laboratory analysis method’s precision.

According to the QAPP, the overall annual coefficient of variation (% CV) should be no more than 25% for both collocated samples and replicate samples. The CV is calculated based upon sample pairs where one or both samples had concentrations greater than or equal to five times the MDL. This precision calculation is different than the RPD criteria between individual sample pairs discussed in the previous paragraph; imprecision of RPD is permitted to be larger than 25% whereas %CV should be below 25%. Table 2-3 below summarizes the collocated sampling % CV for each chemical analyzed in the samples collected at the LWD site during the study period (October 24, 2020 – December 31, 2021). Table 2-4 below summarizes the laboratory replicate sample % CV for each chemical analyzed at all sites during the study period. Data comparisons were not possible for chemicals where all the collocated sample pairs or replicate pairs were less than five times the MDL, so these chemicals are not included in the table. CV calculations were also not possible for chemicals with only one valid collocated or replicate sample pair, as noted in the tables.

Overall, the collocated sample CVs for those COPCs that had at least four valid sample pairs for comparison met the 25% precision goal. The CV for EDC was 24.59%; however, the dataset includes a comparative outlier on 2/21/21. Without the 2/21/21 data point, CV was 11.66%. Re-audit of the 2/21/21 sample show that while both the primary and collocated samples/instruments met study requirements, the flow on the primary sampler was substantially lower (with a higher remaining vacuum) than the collocated sampler. Since both instruments met requirements, data were not invalidated, but the precision calculations for this data are not representative. Additionally, the 2/21/21 sample pair was the lowest EDC concentration still eligible for inclusion in the CV calculation. Higher concentration data was found to have excellent precision. The replicate pair CVs for all COPCs with at least two valid replicate pairs met the 25% precision goal.

Chemicals that were not identified as COPCs were also evaluated. Several of these chemicals exhibited collocated CVs that exceeded the 25% goal, but this imprecision could be due to a number of factors, including a small number of valid sample pairs, and the effect that the percent difference (which is used to calculate the CV) increases as concentrations get lower and closer to zero even as an absolute difference between samples remains constant. Most chemicals

that were not identified as COPCs exhibited replicate CVs that met the 25% goal, except as noted below. Data for the study was considered to meet the DQI for “Precision” for most of the chemicals analyzed.

Table 2-3: Collocated precision CVs by chemical at the LWD site, for sample pairs where at least one sample is ≥ 5x the MDL

Chemical Name[1]	**Number of Sample Pairs (n)**	**CV (%)**	**COPC sites**
COPCs at LWD (collocated sampling site)[1]			
1,1,2-Trichloroethane	11	3.4	CCE, LWD, JRR
1,1-Dichloroethane	16	6.8	CCE, LWD, JRR
1,3-Butadiene	1	N/A[2]	All
Benzene	30	5.4	All
Carbon tetrachloride	29	23.2	All
Chloroform	14	7.7	LWD
Chloroprene	1	N/A	LWD
Ethylene dichloride	20	11.3[3]	All
Vinyl chloride	24	8.5	CCE, LWD, JRR
Other Chemicals (at least one valid sample pair)			
1,1-Dichloroethylene	1	N/A[2]	
Acrolein - Verified	4	203.7	Excluded from risk analysis[4]
Chlorobenzene	1	N/A[2]	
Chloroethane	14	35.8	
Chloromethane	31	10.1	
Dichloromethane	9	62.2	
Ethylbenzene	2	558.6	CCE
Ethylene oxide	13	84.8	Excluded from risk analysis[4]
m/p Xylene	2	583.4	
Methyl chloroform	1	N/A[2]	
Methyl isobutyl ketone	19	35.7	
o-Xylene	1	N/A[2]	
Styrene	1	N/A[2]	
Tetrachloroethylene	2	5.9	
Toluene	6	120.9	

1. Four chemicals were identified as COPCs, but had zero collocated sample pairs > 5x the MDL, and so a CV could not be calculated and these chemicals are not included in the table. These COPCs were bromomethane and trichloroethylene (at LWD) and acetonitrile and hexachlorobutadiene (at Grayson Lake).
2.A CV could not be calculated for chemicals with only one valid sample pair.
3.The CV for EDC was calculated excluding an outlier on 2/21/21, when a low sample flow was noted on the primary sampler. With the outlier included in the calculation, the CV would be 23.8%. See discussion above.
4. Acrolein and EtO were excluded from the risk analysis based on the measurement uncertainty was elevated for these two chemicals. See additional discussion in Section 2.8.2.6.

Table 2-4: Laboratory replicate precision CVs by chemical for samples collected at all sites, for replicate pairs where at least one replicate is ≥ 5x the MDL

Chemical Name[1]	Number of Sample Pairs (n)	CV (%)	COPC sites
COPCs at LWD (collocated sampling site)[1]			
1,1,2-Trichloroethane	22	1.3	CCE, LWD, JRR
1,1-Dichloroethane	24	1.6	CCE, LWD, JRR
Benzene	57	1.8	All
Carbon tetrachloride	57	1.7	All
Chloroform	26	1.8	LWD
Chloroprene	2	5.1	LWD
Ethylene dichloride	40	1.3	All
Vinyl chloride	40	1.8	CCE, LWD, JRR
Other Chemicals (at least one valid sample pair)			
1,1-Dichloroethylene	4	3.4	
Acetonitrile	5	6.0	Excluded from risk analysis at Grayson Lake[2]
Acrolein - Verified	8	77.7	Excluded from risk analysis[2]
Chlorobenzene	2	6.0	
Chloroethane	27	2.8	
Chloromethane	59	2.2	
Dichloromethane	46	2.9	
Ethylene oxide	15	4.7	Excluded from risk analysis[2]
m/p Xylene	15	2.6	
Methyl chloroform	2	40.6	
Methyl isobutyl ketone	35	3.0	
Tetrachloroethylene	4	0.8	
Toluene	27	2.9	

1. Five chemicals were identified as COPCs, but had zero replicate sample pairs > 5x the MDL, and so a CV could not be calculated and these chemicals are not included in the table. These COPCs were 1,3-butadiene (all sites), ethylbenzene (at Calvert City Elementary), bromomethane and trichloroethylene (at LWD) and hexachlorobutadiene (at Grayson Lake).
2. Acrolein and EtO were excluded from the risk analysis based on the measurement uncertainty was elevated for these two chemicals. Acetonitrile data from the Grayson Lake background site was also excluded due to sample contamination. See additional discussion in Section 2.8.2.6.

2.8.2.4 Bias

Bias is the difference of a measurement from a true or accepted value and can be negative or positive. Per the QAPP, bias is measured in two distinct areas: field collection bias and laboratory bias; each of which is described below.

Field Collection Bias: KDAQ applied action and control limits for flows that ensure bias was less than 25%. In combination with performance audits, data from the study met the DQI of “Field Collection Bias.”

Laboratory Bias: In accordance with the QAPP, the ERG laboratory participated in NATTS proficiency tests (PTs). VOC PTs were conducted 1Q21, 2Q21, and 3Q21. All VOC data were found to be within MQOs. As such, data meets the DQI of “Laboratory Bias.”

2.8.2.5 Sensitivity

According to the QAPP, the ERG laboratory was required to report MDLs that were equal to or less than the MDLs MQOs for the NATTS Tier 1 pollutants (USEPA, Technical Assistance Document for the National Air Toxics Trends Stations Program, Revision 4. see: , 2022). Since several chemicals measured during the study are not NATTS Tier 1 pollutants and thus do not have NATTS MDL MQOs, the study MDLs were also compared to the chronic screening levels. As shown in Table 2-5 below, with a few exceptions, most of the project MDLs were lower than the NATTS MQOs (if applicable) and/or the chronic risk screening levels. As such, the study met the DQI for “Sensitivity” for most of the chemicals analyzed. The ERG detection limits are discussed further in Section 2.7

Table 2-5: Project MDLs compared to NATTS Tier 1 MDL MQOs and project screening levels.

Chemical	Project MDL (µg/m^3)	Project Chronic Screening Level (µg/m^3)	NATTS Tier 1 Chemical MDL MQO (µg/m^3)	MDL ≤ Screening Level	MDL ≤ NATTS MQO
1,1,2,2-Tetrachloroethane	0.1085	N/A	N/A	N/A	N/A
1,1,2-Trichloroethane	0.0502	0.0625	N/A	Yes	N/A
1,1-Dichloroethane	0.0287	0.625	N/A	Yes	N/A
1,1-Dichloroethylene	0.0346	20	N/A	Yes	N/A
1,2,4-Trichlorobenzene	0.2493	20	N/A	Yes	N/A
1,2-Dichloropropane	0.0392	0.4	N/A	Yes	N/A
1,3-Butadiene	0.0263	0.0333	0.1	Yes	Yes
1,4-Dichlorobenzene	0.0643	0.0909	N/A	Yes	N/A
Acetonitrile	0.0640	6	N/A	Yes	N/A
Acrolein - Verified	0.2338	0.035	0.09	No	No
Acrylonitrile	0.0237	0.0147	N/A	No	N/A
Benzene	0.0326	0.1282	N/A	Yes	N/A
Bromoform	0.1406	0.9091	N/A	Yes	N/A
Bromomethane	0.0392	0.5	N/A	Yes	N/A
Carbon disulfide	0.0592	70	N/A	Yes	N/A
Carbon tetrachloride	0.0698	0.1667	0.17	Yes	Yes
Chlorobenzene	0.0506	100	N/A	Yes	N/A

Chemical	Project MDL (µg/m^3)	Project Chronic Screening Level (µg/m^3)	NATTS Tier 1 Chemical MDL MQO (µg/m^3)	MDL ≤ Screening Level	MDL ≤ NATTS MQO
Chloroethane	0.0280	1000	N/A	Yes	N/A
Chloroform	0.0358	9.8	0.5	Yes	Yes
Chloromethane	0.0611	9	N/A	Yes	N/A
Chloroprene	0.0416	0.002	N/A	No	N/A
cis-1,3-Dichloropropene	0.0351	N/A	N/A	N/A	N/A
Dichloromethane	0.0580	60	N/A	Yes	N/A
Ethyl acrylate	0.0500	N/A	N/A	N/A	N/A
Ethylbenzene	0.0404	0.4	N/A	Yes	N/A
Ethylene dibromide	0.1037	0.0017	N/A	No	N/A
Ethylene dichloride	0.0293	0.0385	N/A	Yes	N/A
Ethylene oxide	0.0470	0.0002	0.054	No	Yes
Hexachlorobutadiene	0.0405	0.0455	N/A	Yes	N/A
m/p Xylene	0.0382	10	N/A	Yes	N/A
Methyl chloroform	0.0392	500	N/A	Yes	N/A
Methyl isobutyl ketone	0.0308	300	N/A	Yes	N/A
Methyl methacrylate	0.1421	70	N/A	Yes	N/A
Methyl tert-butyl ether	0.0332	3.84	N/A	Yes	N/A
o-Xylene	0.0556	10	N/A	Yes	N/A
Styrene	0.0699	100	N/A	Yes	N/A
Tetrachloroethylene	0.0841	3.8462	0.17	Yes	Yes
Toluene	0.0701	500	N/A	Yes	N/A
trans-1,3-Dichloropropene	0.0676	N/A	N/A	N/A	N/A
Trichloroethylene	0.0484	0.1472	0.2	Yes	Yes
Vinyl chloride	0.0220	0.1136	0.11	Yes	Yes

2.8.2.6 Chemical-Specific Sampling and Analysis Issues

Based on an evaluation of the DQO criteria in the QAPP discussed in detail above, the acrolein and EtO monitoring data collected during the study were excluded from the selection of COPCs and the risk analysis. This decision was made because the following factors indicated that the overall measurement uncertainty for these two chemicals was elevated for this risk assessment. The factors were:

1. Both chemicals have prior documented measurement uncertainty concerns when using the EPA TO-15 VOC canister sampling and analysis method (USEPA, School Air Toxics Monitoring Initiative website., 2009), (USEPA, Data Quality Evaluation Guidelines for Ambient Air Acrolein Measurements. December 17, 2010. Office of Air Quality Planning and Standards (OAQPS). , 2010), (USEPA, Secondary Calibration Source Use for Ethylene Oxide Analysis in the National Air Toxics, 2019), (USEPA,

Dose Response Assessment Tables, Office of Air Quality, Planning and Standards, Table 1 and Table 2, see:, 2021).

2. Both chemicals exhibited poor precision results and did not meet the project DQIs. See Section 2.4.2.3 above (acrolein CV = 203.7% based on 4 sample pairs, EtO CV = 84.8% based on 13 sample pairs).
3. For both chemicals, the project MDLs were significantly higher than the chronic health screening levels. The acrolein MDL was also significantly higher than the NATTS MQO and did not meet the sensitivity DQI. (See Section 2.4.2.6).
4. The concentrations of both chemicals measured in the Calvert City study area were similar to background concentrations measured at the Grayson Lake NATTS site, and at other NATTS sites.
5. No large emissions sources of either chemical were identified in the Calvert City project area.

Acetonitrile data from the Grayson Lake background site was also excluded due to sample contamination. The rationale for excluding data for each of these chemicals is discussed in detail below.

2.8.2.6.1 Acrolein

Acrolein is a widespread pollutant that is an eye and respiratory irritant. The AirToxScreen (ATS) analysis of the 2017 inventory of air toxics emissions data indicates that acrolein is prevalent in many cities throughout the country, including Calvert City, KY. Acrolein is a product of incomplete combustion and comes from fires, boats and planes, wood heating, industrial boilers and exhaust from cars and trucks. It is also found in cigarette smoke and smoke from cooking animal fats and can form in the air when other chemicals break down. Children and adults with asthma and allergies may be more sensitive to Acrolein.

EPA, state, and local air quality agencies are concerned about acrolein in the outdoor air and are working to reduce this pollutant across the country. However, results from EPA's 2009 School Air Toxics Study (USEPA, School Air Toxics Monitoring Initiative website., 2009) raised significant questions about the consistency and reliability of acrolein monitoring results in ambient air, especially the potential for a positive bias in the results when using the TO-15 canister method. In 2010, EPA worked with several state and local air quality agencies to conduct a study to determine whether monitoring results were affected by the process used to clean canisters in preparation for sample collection (USEPA, Data Quality Evaluation Guidelines for Ambient Air Acrolein Measurements. December 17, 2010. Office of Air Quality Planning and Standards (OAQPS). , 2010). The study showed that acrolein can be elevated even in canisters that are considered clean, resulting in ambient measurements that were biased high. Additionally, the study demonstrated that the accuracy of acrolein gas standards used to calibrate analytical systems was quite variable between different laboratories, resulting in significant biases that worsened the uncertainties arising from the canister cleaning issues (USEPA, 2010). This result is that, when

measuring acrolein concentrations in the ranges observed during the study with the TO-15 method, it is likely that the results indicate a positive bias above the true ambient concentrations. In light of this uncertainty, and based on the weight of evidence described above, EPA did not use the acrolein monitoring data collected during this study in evaluating the potential for health risks from exposure to air toxics in the Calvert City Special Study. Additional work is necessary to improve the accuracy of acrolein sample collection and analytical methods.

2.8.2.6.2 Ethylene Oxide

EtO is produced in large volumes at chemical manufacturing facilities. In the U.S., this gas is primarily used to make other chemicals that are used in making a range of products, including antifreeze, textiles, plastics, detergents, and adhesives. It is also used to sterilize devices that cannot be sterilized using steam or radiation, such as some medical and dental equipment. EtO is also used to control insects in some food products such as spices, certain dried herbs, dried vegetables, sesame seeds and walnuts. Our bodies also produce EtO when metabolizing ethylene, which is produced naturally in the body. The percentage of ethylene converted to EtO in the body is unknown but expected to be low.

EtO is a human carcinogen. Scientific evidence in humans indicates that long-term exposure to EtO increases the risk of cancers of the white blood cells, including non-Hodgkin lymphoma, myeloma, and lymphocytic leukemia. Studies also show that long-term exposure to EtO increases the risk of breast cancer in females.

Similar to the acrolein measurement uncertainty issue discussed above, there is also significant uncertainty associated with measuring EtO concentrations in canister samples. Evaluation of current measurement method TO-15, using canisters as the sampling media and Gas Chromatography/Mass Spectrometry (GC/MS) as the analytical instrument for EtO, has revealed positive sampling bias introduced by certain canisters to various degrees (USEPA, Dose Response Assessment Tables, Office of Air Quality, Planning and Standards, Table 1 and Table 2, see:, 2021). Additionally, the stability of EtO gas standards used to calibrate analytical systems exhibited varying degrees of degredation, resulting in possible biases that worsened the uncertainties in analytical measurement (USEPA, Secondary Calibration Source Use for Ethylene Oxide Analysis in the National Air Toxics, 2019). Based on the weight of evidence, EPA decided not to include EtO sampling data in the risk analysis due to the uncertainties with the monitoring method when measuring concentrations in the ranges observed during the study. Additionally, concentration levels detected in this study were generally similar to the Grayson Lake and other NATTS background monitors measured in the same monitoring years. This indicates that the Calvert City monitoring sites were not significantly impacted by local EtO source emissions.

2.8.2.6.3 Acetonitrile

Starting in 2013, a likely sample contamination issue was discovered in the acetonitrile data collected at the Grayson Lake NATTS site. KDAQ identified poor precision data for collocated samples collected using a dual channel sampler that also collects carbonyls. KY flagged the Grayson Lake acetonitrile data in AQS since 2013. The data was excluded from the risk analysis because it is not considered relevant to this study nor representative of actual ambient concentrations.

2.9 Data Screening and Preliminary Analysis

The purpose of selecting a subset of all detected chemicals is to narrow the focus of the risk assessment to just those chemicals detected during the monitoring study that are thought to have a significant contribution to inhalation risk at a given monitoring location. The basic steps used in the screening analysis and selection process to identify chemicals of interest were as follows:

1. Chemicals that were not detected at or above the detection limit in any of the samples at a monitoring site were carried through the risk assessment using the reported concentration of monitoring data at that site.

2. Chemicals that were detected at or above the detection limit at least once but that did not have available dose-response values were retained for further analysis (See Section 4). At the end of this analysis, if a dose-response value was not available and could not be derived from ancillary sources, the chemical was excluded from the risk assessment.

3. Chemicals that were detected at least once at a monitoring site and for which dose-response values were available were retained and used in the acute hazard characterization analysis (see Section 4.2). The rationale for retaining these chemicals for acute hazard characterization only is that a chemical that is detected just once, or a few times, has the potential to result in an acute health hazard if present at relatively high concentrations.

4. Chemicals that were detected in 10% or more of the samples at each monitor were selected as COPCs. These COPCs were used in the chronic risk and hazard assessments. It is important to note that the selection of COPCs also eliminated from further consideration chemicals of low detection frequencies but with relatively high concentrations. Pollutants with this pattern of detection are not expected to result in significant exposure concentrations or chronic health impacts.

2.10 Selection of Chemicals of Potential Concern

Although this study initially focused on EDC, benzene, 1,3-butadiene, vinyl chloride, and acrylonitrile based on the screening of historical monitoring data, it was also important to determine if other HAPs were monitored at concentrations that might have the potential to contribute to health risks, therefore, other HAPs were also considered. Once the monitoring was complete, the basic steps used in the selection process to identify COPCs were as follows:

1. Chemicals with no toxicity data available were removed from calculations but were retained in the uncertainty section and were analyzed using surrogate toxicity values where available.
2. Chemicals with surrogate toxicity estimates were carried through the risk assessment process for comparability with other risk documents and as a generally conservative step.
3. Analytical replicates were averaged in the risk assessment.
4. Chemicals identified at concentrations below the respective detection limits were carried through the COPC selection process using the reported concentration.
5. Chemicals that were not detected in greater than 10% of the samples per monitor were not included in the COPCs.
6. Subsequent to selection of COPCs, the risk assessment then used reported values below the detection limit "as is" and, for true non-detects, a value of ½ the SQL was used as a conservative surrogate of concentration per EPA guidance (USEPA, Air Toxics Risk Assessment Reference Library, Office of Air Quality Planning and Standards, EPA-453-K-04-001A, see: , 2004).[4]
7. Acrolein was removed from further considerations based on sampling method uncertainties (See discussion in Section 2.8.2.6).
8. EtO was removed from further considerations based on sampling method uncertainties (See discussion in Section 2.8.2.6).

Descriptive statistics were calculated such that for each chemical reported at the monitor, the following information was determined:

- the frequency at which the chemical was detected at the monitor;
- the average and median concentrations as well as the standard deviation per chemical; and
- the maximum and minimum detected concentrations.

Table 2.6-1, Table 2.6-2, Table 2.6-3, and Table 2.6-4 provides the results of the COPC selection process for the three Calvert City monitors and Grayson Lake

[4] The ATRA Reference Library (see: https://www.epa.gov/fera/risk-assessment-and-modeling-air-toxics-risk-assessment-reference-library) recommends the use of ½ the quantitation limit as the metric for evaluating non-detects.

(background) monitor. For chemicals detected at a detection frequency of 10% or greater, a statistical summary was created including the range of the detected concentrations, frequency of detections, average concentrations, standard deviations, detection limit (DL) ranges, and the median concentrations. Table 2.10-1,Table 2.10-2,Table 2.10-3, and Table 2.10-4 details the 95UCL along with the data's distribution as provided by EPA's ProUCL software for each COPC. The 95UCL was carried through the risk assessment process. Table 2.10-5, Table 2.10-6, Table 2.10-7, and Table 2.10-8 summarizes the list of chemicals that had low detection frequencies but that will be further examined in the uncertainty section.

2.11 Summary of Chemicals of Potential Concern

All of the COPCs were found at levels above their respective detection limits. The distribution of the data for each chemical was best characterized as lognormal according to EPA's ProUCL. Figure 2-2 shows boxplots of the EDC concentrations at each site. EDC concentrations in this figure are plotted on a logarithmic scale, so each grid line on the vertical y-axis represents a concentration ten times higher than the previous lower gridline. Logarithmic scales are useful in visualizing data with a lognormal distribution, such as the EDC monitoring data. EDC concentrations were highest at the LWD site, and the Johnson Riley Rd. and Calvert City Elementary sites also measured EDC concentrations that were significantly higher than the Grayson Lake background site.

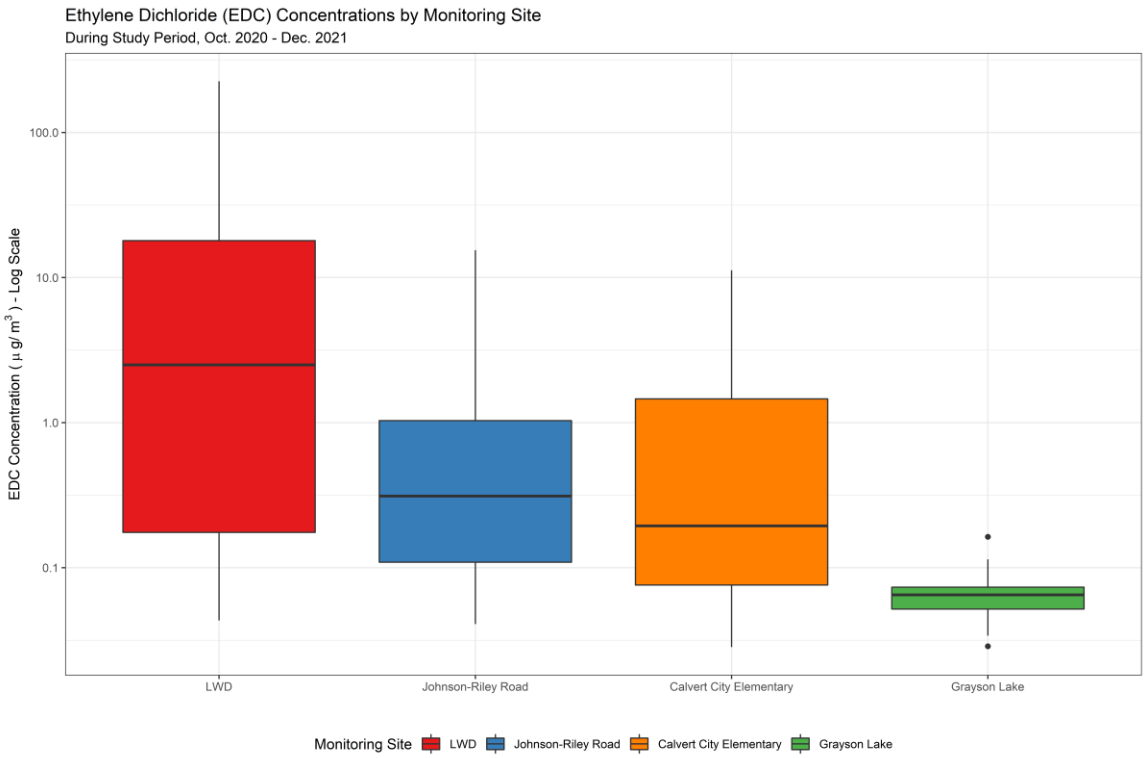

Figure 2-2: Boxplots of ethylene dichloride concentrations by monitoring site, Oct. 2020 – Dec. 2021

2.12 Chemical Screening Results

The results of the screening process are summarized in Table 2.10-1, Table 2.10-2, Table 2.10-3, Table 2.10-4 for all four monitors. These tables show chemicals that were detected at or above respective detection limits at least once, associated frequencies of detection and other descriptive statistics. Chemicals showing frequencies of detection of 10% or above were COPCs as indicated by an “X” in the last column of the tables. Thirty-five chemicals out of a total of 41 were detected at least once in samples collected from the Calvert City School site. Similarly, 35 chemicals for Johnson-Riley Road, 38 chemicals for the LWD, and 33 chemicals for Grayson Lake site were detected. The number of COPCs identified at these sites was 10, 10, 15, and 8 at the Calvert City Elementary School, Johnson-Riley Road, LWD, and Grayson Lake sites, respectively.

A side-by-side comparison of monitoring sites in terms of maximum concentrations and frequency distributions shows some similarities but also some differences among the sites. For example, all sites were identical with respect to COPCs, except for the chemicals acrylonitrile, chloroform, bromomethane,1,1-Dichloroethane, 1,1,2-trichloroethane, trichloroethylene, and chloroprene, which were COPCs at the LWD site, but not at Calvert City

Elementary, Johnson-Riley Road, or Grayson Lake sites. The detection frequencies were also similar across the sample locations.

3 EXPOSURE ASSESSMENT

Exposure assessment is the process that characterizes the route, duration, intensity, and frequency of contact with a chemical by a potential receptor. In this assessment, the receptors of interest were individuals that may reside within the Calvert City, KY monitoring area, and the principal exposure route of interest was inhalation. Two exposure durations were evaluated: including chronic (lifetime) and acute (up to 1 day). For chronic analysis, exposures to continuously low levels of pollutants over a lifetime were evaluated. For acute exposures, the highest monitored HAP concentration detected was compared to the most stringent of the short-term health risk-related comparison levels. If a monitored VOC HAP concentration exceeded the noncancer-based comparison level for that VOC HAP, an acute HQ was calculated using the maximum monitored HAP concentration and acute exposure comparison level for the VOC HAP. The acute HQ is the ratio of the potential exposure to the HAP (represented, in this case, by the maximum monitored metal HAP concentration) to the level at or below which no adverse effects are expected (represented by the sub-chronic or acute exposure comparison level).

VOCs are associated with a variety of health effects that are reviewed in detail in EPA OAQPS' Health Effects Notebooks, EPA's Integrated Risk Information System (IRIS) Toxicology Reviews, the Agency for Toxic Substances and Disease Registry (ATSDR) Toxicological Profiles, and the World Health Organization's International Programme for Chemical Safety (WHO/IPCS) Environmental Health Criteria documents.

3.1 Chronic Exposures

In this assessment, chronic exposure was evaluated based on the 95UCL based on the arithmetic mean concentration for each VOC COPC as measured at the monitor in individual samples. The 95UCL was selected to reflect a more conservative estimate of chronic exposure whereby there is 95% certainty that the true mean is not above the 95UCL concentration ((USEPA, On the Computation of a 95% Upper Confidence Limit of the Unknown Population Mean Based Upon Data Sets with Below Detection Limit Observations, EPA/600/R-06/022 Office of Research and Development, Las Vegas, NV 89119., 2006) (Gilbert, 1987)). Therefore, the 95UCL is typically used as a conservative estimate of the true mean concentration, and, therefore, is considered an appropriate value to use for risk assessments such as this one, where the purpose is to determine if further investigation is warranted.

The following conservative assumptions were used in the assessment of chronic exposure at both the median and 95UCL exposure concentrations:

- A person lives, works, or otherwise is exposed to the ambient air measured at the monitoring location for 24 hours per day, 7 days per week, for a 70-year lifetime.

- The air that the person breathes, both while indoors and outdoors, contains the same concentrations of pollutants measured in the Calvert City study.

- Air quality, as reflected by the monitoring results, was assumed to remain relatively constant over the entire 70-year lifetime of a person living in the area.

- A concentration equal to one half of the SQL was assigned to non-detects for COPCs. Using one half of the SQL, when no chemical was detected due to equipment limitations (or the chemical was detected below the detection limit), assumes that a chemical may be present in the environment, although at undetectable quantities. It should be noted that the EPA recommends the SQLs, as opposed to the minimum detection limits, be used when they are available from the laboratory. EPA also suggests that MDLs may be used if SQLs cannot be obtained (see Air Toxics Risk Assessment Reference Library. Vol. 1. Appendix H). In this risk assessment, SQLs were calculated for each sample by multiplying the reported MDL by 3.18, as specified by the EPA NATTS TAD, Revision 4 (USEPA, 2022).

To estimate the concentration of chemicals a person is exposed to over a 70-year span of time, the monitoring data can be evaluated in several ways such as the arithmetic mean, the median, the highest value measured in the dataset, etc.

In air toxics risk assessments, it is common to use the 95UCL based on the arithmetic mean of a limited dataset (in this study, one year's worth of data) as a conservative surrogate estimate of lifetime exposure (in this case, the 70-year average concentration at the Calvert City monitoring sites). This health protective approach provides a level of confidence that the true lifetime exposure is unlikely to be higher than the average concentration you would get if you had 70 years of monitoring data.

The 95UCL on the mean for each COPC was calculated based on the distribution of the chemical's sampling data using ProUCL version 5.1.002 (USEPA, Calculating Upper Confidence Limits for Exposure Point Concentrations at Hazardous Waste Sites, Office of Solid Waste and Emergency Response 9285: 6-10., 2002) (APPENDIX C: ProUCL Statistical Results contains a detailed output of ProUCL's statistical analyses.

Table 3.1-1, Table 3.1-2, Table 3.1-3, and Table 3.1-4 provides the 95UCL calculations per chemical for the Calvert City sampling results. It is notable that the chemical with the highest 95UCL concentration was EDC (2.009 µg/m^3) at the Calvert City Elementary School monitor, vinyl chloride (3.561 µg/m^3) at the Johnson-Riley Road monitor, EDC (45.24 µg/m^3) at the LWD monitor, and carbon tetrachloride (43.92 µg/m^3) at the Grayson Lake monitor.

As an alternate to the 95UCL of the arithmetic mean, the maximum detected concentrations of each COPC are also provided for comparison with the 95UCL concentration. None of the 95UCLs were above their respective maximum concentrations except for hexachlorobutadiene at the Grayson Lake monitor where the maximum concentration (0.0480 µg/m^3) was used as a surrogate for the 95% UCL (0.335 µg/m^3) (USEPA, Air Toxics Risk Assessment Reference Library, Office of Air Quality Planning and Standards, EPA-453-K-04-001A, see: , 2004).

3.2 Short-Term Exposures

Health effects due to short-term exposure to air pollutants are also possible if concentrations are sufficiently high. Health effects that persons may experience due to 8-hour acute versus 1-14 day short–term exposures to high levels of airborne contaminants can vary significantly from those experienced after long-term exposure to low doses, depending on the contaminant and its concentration. For example, a substance that produces an increase in cancer rates after exposure to low concentrations for a long period of time might also cause immediate and severe eye irritation if present at sufficiently high levels for a short period of time (USEPA, National Advisory Committee for Acute Exposure Guideline Levels for Hazardous Substances, Notice, Federal Register, October 30, pp. 58839–58851, 1997).

Methods to assess short-term health effects, however, are not well established. As a conservative approach for this study, the highest individual concentration for each pollutant measured (as determined by composite 1-in-6-day monitoring samples) was compared to acute benchmark concentrations. Reliance on maximum measured concentrations to evaluate the potential for adverse effects from short-term exposures, as opposed to upper confidence limits of means, treats each sample independently, thus avoiding the potential to “average out” spikes in concentration.

In a secondary screening approach, where the ATSDR acute MRL is the sub-chronic acute screening concentration, if the maximum concentration is greater than the associated MRL, the maximum concentration is replaced by a 14-day surrogate (i.e., four-24-hour samples will be averaged and compared to the acute MRL). This effort is intended to align the exposure concentration more closely with the 14-day acute MRL definition.

All short-term exposure benchmarks were acquired from EPA’s OAQPS via internet download (see Table 2, (USEPA, Dose Response Assessment Tables, Office of Air Quality, Planning and Standards, Table 1 and Table 2, see:, 2021)). There are numerous short-term data sources for the information provided by OAQPS as discussed in Section 4.

4 HAZARD IDENTIFICATION AND DOSE-RESPONSE ASSESSMENT

Hazard identification is the process of determining whether exposure to a stressor can cause an increase in the incidence of specific adverse health effects (e.g., cancer, birth defects). It is also whether the adverse health effect is likely to occur in humans. In the case of chemical stressors, the process examines the available scientific data for a given chemical (or group of chemicals) and develops a weight of evidence to characterize the link between the negative effects and the chemical agent. Exposure to a stressor may generate many different adverse effects in a human: diseases, formation of tumors, reproductive defects, death, or other effects.

4.1 Chronic Dose-Response Information Sources

Dose-response assessments (carcinogenic and non-carcinogenic) for chronic exposure (either by inhalation or ingestion) for the HAP reported in the emissions inventory for this source category are based on the EPA Office of Air Quality Planning and Standards' (OAQPS) existing recommendations for HAPs (USEPA, Dose Response Assessment Tables, Office of Air Quality, Planning and Standards, Table 1 and Table 2, see:, 2021). This information has been obtained from various sources and prioritized according to (1) conceptual consistency with EPA risk assessment guidelines and (2) level of peer review received. The prioritization process was aimed at incorporating the best available science with respect to dose-response information. The recommendations are based on the following sources, in order of priority:

1) **U.S. Environmental Protection Agency (EPA).** EPA has developed dose-response assessments for chronic exposure for many HAPs. These assessments typically provide a qualitative statement regarding the strength of scientific data and specify a reference concentration (RfC, for inhalation) to protect against effects other than cancer and/or an IUR (for inhalation) to estimate the probability of developing cancer. The RfC is defined as an "estimate (with uncertainty spanning perhaps an order of magnitude) of a continuous inhalation exposure to the human population (including sensitive subgroups) that is likely to be without an appreciable risk of deleterious effects during a lifetime." The IUR is defined as "the upper-bound excess cancer risk estimated to result from continuous lifetime exposure to an agent at a concentration of 1 µg/m^3 in air." The Slope Factor (SF) is "an upper bound, approximating a 95 percent confidence limit, on the increased cancer risk from a lifetime exposure to an agent. This estimate, [is] usually expressed in units of proportion (of a population) affected per mg/kg-day…"

EPA disseminates dose-response assessment information in several forms, based on the level of review. The Integrated Risk Information System (IRIS) is an EPA database that contains scientific health assessment information, including dose-response information. All IRIS assessments since 1996 have also undergone independent external peer review. The current IRIS process includes review by EPA scientists, interagency reviewers from other federal agencies, and the public, as well as peer review by independent scientists external to EPA. New IRIS values are developed, and old IRIS values are updated as new health effects data become available. Refer to the IRIS Agenda for detailed information on status and scheduling of current individual IRIS assessments and updates. EPA's science policy approach, under the current carcinogen guidelines, is to use linear low-dose extrapolation as a default option for carcinogens for which the mode of action (MOA) has not been identified. Future EPA dose-response assessments that identify nonlinear MOAs where appropriate will be used (once peer reviewed) in air toxics risk assessments. At this time, however, there are no available carcinogenic dose-response assessments for inhalation exposure that are based on a nonlinear MOA.

2) **U.S. Agency for Toxic Substances and Disease Registry (ATSDR).** ATSDR, which is part of the US Department of Health and Human Services, develops and publishes Minimal Risk Levels (MRLs) for inhalation and oral exposure to many toxic substances. As stated on the ATSDR web site: "Following discussions with scientists within the Department of Health and Human Services (HHS) and the EPA, ATSDR chose to adopt a practice similar to that of the EPA's Reference Dose (RfD) and Reference Concentration (RfC) for deriving substance specific health guidance levels for non-neoplastic endpoints." The MRL is defined as "an estimate of daily human exposure to a substance that is likely to be without an appreciable risk of adverse effects (other than cancer) over a specified duration of exposure." ATSDR describes MRLs as substance-specific estimates to be used by health assessors to select environmental contaminants for further evaluation.

3) **California Environmental Protection Agency (CalEPA).** The CalEPA Office of Environmental Health Hazard Assessment has developed dose-response assessments for many substances, based both on carcinogenicity and health effects other than cancer. The process for developing these assessments is similar to that used by EPA to develop IRIS values and incorporates extensive external scientific peer review. As stated in the CalEPA Technical Support Document for developing their chronic assessments, the guidelines for developing chronic inhalation exposure levels incorporate many recommendations of the EPA (USEPA, Methods for Derivation of Inhalation Reference Concentrations and Application of Inhalation Dosimetry. Office of Research and Development, Washington, DC. EPA/600/8-90/066F,, 1994) and the NAS (NAS, 1994).

The noncancer information includes available inhalation health risk guidance values expressed as chronic inhalation reference exposure levels (RELs). CalEPA defines the REL as "the concentration level at or below which no health effects are anticipated in the general human population." CalEPA's quantitative dose-response information on carcinogenicity by inhalation exposure is expressed in terms of the URE, defined similarly to EPA's URE.

4) **International Agency for Research on Cancer** (**IARC**). The IARC, a branch of the World Health Organization, coordinates and conducts research on the causes of human cancer and develops scientific strategies for cancer control. The IARC sponsors both epidemiological and laboratory research, and disseminates scientific information through meetings, publications, courses, and fellowships. As part of its mission, the IARC assembles evidence that substances cause cancer in humans and issues judgments on the strength of evidence. IARC's categories are Group 1 (carcinogenic in humans), Group 2A (probably carcinogenic), Group 2B (possibly carcinogenic), Group 3 (not classifiable), and Group 4 (probably not carcinogenic). The categorization scheme may be applied to either single chemicals or mixtures; however, IARC does not develop quantitative dose-response metrics such as UREs. IARC's categories for substances support or augment EPA's weight-of evidence (WOE) determinations, which do not cover all substances and in some cases may be out-of-date. The list of IARC evaluations to date is available on-line at http://www.IARC.fr.

4.1.1 Cancer Toxicity Values

A cancer toxicity value represents an estimate of the increased cancer risk from inhalation exposure (typically to a concentration of 1µg/m^3 for a lifetime). This value can be matched with environmental exposure data to estimate health risks. For carcinogens, inhalation toxicity measurements are generally expressed as a risk per unit concentration (e.g., the units of an IUR are risk per µg/m^3) or, for oral exposures, as a risk per daily intake (e.g., the units of the SF are risk per mg/kg–day).

Inhalation Unit Risk (IUR): The upper-bound excess lifetime cancer risk estimated to result from continuous exposure to an agent via inhalation per µg/m^3 over a lifetime. The interpretation of the IUR would be as follows: if IUR = $2x10^{-6}$ per µg/m^3, not more than 2 excess tumors are expected to develop per 1,000,000 people if exposed continuously for a lifetime to 1 ug of the chemical per cubic meter of inhaled air. The number of expected tumors is likely to be less, it may also be none.

In hazard identification of carcinogens under the 1986 EPA guidelines (USEPA, Guidelines for Carcinogen Risk Assessment. Federal Register 51(185):33992, see: National Service Center for Environmental Publications., 1986), human data, animal data, and supporting evidence are combined to characterize the weight–of–evidence (WOE) regarding the chemical's potential as a human carcinogen into one of several categories:

Group A – Carcinogenic to Humans: Agents with adequate human data to demonstrate the causal association of the agent with human cancer (typically epidemiological data).

Group B – Probably Carcinogenic to Humans: Agents with sufficient evidence (i.e., indicative of a causal relationship) from animal bioassay data, but either limited (i.e., indicative of a possible causal relationship, but not exclusive of alternative explanations) human evidence (Group B1), or with little or no human data (Group B2).

Group C – Possibly Carcinogenic to Humans: Agents with limited animal evidence and little or no human data.

Group D – Not Classifiable as to Human Carcinogenicity: Agents without adequate data either to suggest or refute the suggestion of human carcinogenicity.

Group E – Evidence of Non–carcinogenicity for Humans: Agents that show no evidence for carcinogenicity in at least two adequate animal tests in different species or in both adequate epidemiologic and animal studies.

Weight-of-evidence determinations for carcinogenicity developed by the International Agency for Research on Cancer (IARC) were used for carcinogens not characterized by EPA. Carcinogens are categorized by IARC as Group 1 (agents carcinogenic to humans), Group 2A (probable human carcinogen), and Group 2B (possible human carcinogen).

During the time between 1996 and 2005, EPA applied the principles and procedures of the draft revised guidelines on a case-by-case basis for new hazard identifications and dose-response assessments using interim draft guidelines that represented the evolution of risk assessment methods rather than a dramatic shift in methodology. Since 2005, EPA has applied the new

2005 guidelines which reflect EPA's accumulated experience and advances in our knowledge on cancer assessment. On the other hand, assessments for many substances that were prepared under the 1986 guidelines continue to be valid. Therefore, the dose-response assessments of carcinogens reflect a mixture of the application of 1986 guidelines and the more recent guidelines. The current guidelines, finalized in 2005, recommend expressing WOE by narrative statements rather than only hierarchical categories, and expressing them separately for the oral and inhalation routes. The general categories recognized by the 2005 guidelines are [2]:

- Carcinogenic to Humans (CH)
- Likely to be Carcinogenic to Humans (LH)
- Suggestive Evidence of Carcinogenic Potential (SE)
- Inadequate Information to Assess Carcinogenic Potential (InI)
- Not Likely to be Carcinogenic to Humans (NH)

Also note that only those substances that are known or suspected human carcinogens were considered in calculating incremental cancer risks (EPA WOE groups A, B, or C, or IARC WOE classifications of 1, 2A or 2B).

Table 4.1.1-1 contains the chronic inhalation carcinogenic toxicity values for all carcinogenic COPCs associated with the Calvert City study. The table also lists the EPA and IARC WOE for each chemical as well as the source of the information provided.

4.1.2 Chronic Non-cancer Values

For non–cancer effects, inhalation toxicity values are generally expressed as a concentration in air (e.g., a RfC in units of µg/m^3 air). The RfC considers toxic effects for both the respiratory system (portal of entry) and for effects peripheral to the respiratory system (extra respiratory effects). The inhalation RfC is analogous to the oral Reference Dose (RfD) and is similarly intended for use in risk assessments for health effects known or assumed to be produced through a nonlinear (presumed threshold) mode of action.

RfCs are generally derived according to *Methods for Derivation of Inhalation Reference Concentrations and Application of Inhalation Dosimetry* (USEPA, Methods for Derivation of Inhalation Reference Concentrations and Application of Inhalation Dosimetry. Office of Research and Development, Washington, DC. EPA/600/8-90/066F,, 1994). Because RfCs can also be derived for the non-carcinogenic health effects of substances that are also carcinogenic, it is essential to consider the full range of potential outcomes resulting from exposure (i.e., cancer and non-cancer effects).

Table 4.1.2-1 contains the chronic non-carcinogenic toxicity values for all the COPCs associated with the Calvert City study including toxicity value sources previously mentioned in section 4.1.

4.2 Hazard Assessment for Acute Effects

Short-term toxicity values cover a wide spectrum of potential health effects, ranging from mild irritation to life threatening conditions. Several acute toxicity values may be available for the same substance to address different short–term effects on health while sub-chronic effects are adopted from ATSDR acute (1- to 14-day exposures) toxicity concentrations. Available short-term toxicity values are provided for use in Air Toxics Risk Assessments by OAQPS; the underlying sources are described below:

California Acute Reference Exposure Levels (RELs). The California Environmental Protection Agency (CalEPA) has developed acute dose-response reference values for many substances, expressing the results as acute inhalation RELs.

> The acute REL is defined by CalEPA as "the concentration level at or below which no adverse health effects are anticipated for a specified exposure duration (CalEPA, 2002). RELs are based on the most sensitive, relevant, adverse health effect reported in the medical and toxicological literature. RELs are designed to protect the most sensitive individuals in the population by the inclusion of margins of safety. Since margins of safety are incorporated to address data gaps and uncertainties, exceeding the REL does not automatically indicate an adverse health impact." Acute RELs are developed for 1-hour (and 8-hour) exposures. The values incorporate uncertainty factors similar to those used in deriving EPA's inhalation RfCs for chronic exposures.

Acute Exposure Guideline Levels (AEGLs). AEGLs are developed by the National Advisory Committee (NAC) on Acute Exposure Guideline Levels (NAC/AEGL) for Hazardous Substances and then reviewed and published by the National Research Council. As described in the Committee's Standing Operating Procedures, AEGLs "represent threshold exposure limits for the general public and are applicable to emergency exposures ranging from 10-min to 8-h." Their intended application is "for conducting risk assessments to aid in the development of emergency preparedness and prevention plans, as well as real time emergency response actions, for accidental chemical releases at fixed facilities and from transport carriers." The document states that "the primary purpose of the AEGL program and the NAC/AEGL Committee is to develop guideline levels for once-in-a-lifetime, short-term exposures to airborne concentrations of acutely toxic, high-priority chemicals." In detailing the intended application of AEGL values, the document states, "It is anticipated that the AEGL values will be used for regulatory and nonregulatory purposes by U.S. Federal and State agencies, and possibly the international community in conjunction with

chemical emergency response, planning, and prevention programs. More specifically, the AEGL values will be used for conducting various risk assessments to aid in the development of emergency preparedness and prevention plans, as well as real-time emergency response actions, for accidental chemical releases at fixed facilities and from transport carriers."

The NAC/AEGL defines AEGL-1 and AEGL-2 as:

> "AEGL-1 is the airborne concentration (expressed as ppm or mg/m^3) of a substance above which it is predicted that the general population, including susceptible individuals, could experience notable discomfort, irritation, or certain asymptomatic non-sensory effects. However, the effects are not disabling and are transient and reversible upon cessation of exposure."
>
> "AEGL-2 is the airborne concentration (expressed as ppm or mg/m^3) of a substance above which it is predicted that the general population, including susceptible individuals, could experience irreversible or other serious, long-lasting adverse health effects or an impaired ability to escape."
>
> "Airborne concentrations above AEGL-1 represent exposure levels that can produce mild and progressively increasing but transient and nondisabling odor, taste, and sensory irritation or certain asymptomatic, non-sensory effects. With increasing airborne concentrations above each AEGL, there is a progressive increase in the likelihood of occurrence and the severity of effects described for each corresponding AEGL. Although the AEGL values represent threshold levels for the general public, including susceptible subpopulations, such as infants, children, the elderly, persons with asthma, and those with other illnesses, it is recognized that individuals, subject to unique or idiosyncratic responses, could experience the effects described at concentrations below the corresponding AEGL."

Emergency Response Planning Guidelines (ERPGs). The American Industrial Hygiene Association (AIHA) has developed ERPGs for acute exposures at three different levels of severity. These guidelines represent concentrations for exposure of the general population (but not particularly sensitive persons) for up to 1-hour associated with effects expected to be mild or transient (ERPG-1), irreversible or serious (ERPG-2), and potentially life-threatening (ERPG-3) (AIHA, 2001).

ERPG values are described in their supporting documentation as follows: "ERPGs are air concentration guidelines for single exposures to agents and are intended for use as tools to assess the adequacy of accident prevention and emergency response plans, including transportation emergency planning, community emergency response plans, and incident prevention and mitigation."

ERPG-1 and ERPG-2 values are defined by AIHA's Standard Operating Procedures as follows:

> "ERPG-1 is the maximum airborne concentration below which nearly all individuals could be exposed for up to 1 hour without experiencing more than mild, transient health effects or without perceiving a clearly defined objectionable odor."

> "ERPG-2 is the maximum airborne concentration below which nearly all individuals could be exposed for up to 1 hour without experiencing or developing irreversible or other serious adverse health effects or symptoms that could impair an individual's ability to take protective action."

The U.S. Agency for Toxic Substances and Disease Registry (ATSDR). ATSDR develops chronic, intermediate, and acute minimal risk levels (MRLs) for some contaminants. An acute MRL is a sub-chronic benchmark that is considered protective of exposures lasting from 24-hours to 14-days (ATSDR, Minimum Risk Levels, Agency for Toxic Substances and Disease Registry, Atlanta, GA., 2002).

National Institute for Occupational Safety and Health (NIOSH)
As part of its mission to study and protect worker health, NIOSH determines concentrations of substances that are immediately dangerous to life or health (IDLHs). IDLHs were originally determined for 387 substances in the mid-1970's as part of the Standards Completion Program (SCP), a joint project by NIOSH and the Occupational Safety and Health Administration (OSHA), for use in assigning respiratory protection equipment. NIOSH is currently evaluating the scientific adequacy of the criteria and procedures used during the SCP for establishing IDLHs. In the interim, the IDLHs have been reviewed and revised. NIOSH maintains an on-line database of IDLHs, including the basis and references for both the current and original IDLH values (as paraphrased from the SCP draft technical standards). The OAQPS Table 2 provides IDLH values divided by 10 to be comparable to the mild effect levels for 1-hour exposure as determined by NIIOSH. These values are used to develop levels of concern under Title III of the Superfund Amendments and Reauthorization Act, and their use in the accidental release prevention requirements under section 112(r) of the Clean Air Act.

TEELs: U.S. Department of Energy (DOE) DOE has defined Temporary Emergency Exposure Limits (TEELs), which are temporary levels of concern (LOCs) derived according to a tiered, formula-like methodology (described and available online at Temporary Emergency Exposure Limits for Chemicals: Methods and Practice). DOE has developed TEELs with the intention of providing a reference when no other LOC is available. DOE describes TEELs as "approximations of potential values" and "subject to change." The EPA's emergency planning program (section 112(r)) does not generally rely on TEELs. They are provided in Table 2 purely to inform situations in which no other acute

values are available. For example, a finding of an acute exposure near a TEEL value may indicate the need for a more in-depth investigation into the health effects literature. TEELs are not recommended as the basis of regulatory decision-making. Like ERPGs, TEELs are multiple-tiered one-hour exposures, representing concentrations associated with no effects (TEEL-0), mild, transient effects (TEEL-1), irreversible or serious effects (TEEL-2), and potentially life-threatening effects (TEEL-3).

4.2.1 Short-term Hazard Toxicity Values

Hazard identification and dose-response assessment information for short-term inhalation exposure assessments is based on the existing recommendations of OAQPS for HAPs ((USEPA, Dose Response Assessment Tables, Office of Air Quality, Planning and Standards, Table 1 and Table 2, see:, 2021). When the benchmarks are available, the results from acute screening assessments are compared to both “no effects” reference levels for the general public, such as the California Reference Exposure Levels (RELs), and to emergency response levels, such as Acute Exposure Guideline Levels (AEGLs) and Emergency Response Planning Guidelines (ERPGs), with the recognition that the ultimate interpretation of any potential risks associated with an estimated exceedance of a particular reference level depends on the definition of that level and any limitations expressed therein. If comparison concentrations are not provided by the sources discussed above, immediately dangerous to life or health (NIOSH) values are provided as surrogate comparison concentrations. Comparisons among different available inhalation health effect reference values (both acute and chronic) for selected HAPs can be found in an EPA document of graphical arrays (USEPA, Graphical Arrays of Chemical-Specific Health Effect Reference Values for Inhalation Exposures [Final Report], EPA/600/R-09/061, , 2009).

The potential for short-term effects from exposure to airborne COPCs were evaluated. The method used for estimating the risks from routine short-term exposures to the concentrations of most toxic substances found in ambient air samples is done by comparing the maximum concentration detected per HAP to the screening concentrations per the hierarchy provided above.

Table 4 compares the maximum concentrations detected for each COPC to its corresponding benchmark screening concentration(s) which were compiled by OAQPS (see Table 2: (USEPA, Dose Response Assessment Tables, Office of Air Quality, Planning and Standards, Table 1 and Table 2, see:, 2021)). COPCs without toxicity values were not listed in the table. Since all samples were taken over a 24-hour period, MRLs (protective of 24-hr to 14-day exposures) were compared to maximum concentration as a sub-chronic comparison. There were no detected concentrations that exceeded its corresponding acute or sub-chronic benchmark levels.

5 RISK CHARACTERIZATION

The risk characterization integrates the information from the exposure assessment and toxicity assessment steps in the risk assessment to provide an estimate of the magnitude of potential risks and hazards, while defining the strength of the conclusions based on the uncertainty in the information used to generate these estimates. For this risk assessment the risk characterization combined the exposure concentrations with the chronic and short-term toxicity data to provide a quantitative estimate of the potential health impacts. The chronic or lifetime evaluation addresses both cancer and non-cancer health effects. The remainder of this section is divided into three subsections: one for details of the risk characterization for chronic exposure; another for the evaluation of short-term exposures; and a risk summary section. A detailed assessment of the uncertainty in the risk characterization is provided in the Uncertainty Section (Section 6).

5.1 Risk Characterization for Chronic Exposures

The risk characterization for chronic exposures was conducted by combining the relevant toxicity criteria with the exposure concentrations (EC) estimated from the monitoring data for the Calvert City study. The 95UCL exposure case was selected to represent a conservative estimate of exposure and is based on the 95UCL concentrations of the COPCs in air.

In this assessment, risk estimates for COPCs with a cancer endpoint were expressed in terms of the probability of contracting cancer from a lifetime of continuous exposure (70-year lifespan) to a constant air concentration of each COPC. Cancer risk for each COPC at the monitoring location was derived as follows:

$$Risk_x = EC_x \times IUR_x$$

Equation 5-1

Where:

- $Risk_x$ = the risk of the Xth COPC at a monitor;
- EC_x = the exposure point concentration of the COPC (i.e., 95UCL air concentration); and
- IUR_x = the inhalation unit risk of the COPC.

When multiple carcinogens were present simultaneously, the individual risks were summed to create a total cancer risk, as follows:

$$Risk_{total} = \sum (Risk1 + Risk2 + \ldots Riskx)$$

Equation 5-2

Estimates of cancer risk were expressed as a probability, represented in scientific notation as a negative exponent of 10. For example, an additional lifetime risk of developing cancer of 1 chance in 1,000,000 (or one additional cancer per 1,000,000 persons exposed over a lifetime) is written as $1x10^{-6}$ or 1E–06.

5.1.1 Risk Evaluation for Chemicals that are Carcinogens by a Mutagenic Mode of Action

For the COPCs dichloromethane, chloroprene, and trichloroethylene, EPA has concluded that they are carcinogenic by a mutagenic mode of action and recommended that cancer risk assessments include additional factors that are applied for lifetime risk characterization to account for early lifetime susceptibility for ages younger than 16 years using age-specific dependent adjustment factors (ADAFs) with the slope factor provided in OAQPS Dose-Response values in Table 1 and age-specific exposure estimates as described in EPA's *Supplemental Guidance for Assessing Susceptibility from Early-Life Exposure to Carcinogens* (USEPA, Supplemental Guidance for Assessing Susceptibility from Early-Life Exposure to Carcinogens, Risk Assessment Forum, EPA/630/R-03/003F, 2005). The ADAFs are 10 for exposures prior to 2 years of age (i.e., spanning 2-year interval from birth until second birthday), and 3 from ages 2 through 16 (i.e., spanning a 14-year interval from second until sixteenth birthday). For the compound chloroprene, we used the recently published IRIS-adjusted IUR of 5.0×10^{-3} per µg/m3 (USEPA, Chloroprene, 126-99-8, see:, 2016). Assuming continuous exposure within the age group, the cancer risk for each of the remaining three compounds was estimated by:

1. Calculating the adjusted IUR, and
2. Multiplying the adjusted IUR by the exposure concentration

The calculations are as follows:

$$\text{Adjusted IUR} = (\text{IUR}*\text{ED}*\text{ADAF})/70 \qquad \text{Equation 5-3}$$

Where:

IUR = Individual unit risk in 1/µg/m3
ED = Exposure duration in number of years
ADAF = Age-dependent adjustment factor for a given age group

The overall adjusted IUR is calculated by summing all age group adjusted IURs

$$\text{Cancer Risk for a compound} = \text{Adjusted IUR} * \text{EC} \qquad \text{Equation 5-4}$$

Where:

EC = Exposure concentration of the chemical, which in this case is the 95UCL concentration.

An example of calculations is provided below for chloroprene at the LWD site:

Chemical Name	Age (Years)	IUR (1/ug/m^3)	Exposure Duration (Years)	ADAF (Unitless)	Adjusted IUR (1/ug/m^3)
Chloroprene	0-<2	0.003	2	10	$8.6x10^{-4}$
	2-<16	0.003	14	3	$1.8x10^{-3}$
	16-70	0.003	54	1	$2.3x10^{-3}$
			Total		$5x10^{-3}$

Cancer risk for chloroprene at the LWD site =

$$0.121\ \mu g/m3 * 5\ x10^{-3}\ 1/\ \mu g/m3 = 6x10^{-4}$$

5.1.2 Short-term Hazard Characterization

In contrast to cancer risks, non-cancer hazards are not expressed as a probability of an individual suffering an adverse non-cancer effect. Instead, non-cancer hazard to individuals is expressed in terms of the hazard quotient (or HQ), defined as the ratio between the estimated EC and the Reference Concentration (RfC). For a given air toxic, exposures below the RfC (HQ<1) are not likely to be associated with adverse health effects. With exposures increasingly greater than the RfC, the potential for adverse effects increases. HQs were calculated as follows:

$$HQ_x = \frac{EC_x}{RfC_x}$$

Equation 5-5

Where:

HQ_x = the hazard quotient of the Xth COPC at the monitor;
EC_x= the exposure concentration of the COPC (i.e., 95UCL air concentration); and
RfC_x = the reference concentration of the COPC.

When multiple non-carcinogens were present simultaneously, the individual HQs are summed to create an HI, as follows:

$$HI = \sum (HQ1 + HQ2 + HQ3 + \ldots HQ_x)$$

Equation 5-6

Where:

HI = the hazard index of the COPCs at the monitor; and
HQ1 = the Hazard Quotients of COPCs 1 through x.

The HI is a measure of the potential for an adverse health effect from all of the COPCs combined. Different pollutants may cause different adverse health effects or act by different mechanisms of action; therefore, it is often inappropriate to sum HQs associated with different toxicological endpoints (USEPA, Air Toxics Risk Assessment Reference Library, Office of Air Quality Planning and Standards, EPA-453-K-04-001A, see: , 2004). When the HI exceeded a value of 1, the aggregate hazard from exposure to multiple COPCs was assessed by adding the individual HQs for COPCs that act by a similar mechanism of action or impact the same target organ for the critical effect (the result is called a Target Organ Specific Hazard Index or TOSHI). Unless otherwise noted, the HI's presented in this Section are the sums of all HQs for the COPCs identified. This calculation conservatively assumes that all of the COPCs have similarities in their mechanisms of action or target organs for the critical effect. The results of this TOSHI analysis will identify the both the toxicological endpoints on which the TOSHI was based and the COPCs that were included in the TOSHI.

In the risk discussion, the total cancer risk estimates for all compounds with quantitative toxicity estimates for the Calvert City study as well as the 95UCL cancer risk estimates for each chemical along with its percent contribution to the total risks (Table 5.1.2-1, Table 5.1.2-2, Table 5.1.2-3, and Table 5.1.2-4) and HI (Table 4.1.2-1) were presented based on all COPCs selected. Also, the risk drivers were identified based on COPCs that exceed a cancer risk level of $1x10^{-6}$ or an HQ of 0.1. The use of risk drivers helps to focus the risk assessment on those COPCs with the greatest potential to impact human health. Using a HQ of 0.1 to screen out non-cancer risk drivers provides a means to identify COPCs that significantly may contribute to a HI that exceeds a value of 1, at which point, there is a potential for an adverse non-cancer health effect. Likewise, limiting risk drivers to chemicals that pose a cancer greater than $1x10^{-6}$ helps to focus attention on only the highest potential carcinogenic risks.

5.2 Risk Characterization Summary

As discussed above, under the CAA EPA generally strives to protect the greatest number of persons possible to an individual lifetime risk level no higher than 1×10-6 (one in one million) and limiting to no higher than approximately 1×10-4 (one hundred in one million) as the estimated risk that a person living near a source would have if exposed to the maximum pollutant concentrations for 70 years. The risks calculated in this study are discussed within the context of that risk range. The potential cancer risk estimates, along with percent contribution to the total risk, are presented for all COPCs at each of the four monitoring sites in Table 3.1-1, Table 3.1-2, Table 3.1-3, and Table 3.1-4. The tables also contain chronic inhalation carcinogenic toxicity values for the carcinogenic COPCs, the EPA and IARC WOE for each chemical, as well as the source of this information.

5.2.1: Chronic Cancer Summary

Following is a summary of the lifetime cancer risk results at the monitoring sites:

- **Calvert City Elementary site** is $6x10^{-5}$ (rounded to one significant digit, per EPA guidance) with EDC contributing 81% of the risk (i.e., $5x10^{-5}$). The next highest risk contributor was carbon tetrachloride at 6% of the risk ($4x10^{-6}$). The EPA (1986) WOE for EDC was B2 (probable carcinogen) while the carbon tetrachloride EPA (2000) WOE was LH (likely to be carcinogenic to). The IARC WOE for EDC was 2B (possibly carcinogenic) and carbon tetrachloride was 2B (possibly carcinogenic). The cancer IUR estimate for both EDC and carbon tetrachloride was from EPA's IRIS database.

- **Johnson-Riley Road site** is $1x10^{-4}$ (rounded to one significant digit, per EPA guidance) with EDC contributing 63% of the risk (i.e., $7x10^{-5}$). The next highest risk contributor was vinyl chloride at 28% of the risk ($3x10^{-5}$). The EPA (1986) WOE for EDC was B2 (probable carcinogen) while the vinyl chloride EPA (2005) WOE was CH (carcinogenic to humans). The IARC WOE for EDC was 2B (possibly carcinogenic) and vinyl chloride was 1 (carcinogenic to humans). The cancer IUR estimate for both EDC and vinyl chloride was from EPA's IRIS database.

- **LWD site** is $1x10^{-3}$ (rounded to one significant digit, per EPA guidance) with EDC contributing 92% of the risk (i.e., $1x10^{-3}$). The next highest risk contributor was chloroprene at 5% of the risk ($6x10^{-5}$). The EPA (1986) WOE for EDC was B2 (probable carcinogen) while the chloroprene EPA (2005) WOE was LH (likely to be carcinogenic). The IARC WOE for both EDC and chloroprene was 2B (possibly carcinogenic). The cancer IUR estimate for both EDC and chloroprene was from EPA's IRIS database.

- **Grayson Lake site** is $1x10^{-5}$ (rounded to one significant digit, per EPA guidance) with carbon tetrachloride contributing 31% of the risk (i.e., $3x10^{-6}$). The next highest risk contributor was benzene at 30% of the risk ($3x10^{-}$

[6]). The carbon tetrachloride EPA (2000) WOE was LH (likely carcinogenic) while the EPA (2005) WOE for benzene was LH (carcinogenic to humans). The IARC WOE for carbon tetrachloride was 2B (possibly carcinogenic) and benzene was 1 (carcinogenic to humans). The cancer IUR estimate for both carbon tetrachloride and benzene was from EPA's IRIS database.

5.2.2: Chronic Non-cancer Summary

Non-cancer health hazards with percent contributions to the HIs are provided for each monitoring site in Table 4.1.2-1. The table also contain the chronic non-carcinogenic toxicity values for the COPCs, the target organ potentially affected by the respective COPCs as well as the source of the information. As explained in Section 5.1.2, when a HI value is equal to or less than 1 or, where the HI exceeds 1 but the TOSHI value is equal to or less than 1, it is an indication that non-cancer effects are not likely to occur.

Calvert City Elementary School site

At this site, none of the chemicals of potential concern contributed to a HQ or HI. The result for non-cancer hazard analysis at this monitoring site indicated that non-cancer effects are not likely to occur.

Johnson-Riley Road Site

At this site, none of the chemicals of potential concern contributed to a HQ or HI. The result for non-cancer hazard analysis at this monitoring site indicated that non-cancer effects are not likely to occur.

LWD Site

The 95UCL HI for the LWD site was 0.04. No chemicals were at or above the 0.1 HQ-threshold at this site and no chemicals that affect the same organ/systems had a combined HQ (the TOSHI value) above 1. The results for non-cancer hazard analysis at the monitoring site indicates that non-cancer effects are not likely to occur.

Grayson Lake Site

At this site, none of the chemicals of potential concern contributed to a HQ or HI. The result for non-cancer hazard analysis at this monitoring site indicated that non-cancer effects are not likely to occur.

5.2.3: Acute Non-Cancer Hazard Summary

Non-cancer short-term health effects were estimated in much the same way as hazard assessments for non-cancer health effects. Maximum detected

concentrations of each contaminant (CA_{max}) were compared to the associated short-term benchmark concentrations (AB) resulting in the calculation of hazard quotients ($HQ_{short\text{-}term}$):

$$HQ_{short\text{-}term} = \frac{CA_{max}}{AB}$$

Equation 5-5

Note: Both CA_{max} and AB are expressed in the same units.

The acute toxicity characterizations were based on a comparison of the maximum detected concentrations for each COPC to its respective acute screening level. The assessment of acute exposures is not as well developed as the chronic evaluation, leading to a relatively higher degree of uncertainty in the resulting hazard estimates. Nevertheless, HQs were calculated for each COPC.

Table 4.1.2-1 compares all short-term screening levels with their respective maximum concentrations for the study. There were no short-term HQs identified that alone or combined to result in a HI greater than 1.

5.3 Description of Risk Drivers

Following is a brief description of potential risk drivers identified in this study, including sources and potential health effects. Additional information on each of the compounds can be obtained from the EPA's Health Effects Notebook for Hazardous Air Pollutants and ATSDR's ToxFAQs websites. They are presented in alphabetical order.

1,1-Dichloroethane

1,1-Dichloroethane is a colorless, oily liquid with a sweet odor that evaporates easily at room temperature and burns easily. It does not occur naturally in the environment. 1,1-Dichloroethane is used mostly as an intermediate in the manufacture of 1,1,1-trichloroethane (1,1,1-TCE). It is also used in limited amount as a solvent for cleaning and degreasing, and in the manufacture of plastic wrap, adhesives, and synthetic fiber (ATSDR, Toxicological Profile for 1,1-Dichloroethane, U.S. Department of Health and Human Services, see:, 2013). Acute (short-term) inhalation exposure to high levels of ethylidene dichloride in humans results in central nervous system (CNS) depression and a cardio stimulating effect resulting in cardiac arrhythmias. No information is available on the chronic (long-term), reproductive, developmental, or carcinogenic effects of ethylidene dichloride in humans (USEPA, 1,1-Dichloroethane, 75-34-3, see:, 2000).

1,1,2-Trichloroethane

1,1,2-Trichloroethane is a colorless, sweet-smelling liquid. It can be dissolved in water and evaporates easily. 1,1,2-Trichlorethane is used to dissolve other substances and to make other chemicals. It can also be formed when other chemicals break down in the environment (ATSDR, Toxicological Profile for 1,12-Trichloroethane, U.S. Department of Health and Human Services, see: , 2021). No information is available on the acute (short-term), chronic (long-term), developmental, reproductive, or carcinogenic effects of 1,1,2- trichloroethane in humans. The only effect that has been noted in humans is stinging and burning sensations of the skin upon dermal exposure to the chemical (USEPA, 1,1,2-Trichloroethane, 79-00-5, see: , 2000).

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1,3-Butadiene

1,3-Butadiene is a chemical made from the processing of petroleum. It is a colorless gas with a mild gasoline-like odor. Recent production volumes are not available. About 60% of the manufactured 1,3-butadiene is used to make synthetic rubber. Synthetic rubber is widely used for tires on cars and trucks. 1,3-Butadiene is also used to make plastics including acrylics. Small amounts are found in gasoline (ATSDR, Toxicological Profile for 1,3-Butadiene, U.S. Department of Health and Human Services, see: , 2012). Acute (short-term) exposure to 1,3-butadiene by inhalation in humans results in irritation of the eyes, nasal passages, throat, and lungs. Epidemiological studies have reported a possible association between 1,3- butadiene exposure and cardiovascular diseases. Epidemiological studies of workers in rubber plants have shown an association between 1,3-butadiene exposure and increased incidence of leukemia (USEPA, 1,3-butadiene, 106-99-0, see: , 2009).

Acetonitrile

Acetonitrile is predominantly used as a solvent in the manufacture of pharmaceuticals, for spinning fibers and for casting and molding of plastic materials, in lithium batteries, for the extraction of fatty acids from animal and vegetable oils, and in chemical laboratories for the detection of materials such as pesticide residues. Acetonitrile is also used in dyeing textiles and in coating compositions as a stabilizer for chlorinated solvents and in perfume production as a chemical intermediate. Acute (short-term) inhalation exposure results in irritation of mucous membranes. Chronic (long-term) exposure results in central nervous system effects, such as headaches, numbness, and tremors. No data are available on its carcinogenic effects in humans; EPA has classified it as a Group D, not classifiable as to human carcinogenicity (USEPA, Acetonitrile, 75-05-8, see: , 2000).

Acrylonitrile

Acrylonitrile is a colorless, liquid, man-made chemical with a sharp, onion- or garlic-like odor. It can be dissolved in water and evaporates quickly. Acrylonitrile is used to make other chemicals such as plastics, synthetic rubber, and acrylic fibers. A mixture of acrylonitrile and carbon tetrachloride was used as a pesticide in the past; however, all pesticide uses have stopped (ATSDR, Toxicological Profile for Acrylonitrile, U.S. Department of Health and Human Services, see: , 1990). Acute (short-term) exposure of workers to acrylonitrile has been observed to cause mucous membrane irritation, headaches, dizziness, and nausea. No information is available on the reproductive or developmental effects of acrylonitrile in humans (USEPA, Acrylonitrile, 107-13-1, see: , 2000).

Benzene

Benzene is a colorless liquid with a sweet odor. It evaporates into the air very quickly and dissolves slightly in water. It is highly flammable and is formed from both natural processes and human activities. Benzene is widely used in the United States; it ranks in the top 20 chemicals for production volume. Some industries use benzene to make other chemicals which are used to make plastics, resins, and nylon and other synthetic fibers. Benzene is also used to make some types of rubbers, lubricants, dyes, detergents, drugs, and pesticides. Natural sources of benzene include emissions from volcanoes and forest fires. Benzene is also a natural part of crude oil, gasoline, and cigarette smoke (ATSDR, Toxicological Profile for Benzene, U.S. Department of Health and Human Services, see: , 2007). Acute (short-term) inhalation exposure of humans to benzene may cause drowsiness, dizziness, headaches, as well as eye, skin, and respiratory tract irritation, and, at high levels, unconsciousness. Chronic (long-term) inhalation exposure has caused various disorders in the blood, including reduced numbers of red blood cells and aplastic anemia, in occupational settings (USEPA,). Benzene, 71-43-2, see:, 2012).

Carbon tetrachloride

Carbon tetrachloride is a manufactured chemical that does not occur naturally. It is a clear liquid with a sweet smell that can be detected at low levels. It is also called carbon chloride, methane tetrachloride, perchloromethane, tetrachloroethane, or benziform. Carbon tetrachloride is most often found in the air as a colorless gas. It is not flammable and does not dissolve in water very easily. It was used in the production of refrigeration fluid and propellants for aerosol cans, as a pesticide, as a cleaning fluid and degreasing agent, in fire extinguishers, and in spot removers. Because of its harmful effects, these uses are now banned and it is only used in some industrial applications (ATSDR, Toxicological Profile for Carbon Tetrachloride, U.S. Department of Health and

Human Services, see: , 2005).The primary effects of carbon tetrachloride in humans are on the liver, kidneys, and central nervous system (CNS). Human symptoms of acute (short-term) inhalation and oral exposures to carbon tetrachloride include headache, weakness, lethargy, nausea, and vomiting. Acute exposures to higher levels and chronic (long-term) inhalation or oral exposure to carbon tetrachloride produces liver and kidney damage in humans (USEPA, Carbon tetrachloride, 56-23-5, see:, 2000).

Chloroform

Chloroform is a colorless liquid with a pleasant, nonirritating odor and a slightly sweet taste. It will burn only when it reaches very high temperatures. In the past, chloroform was used as an inhaled anesthetic during surgery, but it isn't used that way today. Today, chloroform is used to make other chemicals and can also be formed in small amounts when chlorine is added to water. Other names for chloroform are trichloromethane and methyl trichloride. The major effect from acute (short-term) inhalation exposure to chloroform is central nervous system depression. Chronic (long-term) exposure to chloroform by inhalation in humans has resulted in effects on the liver, including hepatitis and jaundice, and central nervous system effects, such as depression and irritability (USEPA, Chloroform, 67-66-3, see: , 2000).

Chloroprene

Chloroprene is primarily used in the manufacture of polychloroprene (Neoprene TM, duprene) which is a polychloroprene elastomer that is used to make diverse products including adhesives, automotive, and industrial parts such as belts and hoses, wires, cables cover, and other applications requiring weather resistance. Symptoms due to acute (short-term) human exposure to high concentrations of chloroprene include giddiness, headache, irritability, dizziness, insomnia, respiratory irritation, cardiac palpitations, and chest pains to name a few. Chronic (long-term) exposures resulted in fatigue, chest pains, dermatitis, and hair loss. Chloroprene has a mutagenic mode of action for carcinogenicity and EPA has classified chloroprene as likely to be carcinogenic to humans (USEPA, Chloroprene, 126-99-8, see:, 2016).

Ethylbenzene

Ethylbenzene is a colorless, flammable liquid that smells like gasoline.
It is naturally found in coal tar and petroleum and is also found in manufactured products such as inks, pesticides, and paints. Ethylbenzene is used primarily to make another chemical, styrene. Other uses include as a solvent, in fuels, and to make other chemicals (ATSDR, Toxicological Profile for Ethylbenzene, U.S. Department of Health and Human Services, see: , 2010). Acute (short-term) exposure to ethylbenzene in humans results in respiratory effects, such as throat irritation and chest constriction, irritation of the eyes, and neurological effects

such as dizziness. Chronic (long-term) exposure to ethylbenzene by inhalation in humans has shown conflicting results regarding its effects on the blood (USEPA, Ethylbenzene, 100-41-4, see: , 2000).

Ethylene dibromide

Most of the 1,2-Dibromoethane, also known as ethylene dibromide, in the environment is man-made. Small amounts occur naturally in the ocean (thought to be made by algae). It is a colorless liquid with a mild, sweet odor. 1,2-Dibromoethane has been used as a pesticide in soil, and on citrus, vegetable, and grain crops. Most of these uses have been stopped by the EPA since 1984. In the past, it was an additive in leaded gasoline; however, since leaded gasoline is now banned, it is no longer used for this purpose. Uses today include treatment of logs for termites and beetles, control of moths in beehives, control of beetles on ornamental plants, and in production of dyes, resins, gums, and waxes (ATSDR, Toxicological Profile for 1,2-Dibromoethane, U.S. Department of Health and Human Services, see:, 2018).Ethylene dibromide is extremely toxic to humans. The chronic (long-term) effects of exposure to ethylene dibromide have not been well documented in humans. Limited data on men occupationally exposed to ethylene dibromide indicate that long-term exposure to ethylene dibromide can impair reproduction by damaging sperm cells in the testicles (USEPA, Ethylene dibromide, 106-93-4, see: , 2000).

Ethylene dichloride

1,2-Dichloroethane also known as ethylene dichloride is a man-made, clear, oily liquid not found naturally in the environment. It is mainly used to help make plastic and vinyl products, such as polyvinyl chloride (PVC) pipes and other construction materials. 1,2-Dichloroethane is also added to leaded gasoline that is used in aircrafts, racing vehicles, and farm equipment. 1,2-Dichloroethane was formerly used in certain consumer household products such as cleaning agents and adhesives but is generally no longer available for consumer purchase (ATSDR, Toxicological Profile for 1,2-Dichloroethane, U.S. Department of Health and Human Services, see:, 2022). Chronic (long-term) inhalation exposure to ethylene dichloride produced effects on the liver and kidneys in animals. No information is available on the reproductive or developmental effects of ethylene dichloride in humans (USEPA, Ethylene dichloride, 107-06-2, see: , 2000).

Hexachlorobutadiene

Hexachlorobutadiene is a clear liquid that can smell like turpentine. It is not found naturally in the environment. Hexachlorobutadiene is formed as a byproduct when other chemicals are made. Hexachlorobutadiene is used mainly to make rubber compounds. It is also used as a solvent (to dissolve other chemicals), a lubricant, a heat transfer liquid, and a hydraulic fluid (ATSDR, Toxicological

Profile for Hexachlorobutadiene, U.S. Department of Health and Human Services, see: , 2021). No information is available on the health effects of hexachlorobutadiene in humans (USEPA, Hexachlorobutadiene, 87-68-3, see:, 2000).

Trichloroethylene

Trichloroethylene is a colorless, volatile liquid. Liquid trichloroethylene evaporates quickly into the air. It is nonflammable and has a sweet odor. The two major uses of trichloroethylene are as a solvent to remove grease from metal parts and as a chemical that is used to make other chemicals, especially the refrigerant, HFC-134a (ATSDR, Toxicological Profile for Trichloroethylene, U.S. Department of Health and Human Services, see: , 2019).Acute (short-term) and chronic (long-term) inhalation exposure to trichloroethylene can affect the human central nervous system (CNS), with symptoms such as dizziness, headaches, confusion, euphoria, facial numbness, and weakness. Liver, kidney, immunological, endocrine, and developmental effects have also been reported in humans. A recent analysis of available epidemiological studies reports trichloroethylene exposure to be associated with several types of cancers in humans, especially kidney, liver, cervix, and lymphatic system (USEPA, Trichloroethylene, 79-01-6, see: , 2000).

Vinyl chloride

Vinyl chloride is a colorless gas. It burns easily and it is not stable at high temperatures. It has a mild, sweet odor. It is a manufactured substance that does not occur naturally. It can be formed when other substances such as trichloroethane, trichloroethylene, and tetrachloroethylene are broken down. Vinyl chloride is used to make polyvinyl chloride (PVC). PVC is used to make a variety of plastic products, including pipes, wire and cable coatings, and packaging materials. Vinyl chloride is also known as chloroethene, chloroethylene, and ethylene monochloride (ATSDR, Toxicological Profile for Vinyl Chloride, U.S. Department of Health and Human Services, see: , 2006).Acute (short-term) exposure to high levels of vinyl chloride in air has resulted in central nervous system (CNS) effects, such as dizziness, drowsiness, and headaches in humans. Chronic (long-term) exposure to vinyl chloride through inhalation and oral exposure in humans has resulted in CNS effects and liver damage (USEPA, Vinyl chloride, 75-01-4, see: , 2020).

6 UNCERTAINTY ASSESSMENT

This section identifies and characterizes the main sources of uncertainty in this risk evaluation. Beginning with general uncertainties associated with the risk assessment process and finally concluding with those associated with this study.

6.1 General Risk Assessment Process Uncertainties

In this section, separate discussions are provided on uncertainty associated with cancer potency factors and for noncancer reference values. Cancer potency values are derived for chronic (lifetime) exposures. Noncancer dose-response values are generally derived for chronic exposures (up to a lifetime) but may also be derived (per EPA definitions) for acute (less than 24-hours), short-term (from 24-hours up to 30-days), and sub-chronic (30-days up to 10 percent of lifetime) exposure durations, all of which are derived based on an assumption of continuous exposure throughout the duration specified. For the purposes of assessing all potential health risks associated with the emissions included in an assessment, both chronic (cancer and noncancer) and acute/short term (noncancer) dose-response values are described in more detail below.

Although every effort is made to identify peer-reviewed dose-response values for all COPCs identified in this assessment, some HAPs have no peer-reviewed values. Since exposures to these pollutants cannot be included in a quantitative risk estimate, an understatement of risk for these pollutants at estimated exposure levels is possible. To help alleviate this potential underestimation, where HAP similarity with a HAP for which a dose-response value is available, that existing value is used as a surrogate for the assessment of the HAP for which no value is available. It is noted that generally speaking, HAPs of greatest concern due to environmental exposures and hazards are those for which dose-response assessments have been performed, reducing the likelihood of understating risks. Further, HAPs not included in the quantitative assessment are assessed qualitatively and considered in the risk characterization that informs the risk management decisions.

Additionally, chronic dose-response values for certain compounds included in the assessment may be under EPA IRIS review. In those cases, revised assessments may determine in the future that these pollutants are more or less potent than currently thought.

6.1.1 Cancer Assessment Uncertainties

The discussion of dose-response uncertainties in the estimation of cancer risk below focuses on the uncertainties associated with the specific approach currently used by the EPA to develop cancer potency factors. In general, these same uncertainties attend the development of cancer potency factors by CalEPA, the source of peer-reviewed cancer potency factors used where EPA-developed values are not yet available. To place this discussion in context, a quote was

provided from the EPA's *Guidelines for Carcinogen Risk Assessment* (herein referred to as *Cancer Guidelines,* see: (USEPA, Guidelines for Carcinogen Risk Assessment. EPA/630/P-03/001B. Risk Assessment Forum, Washington, DC., 2005) "The primary goal of EPA actions is protection of human health; accordingly, as an Agency policy, risk assessment procedures, including default options that are used in the absence of scientific data to the contrary, should be health protective." The approach adopted in this document is consistent with this approach as described in the *Cancer Guidelines*.

For cancer endpoints, EPA usually derives an oral slope factor for ingestion and a unit risk value for inhalation exposures. These values allow estimation of a lifetime probability of potentially developing cancer given long-term exposures to the pollutant. Depending on the pollutant being evaluated, EPA relies on both animal bioassay and epidemiological studies to characterize cancer risk. As a science policy approach, consistent with the *Cancer Guidelines*, EPA uses animal cancer bioassays as indicators of potential human health risk when other human cancer risk data are unavailable.

Extrapolation of study data to estimate potential risks to human populations is based upon EPA's assessment of the scientific database for a pollutant using EPA's guidance documents and other peer-reviewed methodologies. The EPA *Cancer Guidelines* describe the Agency's recommendations for methodologies for cancer risk assessment. EPA believes that cancer risk estimates developed following the procedures described in the *Cancer Guidelines* and outlined below generally provide an upper bound estimate of risk. That is, EPA's upper bound estimates represent a plausible upper limit to the true value of a quantity (although this is usually not a true statistical confidence limit). In some circumstances, the true risk could be as low as zero; however, in other circumstances the risk could also be greater.[5] When developing an upper bound estimate of risk and to provide risk values that do not underestimate risk, EPA generally relies on conservative default approaches.[6] EPA also uses the upper bound (rather than lower bound or central tendency) estimates in its assessments, although it is noted that this approach can have limitations for some uses (e.g. priority setting, expected benefits analysis).

[5] The exception to this is the URE for benzene, which is considered to cover a range of values, each end of which is considered to be equally plausible, and which is based on maximum likelihood estimates.

[6] According to the NRC report Science and Judgment in Risk Assessment (NRC, 1994) "[Default] options are generic approaches, based on general scientific knowledge and policy judgment, that are applied to various elements of the risk-assessment process when the correct scientific model is unknown or uncertain." The 1983 NRC report Risk Assessment in the Federal Government: Managing the Process defined default option as "the option chosen on the basis of risk assessment policy that appears to be the best choice in the absence of data to the contrary" (NRC, 1983, p. 63). Therefore, default options are not rules that bind the Agency; rather, the Agency may depart from them in evaluating the risks posed by a specific substance when it believes this to be appropriate. In keeping with EPA's goal of protecting public health and the environment, default assumptions are used to ensure that risk to chemicals is not underestimated (although defaults are not intended to overtly overestimate risk). See (USEPA, An Examination of EPA Risk Assessment Principles and Practices, EPA/100/B-04/001., 2004).

Such health risk assessments have associated uncertainties, some of which may be considered quantitatively, and others which generally are expressed qualitatively. Uncertainties may vary substantially among cancer risk assessments associated with exposures to different pollutants, since the assessments employ different databases with different strengths and limitations and the procedures employed may differ in how well they represent actual biological processes for the assessed substance. Some of the major sources of uncertainty and variability in deriving cancer risk values are described more fully below.

(1) The qualitative similarities or differences between tumor responses observed in experimental animal bioassays and those which would occur in humans are a source of uncertainty in cancer risk assessments. In general, EPA does not assume that tumor sites observed in an experimental animal bioassay are necessarily predictive of the sites at which tumors would occur in humans.[7] However, unless scientific support is available to show otherwise, EPA assumes that tumors in animals are relevant in humans, regardless of target organ concordance. For a specific pollutant, qualitative differences in species responses can lead to either under-estimation or over-estimation of human cancer risks.

(2) Uncertainties regarding the most appropriate dose metric for an assessment can also lead to differences in risk predictions. For example, the measure of dose is commonly expressed in units of mg/kg/d ingested or the inhaled concentration of the pollutant. However, data may support development of a pharmacokinetic model for the absorption, distribution, metabolism, and excretion of an agent, which may result in improved dose metrics (e.g., average blood concentration of the pollutant or the quantity of agent metabolized in the body). Quantitative uncertainties result when the appropriate choice of a dose metric is uncertain or when dose metric estimates are themselves uncertain (e.g., as can occur when alternative pharmacokinetic models are available for a compound). Uncertainty in dose estimates may lead to either over or underestimation of risk.

(3) For the quantitative extrapolation of cancer risk estimates from experimental animals to humans, EPA uses scaling methodologies (relating expected response to differences in physical size of the species), which introduce another source of uncertainty. These methodologies are based on both biological data on differences in rates of process according to species size and empirical comparisons of toxicity between experimental animals and humans. For a particular pollutant, the quantitative difference in cancer potency between experimental animals and humans may be either greater

[7] Per the EPA Cancer Guidelines: “The default option is that positive effects in animal cancer studies indicate that the agent under study can have carcinogenic potential in humans.” and “Target organ concordance is not a prerequisite for evaluating the implications of animal study results for humans.”

than or less than that estimated by baseline scientific scaling predictions due to uncertainties associated with limitations in the test data and the correctness of scaled estimates.

(4) EPA cancer risk estimates, whether based on epidemiological or experimental animal data, are generally developed using a benchmark dose (BMD) analysis to estimate a dose at which there is a specified excess risk of cancer, which is used as the point of departure (or POD) for the remainder of the calculation. Statistical uncertainty in developing a POD using a benchmark dose (BMD) approach is generally addressed though use of the 95 percent lower confidence limit on the dose at which the specified excess risk occurs (the BMDL), decreasing the likelihood of understating risk. EPA has generally utilized the multistage model for estimation of the BMDL using cancer bioassay data (see further discussion below).

(5) Extrapolation from high to low doses is an important source of uncertainty in cancer risk assessment. EPA uses different approaches to low dose risk assessment (i.e., developing estimates of risk for exposures to environmental doses of an agent from observations in experimental or epidemiological studies at higher dose) depending on the available data and understanding of a pollutant's mode of action (i.e., the manner in which a pollutant causes cancer). EPA's *Cancer Guidelines* express a preference for the use of reliable, compound-specific, biologically based risk models when feasible; however, such models are rarely available. The mode of action for a pollutant (i.e., the manner in which a pollutant causes cancer) is a key consideration in determining how risks should be estimated for low-dose exposure. A reference value is calculated when the available mode of action data shows the response to be nonlinear (e.g., as in a threshold response). A linear low-dose (straight line from POD) approach is used when available mode of action data supports a linear (e.g., non-threshold) response or as the most common default approach when a compound's mode of action is unknown. Linear extrapolation can be supported by both pollutant-specific data and broader scientific considerations. For example, EPA's *Cancer Guidelines* generally consider a linear dose-response to be appropriate for pollutants that interact with DNA and induce mutations. Pollutants whose effects are additive to background biological processes in cancer development can also be predicted to have low-dose linear responses, although the slope of this relationship may not be the same as the slope estimated by the straight-line approach.

EPA most frequently utilizes a linear low-dose extrapolation approach as a baseline science-policy choice (a "default") when available data do not allow a compound-specific determination. This approach is designed to not underestimate risk in the face of uncertainty and variability. EPA believes that linear dose-response models, when appropriately applied as part of EPA's cancer risk assessment process, provide an upper bound estimate of

risk and generally provide a health protective approach. Note that another source of uncertainty is the characterization of low-dose nonlinear, non-threshold relationships. The National Academy of Sciences (NAS, 1994) has encouraged the exploration of sigmoidal type functions (e.g., log-probit models) in representing dose-response relationships due to the variability in response within human populations. Another National Research Council report (NRC, 2006)(NRC, 2006) suggests that models based on distributions of individual thresholds are likely to lead to sigmoidal-shaped dose-response functions for a population. This report notes sources of variability in the human population: “One might expect these individual tolerances to vary extensively in humans depending on genetics, coincident exposures, nutritional status, and various other susceptibility factors...” Thus, if a distribution of thresholds approach is considered for a carcinogen risk assessment, application would depend on ability of modeling to reflect the degree of variability in response in human populations (as opposed to responses in bioassays with genetically more uniform rodents). Note also that low dose linearity in risk can arise for reasons separate from population variability: due to the nature of a mode of action and additivity of a chemical’s effect on top of background chemical exposures and biological processes.

As noted above, EPA’s current approach to cancer risk assessment typically utilizes a straight-line approach from the BMDL. This is equivalent to using an upper confidence limit on the slope of the straight-line extrapolation. The impact of the choice of the BMDL on bottom line risk estimates can be quantified by comparing risk estimates using the BMDL value to central estimate BMD values, although these differences are generally not a large contributor to uncertainty in risk assessment (Subramaniam, 2006). It is important to note that earlier EPA assessments, including the majority of those for which risk values exist today, were generally developed using the multistage model to extrapolate down to environmental dose levels and did not involve the use of a POD. Subramaniam et. al. (2006) also provides comparisons indicating that slopes based on straight line extrapolation from a POD do not show large differences from those based on the upper confidence limit of the multistage model.

(6) Cancer risk estimates do not generally make specific adjustments to reflect the variability in response within the human population — resulting in another source of uncertainty in assessments. In the diverse human population, some individuals are likely to be more sensitive to the action of a carcinogen than the typical individual, although compound-specific data to evaluate this variability are generally not available. There may also be important life stage differences in the quantitative potency of carcinogens and, with the exception of the recommendations in EPA’s Supplemental Cancer Guidance for carcinogens with a mutagenic mode of action, risk assessments do not generally quantitatively address life stage differences. However, one approach used commonly in EPA assessments that may help

address variability in response is to extrapolate human response from results observed in the most sensitive species and sex tested, resulting typically in the highest URE which can be supported by reliable data, thus supporting estimates that are designed not to underestimate risk in the face of uncertainty and variability.

6.1.2 Chronic Non-Cancer Assessment Uncertainties

Chronic noncancer reference values represent chronic exposure levels that are intended to be health protective. That is, EPA and other organizations, such as the Agency for Toxic substances and disease Registry (ATSDR), which develop noncancer dose-response values use an approach that is intended not to underestimate risk in the face of uncertainty and variability. When there are gaps in the available information, uncertainty factors (UFs) are applied to derive reference values that are intended to be protective against appreciable risk of deleterious effects. Uncertainty factors are commonly default values[8] (e.g., factors of 10 or 3) used in the absence of compound-specific data. Where data are available, uncertainty factors may also be developed using compound-specific information. When data are limited, more assumptions are needed, and more default factors are used. Thus, there may be a greater tendency to overestimate risk—in the sense that further study might support development of reference values that are higher (i.e., less potent) because fewer default assumptions are needed. However, for some pollutants it is possible that risks may be underestimated.

For noncancer endpoints related to chronic exposures, EPA derives a reference dose (RfD) for exposures via ingestion, and a reference concentration (RfC) for inhalation exposures. As stated in the IRIS Glossary, these values provide an estimate (with uncertainty spanning perhaps an order of magnitude) of daily oral exposure (RfD) or of a continuous inhalation exposure (RfC) to the human population (including sensitive subgroups) that is likely to be without an appreciable risk of deleterious effects during a lifetime. To derive values that are intended to be “without appreciable risk,” EPA’s methodology relies upon an uncertainty factor (UF) approach (USEPA, Reference Dose (RfC): Description and Use in Health Risk Assessments, see: , 1993) (USEPA, Methods for Derivation of Inhalation Reference Concentrations and Application of Inhalation Dosimetry. Office of Research and Development, Washington, DC. EPA/600/8-90/066F,, 1994) which includes consideration of both uncertainty and variability.

EPA begins by evaluating all of the available peer-reviewed literature to determine noncancer endpoints of concern, evaluating the quality, strengths and limitations of the available studies. EPA typically chooses the relevant endpoint that occurs at the lowest dose, often using statistical modeling of the available data, and then determines the appropriate POD for derivation of the reference value. A POD is determined by (in order of preference): (1) a statistical

estimation using the BMD approach; (2) use of the dose or concentration at which the toxic response was not significantly elevated (no observed adverse effect level - NOAEL); or (3) use of the lowest observed adverse effect level (LOAEL).

A series of downward adjustments using default UFs is then applied to the POD to estimate the reference value (USEPA, A Review of the Reference Dose and Reference Concentration Processes. , 2002)While collectively termed “UFs”, these factors account for a number of different quantitative considerations when utilizing observed animal (usually rodent) or human toxicity data in a risk assessment. The UFs are intended to account for: (1) variation in susceptibility among the members of the human population (i.e., inter-individual variability); (2) uncertainty in extrapolating from experimental animal data to humans (i.e., interspecies differences); (3) uncertainty in extrapolating from data obtained in a study with less-than-lifetime exposure (i.e., extrapolating from sub-chronic to chronic exposure); (4) uncertainty in extrapolating from a LOAEL in the absence of a NOAEL; and (5) uncertainty when the database is incomplete or there are problems with applicability of available studies. When scientifically sound, peer-reviewed assessment-specific data are not available, default adjustment values are selected for the individual UFs. For each type of uncertainty (when relevant to the assessment), EPA typically applies an UF value of 10 or 3 with the cumulative UF value leading to a downward adjustment of 10- to 3000-fold from the selected POD. An UF of 3 is used when the data do not support the use of a 10-fold factor. If an extrapolation step or adjustment is not relevant to an assessment (e.g., if applying human toxicity data and an interspecies extrapolation is not required) the associated UF is not used. The major adjustment steps are described more fully below.

(1) Heterogeneity among humans is a key source of variability as well as uncertainty. Uncertainty related to human variation is considered in extrapolating doses from a subset or smaller-sized population, often of one sex or of a narrow range of life stages (typical of occupational epidemiologic studies), to a larger, more diverse population. In the absence of pollutant-specific data on human variation, a 10-fold UF is used to account for uncertainty associated with human variation. Human variation may be larger or smaller; however, data to examine the potential magnitude of human variability are often unavailable. In some situations, a smaller UF of 3 may be applied to reflect a known lack of significant variability among humans.

(2) Extrapolation from results of studies in experimental animals to humans is a necessary step for the majority of chemical risk assessments. When interpreting animal data, the concentration at the POD (e.g., NOAEL, BMDL) in an animal model (e.g., rodents) is extrapolated to estimate the human response. While there is long-standing scientific support for the use of animal studies as indicators of potential toxicity to humans, there are uncertainties in such extrapolations. In the absence of data to the contrary, the typical approach is to use the most relevant endpoint from the most sensitive species

and the most sensitive sex in assessing risks to the average human. Typically, compound specific data to evaluate relative sensitivity in humans versus rodents are lacking, thus leading to uncertainty in this extrapolation. Size-related differences (allometric relationships) indicate that typically humans are more sensitive than rodents when compared on a mg/kg/day basis. The default choice of 10 for the interspecies UF is consistent with these differences. For a specific chemical, differences in species responses may be greater or less than this value.

Pharmacokinetic models are useful to examine species differences in pharmacokinetic processing and associated uncertainties; however, such dosimetric adjustments are not always possible. Information may not be available to quantitatively assess toxicokinetic or toxicodynamic differences between animals and humans, and in many cases a 10-fold UF (with separate factors of 3 for toxicokinetic and toxicodynamic components) is used to account for expected species differences and associated uncertainty in extrapolating from laboratory animals to humans in the derivation of a reference value. If information on one or the other of these components is available and accounted for in the cross-species extrapolation, a UF of 3 may be used for the remaining component.

(3) In the case of reference values for chronic exposures where only data from shorter durations are available (e.g., 90-day sub-chronic studies in rodents) or when such data are judged more appropriate for development of an RfC, an additional UF of 3- or 10-fold is typically applied unless the available scientific information supports use of a different value.

(4) Toxicity data are typically limited as to the dose or exposure levels that have been tested in individual studies; in an animal study, for example, treatment groups may differ in exposure by up to an order of magnitude. The preferred approach to arrive at a POD is to use BMD analysis; however, this approach requires adequate quantitative results for a meaningful analysis, which is not always possible. Use of a NOAEL is the next preferred approach after BMD analysis in determining a POD for deriving a health effect reference value. However, many studies lack a dose or exposure level at which an adverse effect is not observed (i.e., a NOAEL is not identified). When using data limited to a LOAEL, a UF of 10- or 3-fold is often applied.

(5) The database UF is intended to account for the potential for deriving an under-protective RfD/RfC due to a data gap preventing complete characterization of the chemical’s toxicity. In the absence of studies for a known or suspected endpoint of concern, a UF of 10- or 3-fold is typically applied.

6.1.3 Acute Non-Cancer Assessment Uncertainties

Many of the UFs used to account for variability and uncertainty in the development of acute reference values are quite similar to those developed for chronic durations. For acute reference values, though, individual UF values may be less than 10. UFs are applied based on chemical- or health effect-specific information or based on the purpose of the reference value. The UFs applied in acute reference value derivation include: 1) heterogeneity among humans; 2) uncertainty in extrapolating from animals to humans; 3) uncertainty in LOAEL to NOAEL adjustments; and 4) uncertainty in accounting for an incomplete database on toxic effects of potential concern. Additional adjustments are often applied to account for uncertainty in extrapolation from observations at one exposure duration (e.g., 4 hours) to arrive at a POD for derivation of an acute reference value at another exposure duration (e.g., 1-hour).

Not all acute dose-response values are developed for the same purpose and care must be taken when interpreting the results of an acute assessment of human health effects relative to the reference value or values being exceeded. Where relevant to the estimated exposures, the lack of dose-response values at different levels of severity should be factored into the risk characterization as potential uncertainties.

6.2 Calvert City, KY Risk Assessment Study Uncertainties

The risk estimates used in air toxics risk assessments usually are not fully probabilistic estimates of risk, but conditional estimates given a considerable number of assumptions about exposure and toxicity. Air toxics risk assessments make use of many different kinds of scientific concepts and data (e.g., exposure, toxicity, epidemiology), all of which are used to characterize the expected risk in a particular environmental context.
Informed use of reliable scientific information from many different sources is a central feature of the risk assessment process. Reliable information may or may not be available for many aspects of a risk assessment. Scientific uncertainty is inherent in the risk assessment process, and risk managers almost always must make decisions using assessments that are not as definitive in all important areas as would be desirable.
Risk assessments also incorporate a variety of professional and science policy judgments (e.g., where to locate monitors and which toxicity studies to use as the basis of developing dose-response values). Risk managers therefore need to understand the strengths and the limitations of each assessment, and to communicate this information to all participants and the public. A critical part of the risk characterization process, therefore, is an evaluation of the assumptions and uncertainties inherent in the risk assessment in order to place the risk estimates in proper perspective. In most cases, the assessment of uncertainty is presented in a qualitative or semi-quantitative fashion, including a discussion of the likely direction and magnitude of the error associated with each important source of uncertainty. Some of the key areas of uncertainty in this risk analysis are presented below.

6.2.1 Specific VOC Toxicity Assessment Uncertainties

The uncertainties associated with several of the VOCs identified in this study are provided below.

1) Methyl methacrylate was identified in this sampling study, but toxicity information is not available.
2) 1,1,2,2-Tetrachloroethane was identified in this sampling study, but toxicity information is not available.
3) M/P xylene was identified in this sampling study, but toxicity information is not available. Nevertheless, for the purposes of this study, Xylenes (mixed) was used as a surrogate since it is the only form of xylene that has a toxicity value (RfC = 100 µg/m^3). This approach is conservative and may cause the study's HI to be higher than the true HI.
4) O-xylene was identified in this sampling study, but toxicity information is not available. Nevertheless, for the purposes of this study, Xylenes (mixed) was used as a surrogate since it is the only form of xylene that has a toxicity value (RfC = 100 µg/m3). This approach is conservative and may cause the study's HI to be higher than the true HI.
5) Chemicals without toxicity estimates for cancer and non-cancer endpoints were identified in this study and thus corresponding risks and/or hazards could not be estimated. In a few instances (as described above), the toxicity values for a surrogate chemical were used to estimate risks. The use of surrogates may cause an over- or under-estimation in the calculated risks/hazards.

6.2.2 Sampling, Analytical, and Potential Exposure Uncertainties

The uncertainties associated with sampling collection and laboratory analysis identified in this study are provided below.

Monitor Location Selection: The risk and hazard estimates provided in this assessment were based on monitoring results from 3 monitoring sites in the Calvert City area. In each case, the assumption is made that the air quality data at the monitoring location can be used to inform next steps based on the potential for exposures within some distance from the monitor (e.g., at the neighborhood level). However, it is not known how well each of these sites represent the potential receptors in immediate vicinity of the monitor (i.e., ambient air concentrations can vary at distance from the monitor); thus, exposure to individuals located at various distances from the monitoring site (and their actual risk) may also vary. If the monitoring sites were unrepresentative of any location beyond where they were sited, the monitoring data may over- or underestimate the true health impacts at the unmonitored locations. The monitoring locations selected were informed by EPA air dispersion modeling of all EDC and vinyl chloride emissions sources in the Calvert City area. The three monitoring sites were located to characterize the areas maximum expected ambient concentration of ethylene dichloride and vinyl chloride, and to characterize a nearby area of

population exposure. The monitoring site selection process is detailed in the study QAPP (KDAQ, Quality Assurance Project Plan for Volatile Organic Compound Monitoring near the Calvert City Industrial Complex. Kentucky Energy and Environment Cabinet, Department for Environmental Protection, Division for Air Quality, Frankfort, KY. , 2021); included in Appendix E).

Sampling Data Sufficiency: The risk and hazard assessment assume that the sampling data are sufficient to draw conclusions regarding the populations that are localized near the monitor's placement. Furthermore, it is assumed that the sampling regime is sufficient to represent the exposures seen by the populations. The following are some of the potential shortcomings of the monitoring data:

The monitoring data cover a little more than one year but are used to represent a full lifetime (approximately 70 years) of exposure. This assumption, while pragmatic from a monitoring study point of view, is also problematic because of possibly of changing conditions over a long period of time. For example, environmental conditions and economic conditions can change over time (e.g., companies come and go and/or make different things), leading to a different exposure profile for people living in the vicinity of a monitor.

Monitoring was staggered during the sampling study to capture samples on every day of the week and every season of the year (it was not feasible to monitor continuously during the project given the methods used). Samples were collected for 24 hours once every six days. This approach, however, left some of the days unsampled over the course of the monitoring program.

The monitors capture a combined 24-hr sample and so do not characterize shorter spikes in concentrations throughout the course of a day. Rather, the monitors provide the 24-hr average concentration of each chemical during each sample.

The monitors only evaluate a specific short list of potential VOC contaminants. Other chemicals may have been present, but not analyzed for.

The monitors only look at outdoor air. No indoor air samples were taken where concentrations of certain toxics may be higher and where exposure times may be greater.

Making these assumptions may have resulted in over- or under-estimation of the potential risks.

Missed and Invalidated Samples and Void Data: The VOC air monitoring study was conducted on a schedule of 1 in 6 days. All of the monitoring sites exceeded the 75% data completeness goal in the QAPP. As is common with any monitoring study, some individual scheduled samples were missed or

invalidated due to harsh weather conditions or equipment malfunctioning. Samples were also voided in the laboratory if the sampling or analysis requirements of the QAPP were not met.

Data Utilized at ½ Sample Quantitation Limit: Sampling data that were reported by the laboratory as "Not Detected" (ND) in a given sample were carried through the risk assessment using ½ the respective chemical's SQL as a surrogate for concentration. This reasonably conservative approach ensures that the chemical is considered to be present at least at some concentration (as opposed to not being present at all). Given the available SQLs, this approach is unlikely to significantly underestimate risk.

Sampling Data Reported as less than the Detection Limit: Analytical laboratories sometimes appear to measure trace level concentrations of chemicals at levels below the MDL when analyzing air samples. By definition, both the identity and concentration of such low-level analytical results are suspect. For this risk assessment, we assumed "detections below the MDL" to be present at a concentration as reported in AQS. This approach is not expected to have a significant impact on the overall conclusions of the assessment.

Sampling Data Chemical-Specific Measurement Uncertainty: As discussed in Section 2.8.2.6, based on a weight of evidence evaluation of the DQO criteria in the QAPP discussed in detail above, the acrolein and ethylene oxide monitoring data collected during the study were excluded from the selection of COPCs and the risk analysis. Acetonitrile data from the Grayson Lake site was also excluded due to sample contamination.

Excluding acrolein and acetonitrile (at Grayson Lake only) from the risk analysis means that hazard indices are likely to be underestimated. We do not have an accurate estimate of the acrolein HQs and how much they would have contributed to the overall hazard indices. Excluding EtO from the risk analysis means that chronic risks are likely to be underestimated. We do not have an accurate estimate of EtO chronic cancer risks were and how much they would have contributed to the cumulative risk. It is important to note that no known EtO sources (sterilizers and/or chemical manufacturers) were identified in the area.

Exposure Duration: The risk estimates for exposure to the airborne concentration found at the four sites assume that an individual is continuously exposed at the same location for 70 years. However, it is important to note that some of the monitoring sites are not located in residential areas. The risks were calculated assuming that residents would be at the monitoring sites for 24-hrs per day, 7-days per week. The actual activity patterns of the residents are not considered but could lead to lower or higher exposures and resulting risks (for example, higher risks might occur for a person who lived in the area but commuted to a job which involved

relatively higher-level exposures to toxic chemicals). Thus, this risk assessment may under- or overestimate the actual risks. Detailed information on the population in the Calvert City area would be needed to reduce this uncertainty.

Exposure Concentration: It is assumed that the exposure concentration calculated using essentially 1 year of monitoring data does not change over a 70-year lifetime. Using the 95UCL as a conservative estimator of the true average helps reduce uncertainty in the annual estimated for the year monitored but does not provide information about changing exposure patterns over the long term in which exposures may go up or down. As such, the computation of the exposure concentration for chemicals in air may have resulted in an overestimate or underestimate of risks. To reduce this uncertainty would require monitoring over several years, or modeling based on changes in estimated future meteorology and chemical emissions.

Toxicity Analysis - Chemicals without Dose-Response Values: Detected chemicals with no available dose-response values were not carried through the risk assessment process. This is likely to result in an underestimate of risk.

Toxicity Analysis - Route to Route Extrapolation: In limited circumstances, risk assessments may use route to route extrapolation (i.e., oral potency estimates extrapolated to inhalation potency) in an attempt to evaluate a chemical with no relevant toxicity information. Route to route extrapolation is recommended only from oral to inhaled exposure and only for carcinogens (USEPA, An Examination of EPA Risk Assessment Principles and Practices, EPA/100/B-04/001., 2004). However, there were no instances where IUR values were missing while Oral Slope factors were available. Therefore, these approaches were not implemented.

Toxicity Assessment: The dose-response values used in this assessment were developed using a variety of assumptions and data, such as using information from laboratory animal studies and extrapolating from high-doses used in experiments to the low-doses actually expected in the environment. A variety of methods are used to ensure a margin of safety in the resulting dose-response values.

Acute Hazard Assessment: Many acute benchmark values used in this study were developed for 8-hour or shorter exposure time periods and then compared to 24-hour sample concentrations. Comparing 24-hour composite sample data to acute toxicity values with significantly lower exposure periods results in uncertainty as to whether some acute risks were undetected. This, coupled with having only sampled on a subset of days during the monitoring period means that the acute risks may be underestimated

7 SUMMARY OF FINDINGS

A risk assessment of the potential for adverse chronic and acute human health impacts from inhalation of air toxics was conducted at three Calvert City monitoring locations. Data were collected for 46 VOCs from three air monitoring sites in these communities from October 2020 to December 2021. Acrolein and EtO were excluded from the risk analysis because present sampling and analysis methods are not reliable enough to accurately measure these chemicals in ambient air in the near-background concentration ranges observed during the study. The EPA is working on developing more accurate methods to measure these two chemicals. AirToxScreen analysis of the 2017 inventory of air toxics emissions data does indicate that acrolein is expected to be prevalent in many communities throughout the country, including Calvert City, KY, as a product of incomplete combustion (e.g., from motor vehicles) rather than from source-specific uses of the chemical.

For each monitoring site, the COPCs were determined to be chemicals that exceeded their screening levels and found in at least 10% of the samples. Data for the COPCs were then used in potential chronic risk and hazard assessments. All four sites had the same COPCs with the exception of 1,1-Dichloroethane and chloroprene. These chemicals were identified at the LWD site as a COPC, but not at the Calvert City Elementary, Johnson-Riley Road, or Grayson Lake sites. For acute hazard assessments, all chemicals that were detected at least once, rather than the COPCs, were evaluated.

In this risk assessment, the potential human health implications of the chronic exposures were characterized for both chronic cancer and non-cancer health effects using the 95UCL concentrations and chronic toxicity benchmark values. In addition, an acute risk characterization was performed. In this analysis, the maximum individual sample concentrations were compared to acute benchmarks.

The remainder of this Section provides the conclusions of the chronic and acute assessments.

7.1 Chronic Risk Characterization

In this risk assessment, the Calvert City Elementary School, Johnson-Riley Road, LWD, and Grayson Lake monitoring sites had a total cancer risk of $6x10^{-5}$, $1x10^{-4}$, $1x10^{-3}$, and $2x10^{-5}$, respectively. This means that, for every 1,000,000 people exposed at the levels measured at the monitor for 70 years, up to 60, 100, 1000, and 20, respectively *might* develop cancer over their lifetime. However, the LWD monitor which had the highest cancer risk, 1,000 in a million, is about 800 meters (about a half mile) from where people live, and risks at the nearest residence would be expected to be different. The calculated risks are *in excess* of a person's chance of developing cancer for reasons *other than* the

chemical exposures being evaluated. While the level of cancer risk that is of concern is a matter of personal and community judgment a cancer risk of greater than 1×10-4 or 100 in a million was considered a level of concern for the purposes of this assessment. The main chemical that contributed the greatest portion of these risks was EDC at all the sites with the exception of Grayson Lake. EDC contributed 63% to 92% of the total risk at the three Calvert City monitoring sites. The main risk driver at Grayson Lake was hexachlorobutadiene, which contributed to 45% of the total risk at this site. Benzene and vinyl chloride are other risk drivers that were found at the three sites, although contributing 27% or less of the risk at each site. The remaining risk drivers, although contributing less to the cumulative risk, include 1,1,2-Trichloroethane and 1,3-Butadiene at the Calvert City Elementary School; 1,1,2-Trichloroethane and 1,3-Butadiene at Johnson Riley Road; Chloroprene and 1,1,2-Trichloroethane at LWD; and 1,3-Butadiene and carbon tetrachloride at Grayson Lake.

Figure 7-1 shows the EDC concentrations measured in this monitoring study (from October 2020 – December 2021), compared to the historical concentration trends at monitoring sites with similar objectives. Data collected prior to 2020 were not used in this assessment, but these historical data provide additional weight of evidence that the EDC concentrations in the Calvert City area have been elevated for several years, and that the monitoring sites in the area consistently measure among the highest EDC concentrations in the country.

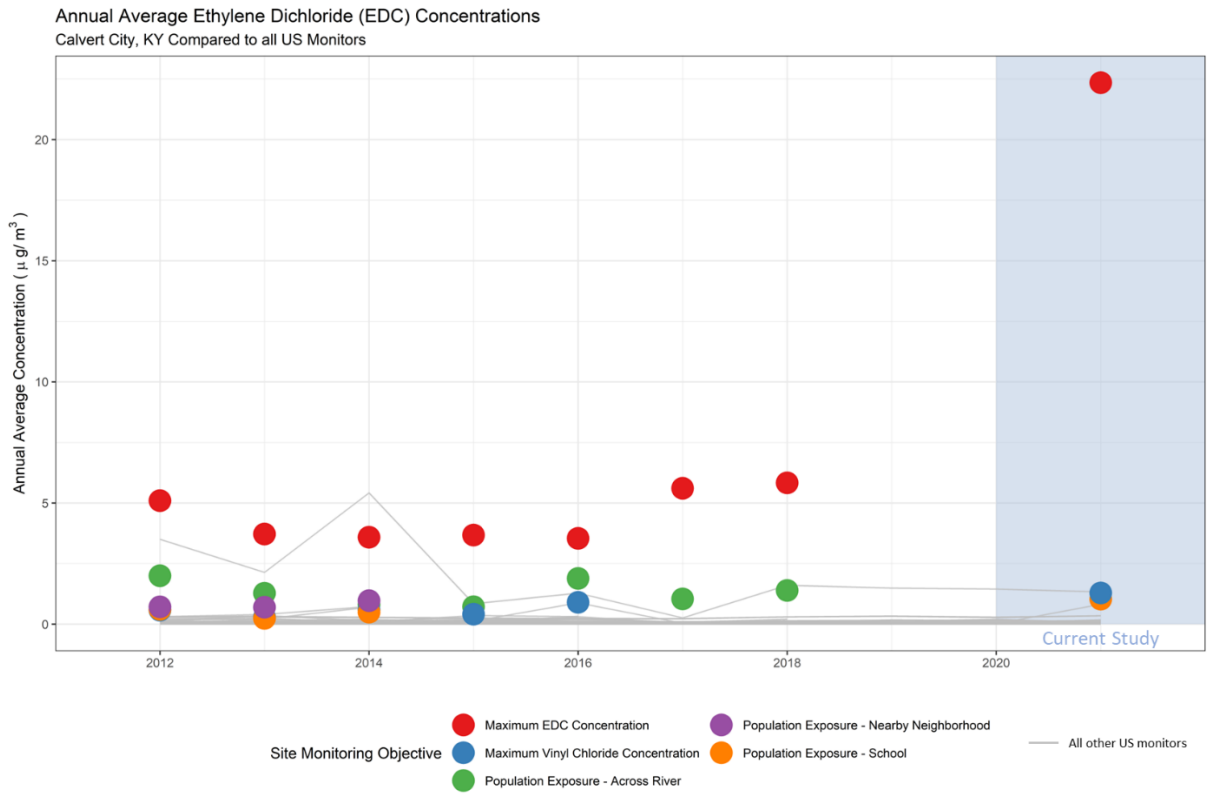

Figure 7-1: Annual average trend of ethylene dichloride concentrations: Calvert City, KY compared to all US monitors in AQS

7.2 Acute Hazard Characterization

The acute analysis compared each chemical's maximum concentration to its corresponding acute benchmark and found that acute effects were not expected.

7.3 Conclusion

EPA generally strives to protect the greatest number of persons possible to an individual lifetime risk level no higher than 1×10^{-6} (one in one million) and limiting to no higher than approximately 1×10^{-4} (one hundred in one million) as the estimated risk that a person living near a source would have if exposed to the maximum pollutant concentrations for 70 years. While this assessment is not a regulatory action under the CAA, it is reasonable to compare the risk estimates to this acceptability range to determine if further action to characterize or reduce risk is warranted.

Based on the results of this risk assessment, further steps to characterize and reduce cancer risks are warranted. EPA will work with Kentucky Division for Air Quality (KDAQ) to determine the appropriate steps to reduce EDC emissions in the area, with the goal of lowering the ambient concentrations.

7.4 Next Steps

7.4.1 EPA Next Steps

Ambient VOC monitoring is ongoing and will continue at the Calvert City and Grayson Lake monitoring sites. EPA is continuing to support KDAQ and will review additional monitoring data as needed in the future.

Recently, EPA proposed new rules for the Synthetic Organic Chemical Manufacturing Industry (also known as the "HON" rules)[9]. Under this proposal, fenceline monitoring would be required at certain HON sources for six specific HAPs, including ethylene dichloride (EDC), which is the main risk driver discussed in this Risk Assessment for Calvert City. Westlake Vinyls is an affected HON source and reports the most EDC emissions of all sources in both Calvert City and the country. The proposed HON rule's fenceline monitoring includes requirements to identify emission sources and make repairs if monitored fenceline concentrations are higher than an action level previously determined in

[9] HON Rule Proposal 88 FR 25080 - 25205, April 25, 2023

the rules by emissions modeling. EPA explained in its proposal that these rules, if finalized, will serve as a backstop to help ensure that emissions of EDC and the other five specific HAP at applicable sources will not be greater than expected from compliance with its proposed emission standards. The proposed HON rule would also require that fenceline monitoring data be reported and it will be made available through a public EPA database. The public comment period for the HON rules recently closed, and EPA is evaluating the voluminous comments it received, including comments on the proposed fenceline monitoring program. EPA is required by a court order to sign the final HON rules by March 29, 2024.[10]

7.4.2 Kentucky Department for Environmental Protection Next Steps

The results of the risk assessment indicated calculated risks exceed the standards established in Kentucky state law and regulations. Applicable air quality regulations in the Commonwealth of Kentucky includes the provisions of 401 KAR 63:020, Section 3. This regulation enables the KDEP to require action when it is deemed necessary if emissions of hazardous matter or toxic substances in such quantities or duration as to be harmful to the health of humans, animals, and plants. The regulation further requires the KDEP (on a facility specific/case-by-case basis) to evaluate the emissions and operational parameters of a facility where the air emissions may be or have been determined to be resulting in the impacts mentioned above.

EDC is a hazardous air pollutant and a hazardous substance. Air quality data at off-site locations collected over time indicate potential impacts to off-site receptors at concentrations that may be harmful to human receptors in the area. The results of the risk assessment indicate calculated risks exceeding the standards established in state law and regulations. In accordance with KRS 224.1-400 and 401 KAR 100:030, target risk in the Commonwealth means an excess cancer risk of $1x10^{-6}$ (one in one million) for cancer endpoints and a hazard index of 1.0 for non-cancer endpoints. These statutory and regulatory requirements, in concert with 401 KAR 63:020, establish target risk in the Commonwealth which is applicable and is the appropriate screening level for directing future permit requirements and amendments related to air emissions and operational parameters at the facility. Therefore, KDAQ is also working to reduce EDC emissions in the area with the goal of lowering ambient concentrations.

KDAQ is continuing to operate the three air toxics monitoring sites in the Calvert City area, with funding support from EPA.

[10] More information on the HON Rule Proposal can be found at EPA's HON webpage: https://www.epa.gov/stationary-sources-air-pollution/synthetic-organic-chemical-manufacturing-industry-organic-national

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9 GLOSSARY

95UCL	95th Percentile Upper Confidence Limit on the Mean
ADAF	Age-dependent Adjustment Factor
AEGLs	Acute Exposure Guidance Levels
AQS	Air Quality System
ATSDR	Agency for Toxic Substances and Disease Registry
BW	Body Weight
CARD	Cardiovascular effects
CAS	Chemical Abstract Service
COC	Chemicals of Concern
COPCs	Chemicals of Potential Concern
CPS_o	Oral Cancer Potency Slope
DEV	Developmental Effects
EC	Exposure Concentration
EPA	U.S. Environmental Protection Agency
ERPGs	Emergency Response Planning Guidelines
HAP	Hazardous Air Pollutant
HEAST	Health Effects Assessment Summary Table
HEM	Hematological Effect
HEP	Hepatic Effect
HI	Hazard Index
HQ	Hazard Quotient
IARC	International Agency for Research on Cancer
IMM	Immunological Effect
IR	Inhalation Rate
KDAQ	Kentucky Division of Air Quality
MMOA	Mutagenic Mode of Action
MRLs	Minimum Risk Levels
NEI	National Exposure Inventory

NEUR	Neurological Effect
OAQPS	Office of Air Quality, Planning and Standards
QA	Quality Assurance
QAPP	Quality Assurance Project Plan
QC	Quality Control
RELs	Reference Exposure Levels
RfC	Reference Concentration
RfD_o	Oral Reference Dose
RME	Reasonable Maximum Exposure
RPR	Reproductive Effect
RSP	Respiratory Effect
SL	Slope Factor
SQL	Sample Quantitation Limit
TICs	Tentatively Identified Compounds
TOSHI	Target Organ Specific Hazard Index
TRI	Toxic Release Inventory
UCL	Upper Confidence Limit
URE	Unit Risk Estimate
USEPA-R4	US Environmental Protection Agency - Region 4
WOE	Weight of Evidence

10 APPENDICES

10.1 APPENDIX A: Monitoring Study Tables

Calvert City, KY VOC Air Monitoring Study

Table 1.2-1: 2021 Census Estimates for Calvert City, KY (Zip Code 42029)

Calvert City, KY Census Overview	
Population Component	Persons
Total Population	2,525
Male	1,095
Female	1,430
Calvert City, KY Age Overview	
Age Group	Persons (Percentage)
Under 5 years	91 or 4%
5 to 9 years	159 or 6%
10 to 14 years	160 or 6%
15 to 19 years	254 or 10%
20 to 54 years	1,137 or 45%
55 to 59 years	146 or 6%
60 to 64 years	142 or 6%
65 to 74 years	167 or 7%
75 to 84 years	141 or 6%
85 years and over	128 or 5%
Median Age (years)	39.2
Calvert City, KY Educational Overview	
Education Level	Persons
Kindergarten	4
Elementary School Grades 1-4	193
Elementary School Grades 5-8	105
High School Grades 9-12	245
College Undergraduate	17
Population 5-9 yrs old (Enrolled in school)	150
Population 10-14 yrs old (Enrolled in school)	158
Population 15-17 yrs old (Enrolled in school)	187
Population 18-19 yrs old (Enrolled in school)	67
Population 20-24 yrs old (Enrolled in school)	0
Population 25-34 yrs old (Enrolled in school)	0
Population 35 and over (Enrolled in school)	9
Population 18-24 yrs old (Enrolled in College or Grad School)	8
White High School Graduate	1,538
White Bachelor's Degree	313
Black High School Graduate	0
Black Bachelor's Degreee	0
American Indian or Alaska Native High School Graduate	3
American Indian or Alaska Native Bachelors Degree Graduate	0

Calvert City, KY Racial Overview	
Race	Persons (Percentage)
White alone	2,386 or 98%
Black or African American alone	8 or 0.3%
American Indian and Alaska Native alone	2 or 0.1%
Asian alone	18 or 0.7%
Native Hawaiian and Other Pacific Islander Alone	0 or 0%
Some other race	14 or 0.6%
Calvert City, KY Income Overview	
Family/Household Characteristics	Income Level (dollars)
Median Household Income (dollars)	$55,938
Mean Household Income (dollars)	$78,222
Median Families Income (dollars)	$69,260
Mean Families Income (dollar)	$93,552
Nonfamily Household Median Income (dollars)	$30,479
Nonfamily Household Mean Income (dollars)	$39,011
Persons in Poverty (percent)	10.2% vs 12.8% in US
Calvert City, KY Income Overview	
Income Range	Household (Percentage)
Household Total Less than $10,000	9.80%
Household Total $10,000 to $14,999	6.30%
Household Total $15,000 to $24,999	8.20%
Household Total $25,000 to $34,999	5.80%
Household Total $35,000 to $49,999	25.90%
Household Total $50,000 to $74,999	11.20%
Household Total $75,000 to $99,999	15.90%
Household Total $100,000 to $149,999	10.70%
Household Total $150,000 to $199,999	4.10%
Household Total $200,000 or more	2.10%

The data provided are estimates for 2021 from the United States Census Bureau. The data is based on Calvert City, KY's zip code (42049). See: https://data.census.gov/cedsci/

Calvert City, KY Census Overview

Population Component	Persons
Total Population	2,525
Male	1,095
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Age Group	Persons (Percentage)
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55 to 59 years	146 or 6%
60 to 64 years	142 or 6%
65 to 74 years	167 or 7%
75 to 84 years	141 or 6%
85 years and over	128 or 5%
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Elementary School Grades 5-8	105
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Household Total $15,000 to $24,999	8.20%
Household Total $25,000 to $34,999	5.80%
Household Total $35,000 to $49,999	25.90%
Household Total $50,000 to $74,999	11.20%
Household Total $75,000 to $99,999	15.90%
Household Total $100,000 to $149,999	10.70%
Household Total $150,000 to $199,999	4.10%
Household Total $200,000 or more	2.10%

The data provided are estimates for 2021 from the United States Census Bureau. The data is based on Calvert City, KY's zip code (42049). See: https://data.census.gov/cedsci/

Table 2.6-1: Chemicals Detected at the Calvert City Elementary School Monitoring Location During the Calvert City, KY Special Air Sampling Study

Chemical	CAS	Detection Frequency	Average Conc. (µg/m^3)	Standard Deviation	Range of Detected Concentrations (µg/m^3)	Median Conc. (µg/m^3)
Carbon disulfide	75-15-0	69/69 or 100%	0.04306	0.02923	0.012 - 0.18	0.0380
1,3-Butadiene	106-99-0	59/69 or 86%	0.0390	0.03323	0.0058 - 0.176	0.0281
Methyl tert-butyl ether	1634-04-4	1/69 or 1%	0.0115	0	0.0115 - 0.012	0.0115
Ethyl acrylate	140-88-5	0/69 or 0%	ND	ND	ND	ND
Methyl methacrylate	80-62-6	1/69 or 1%	0.0102	0	0.0102 - 0.01	0.0102
Acrolein - Verified	107-02-8	68/68 or 100%	0.4790	0.38936	0.0871 - 2.13	0.3118
Methyl isobutyl ketone	108-10-1	69/69 or 100%	0.1441	0.14812	0.0279 - 1.176	0.1204
Ethylene oxide	75-21-8	42/54 or 78%	0.2048	0.12256	0.0396 - 0.681	0.1727
Acetonitrile	75-05-8	60/64 or 94%	0.2143	0.11542	0.068 - 0.651	0.1863
Acrylonitrile	107-13-1	4/69 or 6%	0.0116	0.00493	0.0076 - 0.02	0.0093
Chloromethane	74-87-3	69/69 or 100%	0.9883	0.13172	0.7309 - 1.354	0.9870
Dichloromethane	75-09-2	69/69 or 100%	0.3873	0.21159	0.1441 - 1.414	0.3421
Chloroform	67-66-3	68/69 or 99%	0.1330	0.09967	0.0679 - 0.757	0.0954
Carbon tetrachloride	56-23-5	69/69 or 100%	0.5521	0.19826	0.2176 - 1.881	0.5297
Bromoform	75-25-2	36/69 or 52%	0.0175	0.00557	0.0072 - 0.028	0.0171
Chloroethane	75-00-3	37/69 or 54%	0.0553	0.04350	0.0103 - 0.172	0.0462
1,1-Dichloroethane	75-34-3	40/69 or 58%	0.0653	0.13948	0.0016 - 0.652	0.0113
Methyl chloroform	71-55-6	58/69 or 84%	0.0176	0.01236	0.0087 - 0.072	0.0131
Ethylene dichloride	107-06-2	66/69 or 96%	1.0763	1.87794	0.0283 - 11.21	0.1941
Tetrachloroethylene	127-18-4	49/68 or 72%	0.0406	0.01665	0.0142 - 0.103	0.0353
1,1,2,2-Tetrachloroethane	79-34-5	1/69 or 1%	0.0021	0	0.0021 - 0.002	0.0021
Bromomethane	74-83-9	66/69 or 96%	0.0341	0.00896	0.0229 - 0.081	0.0324
1,1,2-Trichloroethane	79-00-5	22/69 or 32%	0.0749	0.08940	0.0076 - 0.383	0.0428
Trichloroethylene	79-01-6	54/69 or 78%	0.0307	0.00937	0.0086 - 0.044	0.0344
1,1-Dichloroethylene	75-35-4	12/69 or 17%	0.0126	0.00494	0.004 - 0.019	0.0123
1,2-Dichloropropane	78-87-5	4/69 or 6%	0.0204	0.00245	0.0176 - 0.024	0.0201
trans-1,3-Dichloropropene	10061-02-6	0/69 or 0%	ND	ND	ND	ND
cis-1,3-Dichloropropene	10061-01-5	0/69 or 0%	ND	ND	ND	ND
Chloroprene	126-99-8	1/69 or 1%	0.0011	0	0.0011 - 0.001	0.0011
Ethylene dibromide	106-93-4	1/69 or 1%	0.0031	0	0.0031 - 0.003	0.0031
Hexachlorobutadiene	87-68-3	8/69 or 12%	0.0045	0.00332	0.0011 - 0.011	0.0027
Vinyl chloride	75-01-4	41/69 or 59%	0.1613	0.17577	0.0031 - 0.805	0.0992
m/p Xylene	108-38-3	69/69 or 100%	0.2900	0.44702	0.0473 - 3.196	0.1615
Benzene	71-43-2	69/69 or 100%	0.4145	0.14931	0.1281 - 0.936	0.3897
Toluene	108-88-3	69/69 or 100%	0.7883	2.02943	0.1251 - 17.069	0.4220
Ethylbenzene	100-41-4	69/69 or 100%	0.0949	0.11922	0.0178 - 0.86	0.0612
o-Xylene	95-47-6	69/69 or 100%	0.1090	0.12011	0.0182 - 0.799	0.0660
Styrene	100-42-5	46/57 or 81%	0.0422	0.02626	0.0081 - 0.122	0.0341
Chlorobenzene	108-90-7	0/69 or 0%	ND	ND	ND	ND
1,4-Dichlorobenzene	106-46-7	49/69 or 71%	0.0162	0.00855	0.0048 - 0.034	0.0144
1,2,4-Trichlorobenzene	120-82-1	20/69 or 29%	0.0190	0.01982	0.003 - 0.075	0.0078

Table 2.6-2: Chemicals Detected at the Johnson-Riley Road Monitoring Location During the Calvert City, KY Special Air Sampling Study

Chemical	CAS	Detection Frequency	Average Conc. (µg/m^3)	Standard Deviation	Range of Detected Concentrations (µg/m^3)	Median Conc. (µg/m^3)
Carbon disulfide	75-15-0	66/67 or 99%	0.0528	0.03403	0.0134 - 0.176	0.0441
1,3-Butadiene	106-99-0	58/67 or 87%	0.0342	0.02199	0.0077 - 0.093	0.0273
Methyl tert-butyl ether	1634-04-4	2/67 or 3%	0.0094	0.00108	0.0083 - 0.01	0.0094
Ethyl acrylate	140-88-5	1/67 or 1%	0.1138	0	0.1138 - 0.114	0.1138
Methyl methacrylate	80-62-6	4/66 or 6%	0.0784	0.04212	0.0352 - 0.125	0.0766
Acrolein - Verified	107-02-8	66/66 or 100%	0.5795	0.43595	0.0821 - 1.914	0.4333
Methyl isobutyl ketone	108-10-1	67/67 or 100%	0.3013	0.21133	0.0492 - 0.049	0.2769
Ethylene oxide	75-21-8	33/48 or 69%	0.2995	0.22071	0.0677 - 1.16	0.2360
Acetonitrile	75-05-8	60/65 or 92%	0.3736	0.17495	0.0747 - 0.923	0.3148
Acrylonitrile	107-13-1	5/66 or 8%	0.0338	0.01993	0.0195 - 0.073	0.0243
Chloromethane	74-87-3	67/67 or 100%	1.0064	0.14638	0.7413 - 1.392	0.9849
Dichloromethane	75-09-2	67/67 or 100%	0.4372	0.24518	0.1625 - 1.438	0.3577
Chloroform	67-66-3	67/67 or 100%	0.1397	0.10672	0.0708 - 0.708	0.1064
Carbon tetrachloride	56-23-5	67/67 or 100%	0.5153	0.09118	0.1453 - 0.874	0.5039
Bromoform	75-25-2	34/67 or 51%	0.0233	0.01918	0.0093 - 0.116	0.0181
Chloroethane	75-00-3	46/63 or 73%	0.4206	0.63013	0.0132 - 2.744	0.1173
1,1-Dichloroethane	75-34-3	30/54 or 56%	0.1095	0.26950	0.0057 - 1.376	0.0257
Methyl chloroform	71-55-6	45/52 or 87%	0.0245	0.02082	0.0087 - 0.113	0.0153
Ethylene dichloride	107-06-2	50/54 or 93%	1.5524	2.95430	0.0591 - 15.419	0.3225
Tetrachloroethylene	127-18-4	52/56 or 93%	0.0595	0.03045	0.0142 - 0.14	0.0512
1,1,2,2-Tetrachloroethane	79-34-5	0/61 or 0%	ND	ND	ND	ND
Bromomethane	74-83-9	59/60 or 98%	0.0403	0.02356	0.0167 - 0.145	0.0338
1,1,2-Trichloroethane	79-00-5	24/62 or 39%	0.1012	0.13895	0.0076 - 0.584	0.0453
Trichloroethylene	79-01-6	57/67 or 85%	0.0353	0.01270	0.0075 - 0.077	0.0355
1,1-Dichloroethylene	75-35-4	11/67 or 16%	0.0176	0.01618	0.0056 - 0.067	0.0127
1,2-Dichloropropane	78-87-5	1/67 or 1%	0.0407	0	0.0407 - 0.041	0.0407
trans-1,3-Dichloropropene	10061-02-6	0/67 or 0%	ND	ND	ND	ND
cis-1,3-Dichloropropene	10061-01-5	0/67 or 0%	ND	ND	ND	ND
Chloroprene	126-99-8	0/67 or 0%	ND	ND	ND	ND
Ethylene dibromide	106-93-4	0/67 or 0%	ND	ND	ND	ND
Hexachlorobutadiene	87-68-3	7/67 or 10%	0.0084	0.01444	0.0021 - 0.044	0.0021
Vinyl chloride	75-01-4	59/67 or 88%	2.0931	3.32775	0.0036 - 13.751	0.2812
m/p Xylene	108-38-3	67/67 or 100%	0.3122	0.16230	0.0899 - 0.738	0.2900
Benzene	71-43-2	67/67 or 100%	0.4594	0.17975	0.1364 - 0.987	0.4344
Toluene	108-88-3	67/67 or 100%	0.5954	0.33426	0.185 - 1.496	0.5125
Ethylbenzene	100-41-4	67/67 or 100%	0.0967	0.04458	0.0369 - 0.233	0.0881
o-Xylene	95-47-6	67/67 or 100%	0.1344	0.07031	0.0373 - 0.34	0.1263
Styrene	100-42-5	51/57 or 89%	0.0563	0.02902	0.0102 - 0.144	0.0524
Chlorobenzene	108-90-7	6/67 or 9%	0.0159	0.00917	0.0051 - 0.03	0.0152
1,4-Dichlorobenzene	106-46-7	46/67 or 69%	0.0267	0.01335	0.0066 - 0.063	0.0249
1,2,4-Trichlorobenzene	120-82-1	19/67 or 28%	0.0187	0.01622	0.0037 - 0.056	0.0111

Table 2.6-3: Chemicals Detected at the LWD Monitoring Location During the Calvert City, KY Special Air Sampling Study

Chemical	CAS	Detection Frequency	Average Conc. (µg/m^3)	Standard Deviation	Range of Detected Concentrations (µg/m^3)	Median Conc. (µg/m^3)
Carbon disulfide	75-15-0	72/72 or 100%	0.0436	0.03180	0.0067 - 0.178	0.0322
1,3-Butadiene	106-99-0	64/73 or 88%	0.0473	0.05749	0.0076 - 0.373	0.0284
Methyl tert-butyl ether	1634-04-4	1/73 or 1%	0.0076	0	0.0076 - 0.008	0.0076
Ethyl acrylate	140-88-5	0/73 or 0%	ND	ND	ND	ND
Methyl methacrylate	80-62-6	3/73 or 4%	0.0614	0.03469	0.027 - 0.109	0.0483
Acrolein - Verified	107-02-8	73/73 or 100%	0.4690	0.33661	0.0789 - 1.339	0.4379
Methyl isobutyl ketone	108-10-1	73/73 or 100%	0.2308	0.19928	0.0422 - 1.311	0.1778
Ethylene oxide	75-21-8	46/55 or 84%	0.2770	0.26312	0.0276 - 1.496	0.1896
Acetonitrile	75-05-8	59/64 or 92%	0.1987	0.09742	0.0519 - 0.514	0.1826
Acrylonitrile	107-13-1	7/72 or 10%	0.0132	0.01052	0.0035 - 0.036	0.0106
Chloromethane	74-87-3	73/73 or 100%	0.9845	0.16207	0.7206 - 1.555	0.9560
Dichloromethane	75-09-2	73/73 or 100%	0.5548	0.55813	0.1625 - 4.55	0.4133
Chloroform	67-66-3	73/73 or 100%	0.8239	2.11629	0.0688 - 15.427	0.1623
Carbon tetrachloride	56-23-5	73/73 or 100%	0.7475	0.72385	0.0981 - 5.523	0.5426
Bromoform	75-25-2	41/73 or 56%	0.0171	0.00822	0.0052 - 0.048	0.0155
Chloroethane	75-00-3	61/73 or 84%	0.4270	0.69986	0.0108 - 3.746	0.1546
1,1-Dichloroethane	75-34-3	59/73 or 81%	0.9463	2.35199	0.0014 - 16.006	0.1429
Methyl chloroform	71-55-6	66/73 or 90%	0.0254	0.02709	0.0046 - 0.213	0.0183
Ethylene dichloride	107-06-2	72/73 or 99%	22.1010	45.87327	0.0429 - 220.964	2.3472
Tetrachloroethylene	127-18-4	72/73 or 99%	0.1083	0.16557	0.0075 - 1.214	0.0580
1,1,2,2-Tetrachloroethane	79-34-5	19/73 or 26%	0.0179	0.02098	0.0007 - 0.084	0.0106
Bromomethane	74-83-9	70/73 or 96%	0.0442	0.08084	0.0124 - 0.707	0.0311
1,1,2-Trichloroethane	79-00-5	54/72 or 75%	0.6373	1.52959	0.0115 - 10.611	0.1937
Trichloroethylene	79-01-6	67/73 or 92%	0.0542	0.05369	0.0056 - 0.37	0.0408
1,1-Dichloroethylene	75-35-4	38/72 or 53%	0.0855	0.12332	0.0048 - 0.63	0.0293
1,2-Dichloropropane	78-87-5	7/73 or 10%	0.0217	0.01062	0.0106 - 0.042	0.0185
trans-1,3-Dichloropropene	10061-02-6	0/73 or 0%	ND	ND	ND	ND
cis-1,3-Dichloropropene	10061-01-5	0/73 or 0%	ND	ND	ND	ND
Chloroprene	126-99-8	21/73 or 29%	0.0812	0.12537	0.0065 - 0.567	0.0358
Ethylene dibromide	106-93-4	1/73 or 1%	0.0165	0	0.0165 - 0.017	0.0165
Hexachlorobutadiene	87-68-3	12/73 or 16%	0.0096	0.01189	0.0021 - 0.042	0.0035
Vinyl chloride	75-01-4	69/73 or 95%	1.1172	1.34552	0.0033 - 8.23	0.7489
m/p Xylene	108-38-3	61/61 or 100%	0.1806	0.15582	0.0465 - 1.179	0.1502
Benzene	71-43-2	73/73 or 100%	0.4590	0.23590	0.107 - 1.465	0.4057
Toluene	108-88-3	73/73 or 100%	0.3935	0.30505	0.1168 - 2.495	0.3401
Ethylbenzene	100-41-4	73/73 or 100%	0.0645	0.03944	0.0208 - 0.307	0.0604
o-Xylene	95-47-6	73/73 or 100%	0.0722	0.05362	0.0178 - 0.409	0.0634
Styrene	100-42-5	50/64 or 78%	0.0464	0.03591	0.0113 - 0.249	0.0402
Chlorobenzene	108-90-7	29/74 or 39%	0.0713	0.11143	0.0092 - 0.615	0.0377
1,4-Dichlorobenzene	106-46-7	52/73 or 71%	0.0142	0.00754	0.0036 - 0.042	0.0120
1,2,4-Trichlorobenzene	120-82-1	17/73 or 23%	0.0208	0.01619	0.0015 - 0.066	0.0160

Table 2.6-4: Chemicals Detected at the Grayson Lake Monitoring Location During the Calvert City, KY Special Air Sampling Study

Chemical	CAS	Detection Frequency	Average Conc. (µg/m^3)	Standard Deviation	Range of Detected Concentrations (µg/m^3)	Median Conc. (µg/m^3)
Carbon disulfide	75-15-0	68/69 or 99%	0.0339	0.02405	0.0075 - 0.149	0.0271
1,3-Butadiene	106-99-0	52/69 or 75%	0.0249	0.01927	0.0053 - 0.109	0.0179
Methyl tert-butyl ether	1634-04-4	2/69 or 3%	0.0081	0.00054	0.0076 - 0.009	0.0081
Ethyl acrylate	140-88-5	0/69 or 0%	ND	ND	ND	ND
Methyl methacrylate	80-62-6	1/69 or 1%	0.0119	0	0.0119 - 0.012	0.0119
Acrolein - Verified	107-02-8	69/69 or 100%	0.5422	0.36616	0.1357 - 1.779	0.4333
Methyl isobutyl ketone	108-10-1	69/69 or 100%	0.0824	0.05368	0.0184 - 0.291	0.0672
Ethylene oxide	75-21-8	40/53 or 75%	0.2126	0.12554	0.0573 - 0.546	0.1946
Acetonitrile	75-05-8	69/69 or 100%	30.0456	26.24083	0.5792 - 126.577	19.9770
Acrylonitrile	107-13-1	1/69 or 1%	0.0065	0	0.0065 - 0.007	0.0065
Chloromethane	74-87-3	69/69 or 100%	0.9250	0.12828	0.6628 - 1.233	0.9415
Dichloromethane	75-09-2	69/69 or 100%	0.9951	1.53944	0.2115 - 12.886	0.6287
Chloroform	67-66-3	63/67 or 94%	0.0859	0.01212	0.0659 - 0.117	0.0835
Carbon tetrachloride	56-23-5	69/69 or 100%	0.5093	0.09074	0.0723 - 0.654	0.5171
Bromoform	75-25-2	32/69 or 46%	0.0142	0.00789	0.0052 - 0.052	0.0129
Chloroethane	75-00-3	22/69 or 32%	0.0200	0.01789	0.0106 - 0.079	0.0137
1,1-Dichloroethane	75-34-3	21/69 or 30%	0.0071	0.00493	0.0036 - 0.028	0.0061
Methyl chloroform	71-55-6	51/69 or 74%	0.0109	0.00297	0.0076 - 0.029	0.0104
Ethylene dichloride	107-06-2	60/69 or 87%	0.0638	0.02003	0.0287 - 0.163	0.0650
Tetrachloroethylene	127-18-4	28/69 or 41%	0.0375	0.01227	0.0217 - 0.071	0.0339
1,1,2,2-Tetrachloroethane	79-34-5	4/69 or 6%	0.0088	0.01160	0.0014 - 0.029	0.0024
Bromomethane	74-83-9	64/69 or 93%	0.0322	0.01119	0.0206 - 0.083	0.0285
1,1,2-Trichloroethane	79-00-5	1/69 or 1%	0.0322	0	0.0322 - 0.032	0.0322
Trichloroethylene	79-01-6	41/69 or 59%	0.0292	0.00806	0.014 - 0.04	0.0328
1,1-Dichloroethylene	75-35-4	2/69 or 3%	0.0216	0.00654	0.0151 - 0.028	0.0216
1,2-Dichloropropane	78-87-5	3/69 or 4%	0.0276	0.01035	0.0185 - 0.042	0.0222
trans-1,3-Dichloropropene	10061-02-6	0/69 or 0%	ND	ND	ND	ND
cis-1,3-Dichloropropene	10061-01-5	0/69 or 0%	ND	ND	ND	ND
Chloroprene	126-99-8	0/69 or 0%	ND	ND	ND	ND
Ethylene dibromide	106-93-4	0/69 or 0%	ND	ND	ND	ND
Hexachlorobutadiene	87-68-3	8/69 or 12%	0.0088	0.01496	0.0021 - 0.048	0.0021
Vinyl chloride	75-01-4	4/69 or 6%	0.0032	0.00106	0.0015 - 0.004	0.0035
m/p Xylene	108-38-3	69/69 or 100%	0.1211	0.08333	0.0334 - 0.512	0.1012
Benzene	71-43-2	69/69 or 100%	0.3604	0.13756	0.1485 - 0.878	0.3450
Toluene	108-88-3	69/69 or 100%	0.51918	0.29482	0.1586 - 1.451	0.4672
Ethylbenzene	100-41-4	69/69 or 100%	0.04817	0.02710	0.0178 - 0.197	0.0421
o-Xylene	95-47-6	69/69 or 100%	0.05255	0.03451	0.0156 - 0.235	0.0447
Styrene	100-42-5	55/61 or 90%	0.04646	0.07255	0.0098 - 0.486	0.0264
Chlorobenzene	108-90-7	4/69 or 6%	0.00783	0.00156	0.0055 - 0.01	0.0081
1,4-Dichlorobenzene	106-46-7	28/69 or 41%	0.00906	0.00573	0.0042 - 0.036	0.0081
1,2,4-Trichlorobenzene	120-82-1	14/69 or 20%	0.01399	0.01230	0.003 - 0.045	0.0082

Data provided by Eastern Research Group per analysis of samples taken by KDAQ from October 2020 through December 2021. Frequency Detected excludes “Non-detects” and "Invalid" samples. ProUCL v 5.1.002 was utilized to calculate the 95% Upper Confidence on the Mean concentrations as well as Standard Deviations, Medians and Averages of valid samples. ND denotes that the chemical of interest was not detected in the sample. For risk screening purposes, note that *m/p Xylene and o-Xylene* levels are evaluated, and Xylenes (mixed) (CAS 1330-20-7) was used as a surrogate as discussed in section 6.1.

Table 2.10-1: Chemicals of Potential Concern Identification and Exposure Point Concentration Determination for the Calvert City Elementary School Monitoring Location, Calvert City, KY Air Sampling Study

Chemical	CAS	Detection Frequency	Average Conc. (µg/m^3)	Range of Detected Concentrations (µg/m^3)	ProUCL Suggested 95% UCL Distribution for the Detected Chemicals	95% UCL Concentration (µg/m^3)	Chemical of Potential Concern
1,3-Butadiene	106-99-0	59/69 or 86%	0.0390	0.0058 - 0.176	95% Approximate Gamma UCL	0.0482	X
Acrylonitrile	107-13-1	4/69 or 6%	0.0116	0.0076 - 0.02	95% Chebyshev (Mean, Sd) UCL	0.00223	
Carbon tetrachloride	56-23-5	69/69 or 100%	0.5521	0.2176 - 1.881	95% Modified-t UCL	0.595	X
1,1-Dichloroethane	75-34-3	40/69 or 58%	0.0653	0.0016 - 0.652	95% Chebyshev (Mean, Sd) UCL	0.113	X
Ethylene dichloride	107-06-2	66/69 or 96%	1.0763	0.0283 - 11.21	95% Chebyshev (Mean, Sd) UCL	2.009	X
1,1,2-Trichloroethane	79-00-5	22/69 or 32%	0.0749	0.0076 - 0.383	95% Chebyshev (Mean, Sd) UCL	0.115	X
Ethylene dibromide	106-93-4	1/69 or 1%	0.0031	0.0031 - 0.003	95% Chebyshev (Mean, Sd) UCL	0.00024	
Vinyl chloride	75-01-4	41/69 or 59%	0.1613	0.0031 - 0.805	95% Chebyshev (Mean, Sd) UCL	0.189	X
Benzene	71-43-2	69/69 or 100%	0.4145	0.1281 - 0.936	95% Student's-t UCL	0.445	X
Ethylbenzene	100-41-4	69/69 or 100%	0.0949	0.0178 - 0.86	95% H-UCL	0.105	X

Table 2.10-2: Chemicals of Potential Concern Identification and Exposure Point Concentration Determination for the Johnson-Riley Road Monitoring Location, Calvert City, KY Air Sampling Study

Chemical	CAS	Detection Frequency	Average Conc. (µg/m^3)	Range of Detected Concentrations (µg/m^3)	ProUCL Suggested 95% UCL Distribution for the Detected Chemicals	95% UCL Concentration (µg/m^3)	Chemical of Potential Concern
1,3-Butadiene	106-99-0	58/67 or 87%	0.0342	0.0077 - 0.093	95% Approximate Gamma UCL	0.0399	X
Acrylonitrile	107-13-1	5/66 or 8%	0.0338	0.0195 - 0.073	95% Chebyshev (Mean, Sd) UCL	0.00823	
Carbon tetrachloride	56-23-5	67/67 or 100%	0.5153	0.1453 - 0.874	95% Student's-t UCL	0.534	X
1,1-Dichloroethane	75-34-3	30/54 or 56%	0.1095	0.0057 - 1.376	95% Chebyshev (Mean, Sd) UCL	0.177	X
Ethylene dichloride	107-06-2	50/54 or 93%	1.5524	0.0591 - 15.419	95% Chebyshev (Mean, Sd) UCL	2.705	X
1,1,2-Trichloroethane	79-00-5	24/62 or 39%	0.1012	0.0076 - 0.584	95% Chebyshev (Mean, Sd) UCL	0.14	X
Vinyl chloride	75-01-4	59/67 or 88%	2.0931	0.0036 - 13.751	95% Chebyshev (Mean, Sd) UCL	3.561	X
Benzene	71-43-2	67/67 or 100%	0.4594	0.1364 - 0.987	95% Approximate Gamma UCL	0.499	X

Table 2.10-3: Chemicals of Potential Concern Identification and Exposure Point Concentration Determination for the LWD Monitoring Location, Calvert City, KY Air Sampling Study

Chemical	CAS	Detection Frequency	Average Conc. (µg/m^3)	Range of Detected Concentrations (µg/m^3)	ProUCL Suggested 95% UCL Distribution for the Detected Chemicals	95% UCL Concentration (µg/m^3)	Chemical of Potential Concern
1,3-Butadiene	106-99-0	64/73 or 88%	0.0473	0.0076 - 0.373	95% H-UCL	0.0555	X
Acrylonitrile	107-13-1	7/72 or 10%	0.0132	0.0035 - 0.036	95% Chebyshev (Mean, Sd) UCL	0.00391	
Chloroform	67-66-3	73/73 or 100%	0.8239	0.0688 - 15.427	95% Chebyshev (Mean, Sd) UCL	1.911	X
Carbon tetrachloride	56-23-5	73/73 or 100%	0.7475	0.0981 - 5.523	95% Chebyshev (Mean, Sd) UCL	1.119	X
1,1-Dichloroethane	75-34-3	59/73 or 81%	0.9463	0.0014 - 16.006	95% H-UCL	1.758	X
Ethylene dichloride	107-06-2	72/73 or 99%	22.1010	0.0429 - 220.964	95% Chebyshev (Mean, Sd) UCL	45.24	X
Bromomethane	74-83-9	70/73 or 96%	0.0442	0.0124 - 0.707	95% Chebyshev (Mean, Sd) UCL	0.0876	X
1,1,2-Trichloroethane	79-00-5	54/72 or 75%	0.6373	0.0115 - 10.611	95% Chebyshev (Mean, Sd) UCL	1.181	X
Trichloroethylene	79-01-6	67/73 or 92%	0.0542	0.0056 - 0.37	95% H-UCL	0.065	X
Chloroprene	126-99-8	21/73 or 29%	0.0812	0.0065 - 0.567	95% Chebyshev (Mean, Sd) UCL	0.121	X
Ethylene dibromide	106-93-4	1/73 or 1%	0.0165	0.0165 - 0.017	95% Chebyshev (Mean, Sd) UCL	0.00121	
Vinyl chloride	75-01-4	69/73 or 95%	1.1172	0.0033 - 8.23	95% Approximate Gamma UCL	1.364	X
Benzene	71-43-2	73/73 or 100%	0.4590	0.107 - 1.465	95% H-UCL	0.506	X

Table 2.10-4: Chemicals of Potential Concern Identification and Exposure Point Concentration Determination for the Grayson Lake Monitoring Location, Calvert City, KY Air Sampling Study

Chemical	CAS	Detection Frequency	Average Conc. (µg/m^3)	Range of Detected Concentrations (µg/m^3)	ProUCL Suggested 95% UCL Distribution for the Detected Chemicals	95% UCL Concentration (µg/m^3)	Chemical of Potential Concern
1,3-Butadiene	106-99-0	52/69 or 75%	0.0249	0.0053 - 0.109	95% Chebyshev (Mean, Sd) UCL	0.0387	X
Carbon tetrachloride	56-23-5	69/69 or 100%	0.5093	0.0723 - 0.654	95% Student's-t UCL	0.528	X
Ethylene dichloride	107-06-2	60/69 or 87%	0.0638	0.0287 - 0.163	95% Modified-t UCL	0.0684	X
Hexachlorobutadiene	87-68-3	8/69 or 12%	0.0088	0.0021 - 0.048	95% Chebyshev (Mean, Sd) UCL	0.335	X
Benzene	71-43-2	69/69 or 100%	0.3604	0.1485 - 0.878	95% Student's-t UCL	0.388	X

Chemical concentration data were obtained from ERG and reflect data collected by KDAQ. The 95 percentile Upper Confidence Limits for the mean per chemical, Distribution for the Detected Chemicals, and Median Concentrations were calculated using ProUCL (see: https://www.epa.gov/land-research/proucl-software). If a chemical was "Not Detected", 1/2 sample quantitation limit was assumed for the chemical on that day. The "Chemicals of Potential Concern" column indicates (X) that the chemical was retained because it was detected above detection limit in at least 10% of the samples.

Table 2.10-5: Chemicals Deleted Due to Low Detection Frequencies for the Calvert City Elementary School Monitoring Location, Calvert City, KY Air Sampling Study

Chemical	CAS	Detection Frequency	Average Conc. (µg/m^3)	Range of Detected Concentrations (µg/m^3)	ProUCL Suggested 95% UCL Distribution for the Detected Chemicals	95% UCL Concentration (µg/m^3)
Acrylonitrile	107-13-1	4/69 or 6%	0.0116	0.0076 - 0.02	95% Chebyshev (Mean, Sd) UCL	0.00223
Ethylene dibromide	106-93-4	1/69 or 1%	0.0031	0.0031 - 0.003	95% Chebyshev (Mean, Sd) UCL	0.00024

Table 2.10-6: Chemicals Deleted Due to Low Detection Frequencies for the Johnson-Riley Road Monitoring Location, Calvert City, KY Air Sampling Study

Chemical	CAS	Detection Frequency	Average Conc. (µg/m^3)	Range of Detected Concentrations (µg/m^3)	ProUCL Suggested 95% UCL Distribution for the Detected Chemicals	95% UCL Concentration (µg/m^3)
Acrylonitrile	107-13-1	5/66 or 8%	0.0338	0.0195 - 0.073	95% Chebyshev (Mean, Sd) UCL	0.00823

Table 2.10-7: Chemicals Deleted Due to Low Detection Frequencies for the LWD Monitoring Location, Calvert City, KY Air Sampling Study

Chemical	CAS	Detection Frequency	Average Conc. (µg/m^3)	Range of Detected Concentrations (µg/m^3)	ProUCL Suggested 95% UCL Distribution for the Detected Chemicals	95% UCL Concentration (µg/m^3)
Acrylonitrile	107-13-1	7/72 or 10%	0.0132	0.0035 - 0.036	95% Chebyshev (Mean, Sd) UCL	0.00391
Ethylene dibromide	106-93-4	1/73 or 1%	0.0165	0.0165 - 0.017	95% Chebyshev (Mean, Sd) UCL	0.00121

Table 2.10-8: Chemicals Deleted Due to Low Detection Frequencies for the Grayson Lake Monitoring Location, Calvert City, KY Air Sampling Study

Chemical	CAS	Detection Frequency	Average Conc. (µg/m^3)	Range of Detected Concentrations (µg/m^3)	ProUCL Suggested 95% UCL Distribution for the Detected Chemicals	95% UCL Concentration (µg/m^3)
Acetonitrile	75-05-8	69/69 or 100%	30.04562	0.5792 - 126.577	95% Chebyshev (Mean, Sd) UCL	43.92

Acrylonitrile and Ethylene dibromide will be evaluated in the Uncertainty Section because although it was not detected in greater than 10% of the samples, high short-term exposures could lead to acute health effects. As discussed in section 2.8.2.6.3, acetonitrile was excluded at the Grayson Lake site due to canister contamination.

Table 3.1-1: Chronic Dose-Response Toxicity Values for the Calvert City Elementary School Monitoring Location, Calvert City, KY Chemicals of Potential Concern

Chemical	CAS	ProUCL Suggested 95% UCL Disrubtion for the Detected Chemical	Median Concentration (µg/m^3)	IUR (1/µg/m^3)	EPA MOA	EPA WOE	Source	IARC WOE	RfC (µg/m^3)	Source
Ethylene dichloride	107-06-2	95% Chebyshev (Mean, Sd) UCL	0.172	0.000026		B2	IRIS	2B	2400	ATSDR
Dichloromethane	75-09-2	95% H-UCL	0.342	*0.000068*	M	LH	IRIS	2A		
Carbon tetrachloride	56-23-5	95% Modified-t UCL	0.53	0.000006		LH	IRIS	2B	100	IRIS
Benzene	71-43-2	95% Student's-t UCL	0.39	0.0000078		CH	IRIS	1	30	IRIS
1,1,2-Trichloroethane	79-00-5	95% Chebyshev (Mean, Sd) UCL	0.0937	0.000016		C	IRIS	3		
Vinyl chloride	75-01-4	95% Chebyshev (Mean, Sd) UCL	0.035	0.0000088		CH	IRIS	1	100	IRIS
1,3-Butadiene	106-99-0	95% Approximate Gamma UCL	0.0292	0.00003		CH	IRIS	1	2	IRIS
Ethylbenzene	100-41-4	95% H-UCL	0.0612	0.0000025		D	CAL	2B	260	ATSDR
1,1-Dichloroethane	75-34-3	95% Chebyshev (Mean, Sd) UCL	0.0457	0.0000016		C	CAL		500	HEAST

Table 3.1-2: Chronic Dose-Response Toxicity Values for the Johnson-Riley Monitoring Location, Calvert City, KY Chemicals of Potential Concern

Chemical	CAS	ProUCL Suggested 95% UCL Distribution for the Detected Chemical	Median Concentration (µg/m^3)	IUR (1/µg/m^3)	EPA MOA	EPA WOE	Source	IARC WOE	IARC WOE	R_fC (µg/m^3)	Source
Ethylene dichloride	107-06-2	95% Chebyshev (Mean, Sd) UCL	0.276	0.000026		B2	IRIS	2B	2B	2400	ATSDR
Vinyl chloride	75-01-4	95% Chebyshev (Mean, Sd) UCL	0.144	0.0000088		CH	IRIS	1	1	100	IRIS
Benzene	71-43-2	95% Approximate Gamma UCL	0.434	0.0000078		CH	IRIS	1	1	30	IRIS
Carbon tetrachloride	56-23-5	95% Student's-t UCL	0.504	0.000006		LH	IRIS	2B	2B	100	IRIS
1,1,2-Trichloroethane	79-00-5	95% Chebyshev (Mean, Sd) UCL	0.0937	0.000016		C	IRIS	3	3		
1,3-Butadiene	106-99-0	95% Approximate Gamma UCL	0.0363	0.00003		CH	IRIS	1	1	2	IRIS
1,1-Dichloroethane	75-34-3	95% Chebyshev (Mean, Sd) UCL	0.0257	0.0000016		C	CAL			500	HEAST

Table 3.1-3: Chronic Dose-Response Toxicity Values for the LWD Monitoring Location, Calvert City, KY Chemicals of Potential Concern

Chemical	CAS	ProUCL Suggested 95% UCL Distribution for the Detected Chemical	Median Concentration (µg/m^3)	IUR (1/µg/m^3)	EPA MOA	EPA WOE	Source	IARC WOE	IARC WOE	R_fC (µg/m^3)	Source
Ethylene dichloride	107-06-2	95% Chebyshev (Mean, Sd) UCL	2.193	0.000026		B2	IRIS	2B	2B	2400	ATSDR
Chloroprene	126-99-8	95% Chebyshev (Mean, Sd) UCL	0.0984	*0.00048*	M	LH	IRIS	2B	2B	20	IRIS
1,1,2-Trichloroethane	79-00-5	95% Chebyshev (Mean, Sd) UCL	0.0937	0.000016		C	IRIS	3	3		
Vinyl chloride	75-01-4	95% Approximate Gamma UCL	0.718	0.0000088		CH	IRIS	1	1	100	IRIS
Carbon tetrachloride	56-23-5	95% Chebyshev (Mean, Sd) UCL	0.543	0.000006		LH	IRIS	2B	2B	100	IRIS
Benzene	71-43-2	95% H-UCL	0.406	0.0000078		CH	IRIS	1	1	30	IRIS
1,1-Dichloroethane	75-34-3	95% H-UCL	0.0773	0.0000016		C	CAL			500	HEAST
1,3-Butadiene	106-99-0	95% H-UCL	0.0325	0.00003		CH	IRIS	1	1	2	IRIS
Trichloroethylene	79-01-6	95% H-UCL	0.0408	*0.0000068*	M	CH	IRIS	1		2	IRIS
Bromomethane	74-83-9	95% Chebyshev (Mean, Sd) UCL	0.0311			D		3		5	IRIS
Chloroform	67-66-3	95% Chebyshev (Mean, Sd) UCL	0.1623			LH		2B		98	ATSDR

Table 3.1-4: Chronic Dose-Response Toxicity Values for the Grayson Lake Monitoring Location, Calvert City, KY Chemicals of Potential Concern

Chemical	CAS	ProUCL Suggested 95% UCL Disrubtion for the Detected Chemical	Median Concentration ($\mu g/m^3$)	IUR ($1/\mu g/m^3$)	EPA MOA	EPA WOE	Source	IARC WOE	RfC ($\mu g/m^3$)	Source
Carbon tetrachloride	56-23-5	95% Student's-t UCL	0.517	0.000006		LH	IRIS	2B	100	IRIS
Benzene	71-43-2	95% Student's-t UCL	0.345	0.0000078		CH	IRIS	1	30	IRIS
Ethylene dichloride	107-06-2	95% Modified-t UCL	0.0676	0.000026		B2	IRIS	2B	2400	ATSDR
1,3-Butadiene	106-99-0	95% Chebyshev (Mean, Sd) UCL	0.0239	0.00003		CH	IRIS	1	2	IRIS
Hexachlorobutadiene	87-68-3	95% Chebyshev (Mean, Sd) UCL	0.319	0.000022		C	IRIS	3		
Dichloromethane	75-09-2	95% H-UCL	0.6287	*0.000068*	M	LH	IRIS	2A		
Acetronitrile	75-05-8	95% Chebyshev (Mean, Sd) UCL	0.1946			InI			60	IRIS

* For risk assessment purposes, note that Chloroprene, Dichloromethane, and trichloroethylene are mutagens. The IRIS IUR (Chloroprene (0.0003), Dichloromethane ($1x10^{-8}$), and Trichloroethylene ($4.1x10^{-6}$) were modified and the surrogate IUR shown in Table 4.1.1-1 through 4.1.1- were used to reflect the mutagenicity nature of this chemical. The cancer Inhalation Unit Risk (IUR) values were acquired from the Office of Air Quality Planning and Standards (Table 1). IARC WOE = weight-of-evidence for carcinogenicity in humans (1 - carcinogenic; 2A – probably carcinogenic; 2B - possibly carcinogenic; 3 - not classifiable; 4 - probably not carcinogenic). EPA WOE using the 1986 guidelines (as superseded for specific compounds by the 1999 interim guidelines): A - human carcinogen; B1 - probable carcinogen, limited human evidence; B2 - probable carcinogen, sufficient evidence in animals; C - possible human carcinogen; D - not classifiable E - evidence of non-carcinogenicity. EPA WOE using the 1999 guidelines: CH - carcinogenic to humans; LH - likely to be carcinogenic; SE - suggestive evidence for carcinogenicity; InI - inadequate information to determine carcinogenicity; NH - not likely to be carcinogenic). Source: Office of Air Quality, Planning and Standards, Table 1, see Dose-Response Assessment Tables. Abbreviations: IRIS = Integrated Risk Information System, CAL=California EPA, ATSDR=Agency for Toxic Substances and Disease Registry, and NAAQS=National Ambient Air Quality Standard.

Table 4.1.1-1: Short-term Dose-Response Concentrations for the Calvert City, KY Chemicals of Potential Concern

Chemical		Maximum Concentration (µg/m^3)				EPA OAQPS Acute Toxicity Values (µg/m^3)											
Chemical	CAS #	CCKY	JRKY	LWD	GLKY	AEGL-1 (1-h)	AEGL-1 (8-h)	AEGL-2 (1-h)	AEGL-2 (8-h)	ERPG-1	ERPG-2	MRL	REL	IDLH/10	TEEL-1	Final Acute Screening Level (µg/m^3)	Max Conc. > Acute?
1,1,2-Trichloroethane	79-00-5	0.3830	0.5837	10.6107	0.0320							160		55000		160	
1,1-Dichloroethane	75-34-3	0.6516	1.3760	16.0057	0.0279									1200000		1200000	
1,3-Butadiene	106-99-0	0.1761	0.0933	0.3727	0.1095	1500000	1500000	12000000	6000000	22000	1100000		660			660	
Acetonitrile	75-05-8	0.6513	0.9233	0.5137	126.5768	22000		84000	24000							22000	
Acrylonitrile	107-13-1	0.0200	0.0731	0.0358	0.0065			3700	560	22000	76000	220				220	
Benzene	71-43-2	0.9359	0.9870	1.4646	0.8784	170000	29000	2600000	640000	160000	480000	29	27			27	
Bromomethane	74-83-9	0.0810	0.1500	0.7066	0.0520			820000	260000		190000		3900			3900	
Carbon tetrachloride	56-23-5	1.8808	0.8744	5.5230	0.6542			82000	36000	130000	630000		1900			1900	
Chloroform	67-66-3	0.7600	0.7079	15.4272	0.1172			310000	140000		240000	490	150			150	
Chloroprene	126-99-8	0.0011	ND	0.5667	ND									110000		110000	
Dichloromethane	75-09-2	1.4136	1.4379	4.5499	12.8856	690000		1900000	210000	1000000	2600000	2100	14000			2100	
Ethylbenzene	100-41-4	0.8597	0.2332	0.3070	0.1967	140000	140000	4800000	2500000			22000				22000	
Ethylene dibromide	106-93-4	0.0031	ND	0.0165	ND	130000	35000	180000	50000							35000	
Ethylene dichloride	107-06-2	11.2101	15.4189	220.9641	0.1631					200000	810000					200000	
Hexachlorobutadiene	87-68-3	0.0110	0.0437	0.0421	0.0480					11000	32000					11000	
Trichloroethylene	79-01-6	0.0440	0.0768	0.3702	0.0398	700000	410000	2400000	1300000	540000	2700000					410000	
Vinyl chloride	75-01-4	0.8051	13.7509	8.2301	0.0043	640000	180000	3100000	2100000	1300000	13000000	1300	180000			1300	

Short-term Toxicity Dose-Response Values for Screening Risk Assessments (08/31/2021). AEGL = Acute exposure guideline levels for mild effects (AEGL-1) and moderate effects (AEGL-2) for 1- and 8-hour exposures. ERPG = US DOE Emergency Removal Program guidelines for mild or transient effects (ERPG-1) and irreversible or serious effects (ERPG-2) for 1-hour exposures. Acute MRL (aka sub-chronic) = ATSDR minimum risk levels for no adverse effects for 1 to 14-day exposures. REL = California EPA reference exposure level for no adverse effects. Most, but not all, RELs are for 1-hour exposures. IDLH/10 = One-tenth of levels determined by NIOSH to be imminently dangerous to life and health, approximately comparable to mild effects levels for 1-hour exposures. *ND = chemical was not detected at the specified monitor. Source: Office of Air Quality Planning and Standards, see http://www2.epa.gov/fera/sources-acute-dose-response-information. The "Max conc. > Acute?" column would identify instances where the maximum concentration detected exceeds any of its corresponding acute exposure guidelines. See Air Toxics Risk Assessment Reference Library Volume 1, pages 12-26 through 12-30.

Table 4.1.2-1: Chronic Non-Cancer Hazard and Toxicity Analysis for the LWD Air Chemicals of Potential Concern

Chemical	CAS	R_fC ($\mu g/m^3$)	Source	95% UCL Concentration ($\mu g/m^3$)	95% HQ=0.1	% of Hazard Index	Target Organ	Target Effect	EPA Confidence in RfC
Chloroform	67-66-3	98	ATSDR	1.911	0.02	53%	Liver	Hepatomegaly in humans	NA
Bromomethane	74-83-9	5	IRIS	0.0876	0.02	47%	Respiratory	Degenerative and proliferative lesions of the olfactory epithelium of the nasal cavity	High
				Hazard Index	0.04				

The chronic toxicity Reference Concentrations (RfCs: gray column) were acquired from the Office of Air Quality Planning and Standards, Table 1, see Dose-Response Assessment Tables). Target Organ definitions were derived from Integrated Risk Information System (IRIS: http://www.epa.gov/iris). Source abbreviations are as follows: IRIS = Integrated Risk Information System; and ATSDR = US Agency for Toxic Substances and Disease Registry. NA denotes the information is not available.

Table 5.1.2-1: Chronic Cancer Risks for the Calvert City Elementary School, KY Air Chemicals of Potential Concern

Chemical	CAS	IUR (1/µg/m³)	EPA MOA	EPA WOE	Source	IARC WOE	Median Concentration (µg/m³)	Average Concentration (µg/m3)	95% UCL Concentration (µg/m³)	95% UCL Risk	% of Total Max Risk (>1%)	Accum. Total Risk (<96%)	10^{-6} Screening Conc. (µg/m³)	95% UCL Exceeds Screen? (Fail)
Ethylene dichloride	107-06-2	0.000026		B2	IRIS	2B	0.172	1.076	2.009	5E-05	80.77%	80.77%	0.0385	Fail
Carbon tetrachloride	56-23-5	0.000006		LH	IRIS	2B	0.53	0.552	0.595	4E-06	5.52%	86.29%	0.1667	Fail
Benzene	71-43-2	0.0000078		CH	IRIS	1	0.39	0.414	0.445	3E-06	5.37%	91.66%	0.1282	Fail
1,1,2-Trichloroethane	79-00-5	0.000016		C	IRIS	3	0.0937	0.0749	0.115	2E-06	2.85%	94.51%	0.0625	Fail
Vinyl chloride	75-01-4	0.0000088		CH	IRIS	1	0.035	0.161	0.189	2E-06	2.57%	97.08%	0.11364	Fail
1,3-Butadiene	106-99-0	0.00003		CH	IRIS	1	0.0292	0.0390	0.0482	1E-06	2.24%	99.31%	0.03333	Fail
Ethylbenzene	100-41-4	0.0000025		D	CAL	2B	0.0612	0.0949	0.105	3E-07	0.41%	99.72%	0.4	
1,1-Dichloroethane	75-34-3	0.0000016		C	CAL		0.0457	0.0653	0.113	2E-07	0.28%	100.00%	0.625	
									Total risk	6E-05				

Table 5.1.2-2: Chronic Cancer Risks for the Johnson-Riley Road Air Chemicals of Potential Concern

Chemical	CAS	IUR (1/µg/m³)	EPA MOA	EPA WOE	Source	IARC WOE	Median Concentration (µg/m³)	Average Concentration (µg/m3)	95% UCL Concentration (µg/m³)	95% UCL Risk	% of Total Max Risk (>1%)	Accum. Total Risk (<96%)	10^{-6} Screening Conc. (µg/m³)	95% UCL Exceeds Screen? (Fail)
Ethylene dichloride	107-06-2	0.000026		B2	IRIS	2B	0.276	1.366	2.705	7E-05	62.52%	62.52%	0.0385	Fail
Vinyl chloride	75-01-4	0.0000088		CH	IRIS	1	0.144	2.093	3.561	3E-05	27.86%	90.38%	0.1667	Fail
Benzene	71-43-2	0.0000078		CH	IRIS	1	0.434	0.459	0.499	4E-06	3.46%	93.84%	0.1282	Fail
Carbon tetrachloride	56-23-5	0.000006		LH	IRIS	2B	0.504	0.515	0.534	3E-06	2.85%	96.69%	0.1667	Fail
1,1,2-Trichloroethane	79-00-5	0.000016		C	IRIS	3	0.0937	0.098	0.14	2E-06	1.99%	98.68%	0.0625	Fail
1,3-Butadiene	106-99-0	0.00003		CH	IRIS	1	0.0363	0.0342	0.0399	1E-06	1.06%	99.75%	0.0333	Fail
1,1-Dichloroethane	75-34-3	0.0000016		C	CAL		0.0257	0.110	0.177	3E-07	0.25%	100.00%	0.625	
									Total risk	1E-04				

Table 5.1.2-3: Chronic Cancer Risks for the LWD Air Chemicals of Potential Concern

Chemical	CAS	IUR (1/µg/m³)	EPA MOA	EPA WOE	Source	IARC WOE	Median Concentration (µg/m³)	Average Concentration (µg/m3)	95% UCL Concentration (µg/m³)	95% UCL Risk	% of Total Max Risk (>1%)	Accum. Total Risk (<96%)	10^{-6} Screening Conc. (µg/m³)	95% UCL Exceeds Screen? (Fail)
Ethylene dichloride	107-06-2	0.000026		B2	IRIS	2B	2.193	22.10	45.24	1E-03	96.20%	96.20%	0.0385	Fail
1,1,2-Trichloroethane	79-00-5	0.000016		C	IRIS	3	0.0937	0.6373	1.181	2E-05	1.55%	97.75%	0.0625	Fail
Vinyl chloride	75-01-4	0.0000088		CH	IRIS	1	0.718	1.117	1.364	1E-05	0.98%	98.73%	0.1667	Fail
Carbon tetrachloride	56-23-5	0.000006		LH	IRIS	2B	0.543	0.7475	1.119	7E-06	0.55%	99.28%	0.1667	Fail
Benzene	71-43-2	0.0000078		CH	IRIS	1	0.406	0.459	0.506	4E-06	0.32%	99.60%	0.1282	Fail
1,1-Dichloroethane	75-34-3	0.0000016		C	CAL		0.0773	0.9463	1.758	3E-06	0.23%	99.83%	0.625	Fail
1,3-Butadiene	106-99-0	0.00003		CH	IRIS	1	0.0325	0.0478	0.0555	2E-06	0.14%	99.97%	0.0333	Fail
Trichloroethylene	79-01-6	*0.0000068*	M	CH	IRIS	1	0.0408	0.054	0.065	4E-07	0.03%	100.00%	0.1472	
									Total risk	1E-03				

Table 5.1.2-4: Chronic Cancer Risks for the Grayson-Lake (Background) Air Chemicals of Potential Concern

Chemical	CAS	IUR (1/µg/m^3)	EPA MOA	EPA WOE	Source	IARC WOE	Median Concentration (µg/m^3)	Average Concentration (µg/m3)	95% UCL Concentration (µg/m^3)	95% UCL Risk	% of Total Max Risk (>1%)	Accum. Total Risk (<96%)	10^{-6} Screening Conc. (µg/m^3)	95% UCL Exceeds Screen? (Fail)
Carbon tetrachloride	56-23-5	0.000006		LH	IRIS	2B	0.517	0.509	0.528	3.2E-06	31.09%	31.09%	0.1667	Fail
Benzene	71-43-2	0.0000078		CH	IRIS	1	0.345	0.360	0.388	3.0E-06	29.70%	60.79%	0.1282	Fail
Ethylene dichloride	107-06-2	0.000026		B2	IRIS	2B	0.0676	0.0638	0.0684	1.8E-06	17.45%	78.25%	0.0385	Fail
1,3-Butadiene	106-99-0	0.00003		CH	IRIS	1	0.0239	0.0249	0.0387	1.2E-06	11.39%	89.64%	0.0333	Fail
Hexachlorobutadiene	87-68-3	0.000022		C	IRIS	3	0.319	0.0088	*0.0480*	1.1E-06	10.36%	100.00%	0.0455	Fail
									Total risk	**1E-05**				

*Risks listed in RED (and Chemical name in light blue) fall above the high end of EPA's risk range (10^{-4} through 10^{-6}). The chronic toxicity Inhalation Unit Risks (IUR) were acquired from the Office of Air Quality Planning and Standards (Table 1). Risk Calculation Methodology: See Air Toxics Risk Assessment Reference Library Volume 1, pages 13-5 through 13-7. The Accumulated Total Risk values are in pink generally including up to 90% of the risk.

10.2 APPENDIX B: Monitoring Data

Calvert City, KY
VOC Air Monitoring Data

Air monitoring data used in this assessment is provided in a separate spreadsheet “Appendix B - Calvert City, KY VOC Air Monitoring Data.xlsx.” Samples were taken at the Calvert City Elementary, Johnson-Riley Road, LWD, and Grayson Lake monitoring sites, operated by the Kentucky Division for Air Quality. The sampling period was from October of 2020 through December 2021. All data was reported to and retrieved from EPA’s Air Quality System (AQS) database and are available on EPA’s website (epa.gov/outdoor-air-quality-data).

The following provides information respect to the use (or not) of certain COPC samples in the risk assessment calculations:

1. Samples and their replicates were averaged, and that number was used in the analysis (not the higher of the two numbers).
2. Other directions regarding the use of certain samples are provided in the “Notes” column on the right.
3. Other qualifiers in the sample set are listed in the QAPP (KDAQ, Quality Assurance Project Plan for Volatile Organic Compound Monitoring near the Calvert City Industrial Complex. Kentucky Energy and Environment Cabinet, Department for Environmental Protection, Division for Air Quality, Frankfort, KY. , 2021):

10.3 APPENDIX C: ProUCL Statistical Results

Calvert City, KY VOC Study
ProUCL Statistical Results

The following calculations were produced using ProUCL 5.1.002 Statistical Software for Environmental Applications for Data Sets with and without Non-detect Observations (See: https://www.epa.gov/land-research/proucl-software).

10.3.1 Calvert City Elementary School

UCL Statistics for Uncensored Full Data Sets

User Selected Options	
Date/Time of Computation	ProUCL 5.16/14/2022 4:42:52 PM
From File	WorkSheet.xls
Full Precision	OFF
Confidence Coefficient	95%
Number of Bootstrap Operations	2000

1,3-Butadiene

General Statistics

Total Number of Observations	69	Number of Distinct Observations	56
		Number of Missing Observations	0
Minimum	0.00575	Mean	0.0417
Maximum	0.176	Median	0.0292
SD	0.0317	Std. Error of Mean	0.00381
Coefficient of Variation	0.759	Skewness	1.851

Normal GOF Test

Shapiro Wilk Test Statistic	0.832	**Shapiro Wilk GOF Test**	
5% Shapiro Wilk P Value	1.362E-10	Data Not Normal at 5% Significance Level	
Lilliefors Test Statistic	0.186	**Lilliefors GOF Test**	
5% Lilliefors Critical Value	0.107	Data Not Normal at 5% Significance Level	

Data Not Normal at 5% Significance Level

Assuming Normal Distribution

95% Normal UCL	**95% UCLs (Adjusted for Skewness)**

95% Student's-t UCL	0.0481	95% Adjusted-CLT UCL (Chen-1995)	0.0489
		95% Modified-t UCL (Johnson-1978)	0.0482

Gamma GOF Test

A-D Test Statistic	0.745	**Anderson-Darling Gamma GOF Test**
5% A-D Critical Value	0.763	Detected data appear Gamma Distributed at 5% Significance Level
K-S Test Statistic	0.126	**Kolmogorov-Smirnov Gamma GOF Test**
5% K-S Critical Value	0.109	Data Not Gamma Distributed at 5% Significance Level

Detected data follow Appr. Gamma Distribution at 5% Significance Level

Gamma Statistics

k hat (MLE)	2.143	k star (bias corrected MLE)	2.059
Theta hat (MLE)	0.0195	Theta star (bias corrected MLE)	0.0203
nu hat (MLE)	295.7	nu star (bias corrected)	284.2
MLE Mean (bias corrected)	0.0417	MLE Sd (bias corrected)	0.0291
		Approximate Chi Square Value (0.05)	246.2
Adjusted Level of Significance	0.0465	Adjusted Chi Square Value	245.4

Assuming Gamma Distribution

95% Approximate Gamma UCL (use when n>=50)	0.0482	95% Adjusted Gamma UCL (use when n<50)	0.0483

Lognormal GOF Test

Shapiro Wilk Test Statistic	0.979	**Shapiro Wilk Lognormal GOF Test**
5% Shapiro Wilk P Value	0.577	Data appear Lognormal at 5% Significance Level
Lilliefors Test Statistic	0.0931	**Lilliefors Lognormal GOF Test**
5% Lilliefors Critical Value	0.107	Data appear Lognormal at 5% Significance Level

Data appear Lognormal at 5% Significance Level

Lognormal Statistics

Minimum of Logged Data	-5.158	Mean of logged Data	-3.427
Maximum of Logged Data	-1.737	SD of logged Data	0.724

Assuming Lognormal Distribution

95% H-UCL	0.0505	90% Chebyshev (MVUE) UCL	0.0542
95% Chebyshev (MVUE) UCL	0.0597	97.5% Chebyshev (MVUE) UCL	0.0673
99% Chebyshev (MVUE) UCL	0.0823		

Nonparametric Distribution Free UCL Statistics

Data appear to follow a Discernible Distribution at 5% Significance Level

Nonparametric Distribution Free UCLs

95% CLT UCL	0.048	95% Jackknife UCL	0.0481
95% Standard Bootstrap UCL	0.048	95% Bootstrap-t UCL	0.0491
95% Hall's Bootstrap UCL	0.0495	95% Percentile Bootstrap UCL	0.0477
95% BCA Bootstrap UCL	0.0492		
90% Chebyshev(Mean, Sd) UCL	0.0532	95% Chebyshev(Mean, Sd) UCL	0.0584
97.5% Chebyshev(Mean, Sd) UCL	0.0656	99% Chebyshev(Mean, Sd) UCL	0.0797

Suggested UCL to Use

95% Approximate Gamma UCL 0.0482

When a data set follows an approximate (e.g., normal) distribution passing one of the GOF test

When applicable, it is suggested to use a UCL based upon a distribution (e.g., gamma) passing both GOF tests in ProUCL

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.

Recommendations are based upon data size, data distribution, and skewness.

These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).

However, simulations results will not cover all Real World data sets; for additional insight the user may want to consult a statistician.

Carbon tetrachloride

General Statistics

Total Number of Observations	69	Number of Distinct Observations	64
		Number of Missing Observations	0
Minimum	0.218	Mean	0.552
Maximum	1.881	Median	0.53
SD	0.2	Std. Error of Mean	0.024
Coefficient of Variation	0.362	Skewness	4.827

Normal GOF Test

Shapiro Wilk Test Statistic	0.561	**Shapiro Wilk GOF Test**	
5% Shapiro Wilk P Value	0	Data Not Normal at 5% Significance Level	
Lilliefors Test Statistic	0.308	**Lilliefors GOF Test**	
5% Lilliefors Critical Value	0.107	Data Not Normal at 5% Significance Level	

Data Not Normal at 5% Significance Level

Assuming Normal Distribution

95% Normal UCL		**95% UCLs (Adjusted for Skewness)**	
95% Student's-t UCL	0.592	95% Adjusted-CLT UCL (Chen-1995)	0.607
		95% Modified-t UCL (Johnson-1978)	0.595

Gamma GOF Test

A-D Test Statistic	5.617	**Anderson-Darling Gamma GOF Test**	
5% A-D Critical Value	0.75	Data Not Gamma Distributed at 5% Significance Level	
K-S Test Statistic	0.252	**Kolmogorov-Smirnov Gamma GOF Test**	
5% K-S Critical Value	0.107	Data Not Gamma Distributed at 5% Significance Level	

Data Not Gamma Distributed at 5% Significance Level

Gamma Statistics

k hat (MLE)	13.02	k star (bias corrected MLE)	12.46
Theta hat (MLE)	0.0424	Theta star (bias corrected MLE)	0.0443
nu hat (MLE)	1796	nu star (bias corrected)	1720
MLE Mean (bias corrected)	0.552	MLE Sd (bias corrected)	0.156
		Approximate Chi Square Value (0.05)	1624
Adjusted Level of Significance	0.0465	Adjusted Chi Square Value	1622

Assuming Gamma Distribution

95% Approximate Gamma UCL (use when n>=50))	0.585	95% Adjusted Gamma UCL (use when n<50)	0.585

Lognormal GOF Test

Shapiro Wilk Test Statistic	0.806	**Shapiro Wilk Lognormal GOF Test**	
5% Shapiro Wilk P Value	2.422E-12	Data Not Lognormal at 5% Significance Level	
Lilliefors Test Statistic	0.225	**Lilliefors Lognormal GOF Test**	
5% Lilliefors Critical Value	0.107	Data Not Lognormal at 5% Significance Level	

Data Not Lognormal at 5% Significance Level

Lognormal Statistics

Minimum of Logged Data	-1.525	Mean of logged Data	-0.633
Maximum of Logged Data	0.632	SD of logged Data	0.259

Assuming Lognormal Distribution

95% H-UCL	0.58	90% Chebyshev (MVUE) UCL	0.601
95% Chebyshev (MVUE) UCL	0.624	97.5% Chebyshev (MVUE) UCL	0.657
99% Chebyshev (MVUE) UCL	0.721		

Nonparametric Distribution Free UCL Statistics

Data do not follow a Discernible Distribution (0.05)

Nonparametric Distribution Free UCLs

95% CLT UCL	0.592	95% Jackknife UCL	0.592
95% Standard Bootstrap UCL	0.591	95% Bootstrap-t UCL	0.631
95% Hall's Bootstrap UCL	0.799	95% Percentile Bootstrap UCL	0.594
95% BCA Bootstrap UCL	0.614		
90% Chebyshev(Mean, Sd) UCL	0.624	95% Chebyshev(Mean, Sd) UCL	0.657
97.5% Chebyshev(Mean, Sd) UCL	0.702	99% Chebyshev(Mean, Sd) UCL	0.791

Suggested UCL to Use

95% Student's-t UCL	0.592	or 95% Modified-t UCL	0.595

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
Recommendations are based upon data size, data distribution, and skewness.
These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).
However, simulations results will not cover all Real World data sets; for additional insight the user may want to consult a statistician.

1,1-Dichloroethane

General Statistics

Total Number of Observations	69	Number of Distinct Observations	33
		Number of Missing Observations	0
Minimum	0.00162	Mean	0.0571
Maximum	0.652	Median	0.0457
SD	0.107	Std. Error of Mean	0.0129
Coefficient of Variation	1.883	Skewness	4.823

Normal GOF Test

Shapiro Wilk Test Statistic	0.404	**Shapiro Wilk GOF Test**	
5% Shapiro Wilk P Value	0	Data Not Normal at 5% Significance Level	
Lilliefors Test Statistic	0.376	**Lilliefors GOF Test**	
5% Lilliefors Critical Value	0.107	Data Not Normal at 5% Significance Level	

Data Not Normal at 5% Significance Level

Assuming Normal Distribution

95% Normal UCL		**95% UCLs (Adjusted for Skewness)**	
95% Student's-t UCL	0.0786	95% Adjusted-CLT UCL (Chen-1995)	0.0863
		95% Modified-t UCL (Johnson-1978)	0.0799

Gamma GOF Test

A-D Test Statistic	4.618	**Anderson-Darling Gamma GOF Test**	
5% A-D Critical Value	0.789	Data Not Gamma Distributed at 5% Significance Level	
K-S Test Statistic	0.254	**Kolmogorov-Smirnov Gamma GOF Test**	
5% K-S Critical Value	0.111	Data Not Gamma Distributed at 5% Significance Level	

Data Not Gamma Distributed at 5% Significance Level

Gamma Statistics

k hat (MLE)	0.823	k star (bias corrected MLE)	0.797
Theta hat (MLE)	0.0693	Theta star (bias corrected MLE)	0.0716
nu hat (MLE)	113.6	nu star (bias corrected)	110
MLE Mean (bias corrected)	0.0571	MLE Sd (bias corrected)	0.0639
		Approximate Chi Square Value (0.05)	86.79
Adjusted Level of Significance	0.0465	Adjusted Chi Square Value	86.35

Assuming Gamma Distribution

95% Approximate Gamma UCL (use when n>=50))	0.0723	95% Adjusted Gamma UCL (use when n<50)	0.0727

Lognormal GOF Test

Shapiro Wilk Test Statistic	0.89	**Shapiro Wilk Lognormal GOF Test**	
5% Shapiro Wilk P Value	1.3191E-6	Data Not Lognormal at 5% Significance Level	
Lilliefors Test Statistic	0.255	**Lilliefors Lognormal GOF Test**	
5% Lilliefors Critical Value	0.107	Data Not Lognormal at 5% Significance Level	

Data Not Lognormal at 5% Significance Level

Lognormal Statistics

Minimum of Logged Data	-6.426	Mean of logged Data	-3.582
Maximum of Logged Data	-0.428	SD of logged Data	1.194

Assuming Lognormal Distribution

95% H-UCL	0.0776	90% Chebyshev (MVUE) UCL	0.0859
95% Chebyshev (MVUE) UCL	0.0995	97.5% Chebyshev (MVUE) UCL	0.118
99% Chebyshev (MVUE) UCL	0.156		

Nonparametric Distribution Free UCL Statistics

Data do not follow a Discernible Distribution (0.05)

Nonparametric Distribution Free UCLs

95% CLT UCL	0.0783	95% Jackknife UCL	0.0786
95% Standard Bootstrap UCL	0.0778	95% Bootstrap-t UCL	0.115
95% Hall's Bootstrap UCL	0.18	95% Percentile Bootstrap UCL	0.0793
95% BCA Bootstrap UCL	0.0889		
90% Chebyshev(Mean, Sd) UCL	0.0959	95% Chebyshev(Mean, Sd) UCL	0.113
97.5% Chebyshev(Mean, Sd) UCL	0.138	99% Chebyshev(Mean, Sd) UCL	0.186

Suggested UCL to Use

95% Chebyshev (Mean, Sd) UCL	0.113

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.

Recommendations are based upon data size, data distribution, and skewness.

These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).

However, simulations results will not cover all Real World data sets; for additional insight the user may want to consult a statistician.

Ethylene dichloride

General Statistics

Total Number of Observations	69	Number of Distinct Observations	65
		Number of Missing Observations	0
Minimum	0.0283	Mean	1.032
Maximum	11.21	Median	0.172
SD	1.862	Std. Error of Mean	0.224
Coefficient of Variation	1.805	Skewness	3.242

Normal GOF Test

Shapiro Wilk Test Statistic	0.6	**Shapiro Wilk GOF Test**	
5% Shapiro Wilk P Value	0	Data Not Normal at 5% Significance Level	
Lilliefors Test Statistic	0.295	**Lilliefors GOF Test**	
5% Lilliefors Critical Value	0.107	Data Not Normal at 5% Significance Level	

Data Not Normal at 5% Significance Level

Assuming Normal Distribution

95% Normal UCL		**95% UCLs (Adjusted for Skewness)**	
95% Student's-t UCL	1.405	95% Adjusted-CLT UCL (Chen-1995)	1.494
		95% Modified-t UCL (Johnson-1978)	1.42

Gamma GOF Test

A-D Test Statistic	4.239	**Anderson-Darling Gamma GOF Test**	
5% A-D Critical Value	0.82	Data Not Gamma Distributed at 5% Significance Level	
K-S Test Statistic	0.205	**Kolmogorov-Smirnov Gamma GOF Test**	
5% K-S Critical Value	0.114	Data Not Gamma Distributed at 5% Significance Level	

Data Not Gamma Distributed at 5% Significance Level

Gamma Statistics

k hat (MLE)	0.486	k star (bias corrected MLE)	0.475
Theta hat (MLE)	2.122	Theta star (bias corrected MLE)	2.173

nu hat (MLE)	67.08	nu star (bias corrected)	65.5
MLE Mean (bias corrected)	1.032	MLE Sd (bias corrected)	1.497
		Approximate Chi Square Value (0.05)	47.87
Adjusted Level of Significance	0.0465	Adjusted Chi Square Value	47.55

Assuming Gamma Distribution

95% Approximate Gamma UCL (use when n>=50))	1.411	95% Adjusted Gamma UCL (use when n<50)	1.421

Lognormal GOF Test

Shapiro Wilk Test Statistic	0.884	**Shapiro Wilk Lognormal GOF Test**	
5% Shapiro Wilk P Value	5.2671E-7	Data Not Lognormal at 5% Significance Level	
Lilliefors Test Statistic	0.193	**Lilliefors Lognormal GOF Test**	
5% Lilliefors Critical Value	0.107	Data Not Lognormal at 5% Significance Level	

Data Not Lognormal at 5% Significance Level

Lognormal Statistics

Minimum of Logged Data	-3.564	Mean of logged Data	-1.281
Maximum of Logged Data	2.417	SD of logged Data	1.64

Assuming Lognormal Distribution

95% H-UCL	1.75	90% Chebyshev (MVUE) UCL	1.871
95% Chebyshev (MVUE) UCL	2.256	97.5% Chebyshev (MVUE) UCL	2.791
99% Chebyshev (MVUE) UCL	3.841		

Nonparametric Distribution Free UCL Statistics

Data do not follow a Discernible Distribution (0.05)

Nonparametric Distribution Free UCLs

95% CLT UCL	1.4	95% Jackknife UCL	1.405
95% Standard Bootstrap UCL	1.397	95% Bootstrap-t UCL	1.557
95% Hall's Bootstrap UCL	1.678	95% Percentile Bootstrap UCL	1.457

95% BCA Bootstrap UCL	1.527		
90% Chebyshev(Mean, Sd) UCL	1.704	95% Chebyshev(Mean, Sd) UCL	2.009
97.5% Chebyshev(Mean, Sd) UCL	2.432	99% Chebyshev(Mean, Sd) UCL	3.262

Suggested UCL to Use

95% Chebyshev (Mean, Sd) UCL	2.009

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
Recommendations are based upon data size, data distribution, and skewness.
These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).
However, simulations results will not cover all Real World data sets; for additional insight the user may want to consult a statistician.

1,1,2-Trichloroethane

General Statistics

Total Number of Observations	69	Number of Distinct Observations	22
		Number of Missing Observations	0
Minimum	0.00764	Mean	0.0877
Maximum	0.383	Median	0.0937
SD	0.0516	Std. Error of Mean	0.00621
Coefficient of Variation	0.589	Skewness	3.233

Normal GOF Test

Shapiro Wilk Test Statistic	0.576	**Shapiro Wilk GOF Test**
5% Shapiro Wilk P Value	0	Data Not Normal at 5% Significance Level
Lilliefors Test Statistic	0.395	**Lilliefors GOF Test**
5% Lilliefors Critical Value	0.107	Data Not Normal at 5% Significance Level

Data Not Normal at 5% Significance Level

Assuming Normal Distribution

95% Normal UCL		95% UCLs (Adjusted for Skewness)	
95% Student's-t UCL	0.098	95% Adjusted-CLT UCL (Chen-1995)	0.1
		95% Modified-t UCL (Johnson-1978)	0.0985

Gamma GOF Test

A-D Test Statistic	10.64	**Anderson-Darling Gamma GOF Test**	
5% A-D Critical Value	0.757	Data Not Gamma Distributed at 5% Significance Level	
K-S Test Statistic	0.374	**Kolmogorov-Smirnov Gamma GOF Test**	
5% K-S Critical Value	0.108	Data Not Gamma Distributed at 5% Significance Level	

Data Not Gamma Distributed at 5% Significance Level

Gamma Statistics

k hat (MLE)	3.232	k star (bias corrected MLE)	3.101
Theta hat (MLE)	0.0271	Theta star (bias corrected MLE)	0.0283
nu hat (MLE)	446	nu star (bias corrected)	428
MLE Mean (bias corrected)	0.0877	MLE Sd (bias corrected)	0.0498
		Approximate Chi Square Value (0.05)	381
Adjusted Level of Significance	0.0465	Adjusted Chi Square Value	380.1

Assuming Gamma Distribution

95% Approximate Gamma UCL (use when n>=50))	0.0985	95% Adjusted Gamma UCL (use when n<50)	0.0987

Lognormal GOF Test

Shapiro Wilk Test Statistic	0.696	**Shapiro Wilk Lognormal GOF Test**	
5% Shapiro Wilk P Value	0	Data Not Lognormal at 5% Significance Level	
Lilliefors Test Statistic	0.394	**Lilliefors Lognormal GOF Test**	
5% Lilliefors Critical Value	0.107	Data Not Lognormal at 5% Significance Level	

Data Not Lognormal at 5% Significance Level

Lognormal Statistics

Minimum of Logged Data	-4.875	Mean of logged Data	-2.597

Maximum of Logged Data	-0.96	SD of logged Data	0.638

Assuming Lognormal Distribution

95% H-UCL	0.106	90% Chebyshev (MVUE) UCL	0.114
95% Chebyshev (MVUE) UCL	0.124	97.5% Chebyshev (MVUE) UCL	0.138
99% Chebyshev (MVUE) UCL	0.167		

Nonparametric Distribution Free UCL Statistics

Data do not follow a Discernible Distribution (0.05)

Nonparametric Distribution Free UCLs

95% CLT UCL	0.0979	95% Jackknife UCL	0.098
95% Standard Bootstrap UCL	0.0977	95% Bootstrap-t UCL	0.102
95% Hall's Bootstrap UCL	0.149	95% Percentile Bootstrap UCL	0.0989
95% BCA Bootstrap UCL	0.101		
90% Chebyshev(Mean, Sd) UCL	0.106	95% Chebyshev(Mean, Sd) UCL	0.115
97.5% Chebyshev(Mean, Sd) UCL	0.126	99% Chebyshev(Mean, Sd) UCL	0.15

Suggested UCL to Use

95% Chebyshev (Mean, Sd) UCL	0.115

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
Recommendations are based upon data size, data distribution, and skewness.
These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).
However, simulations results will not cover all Real World data sets; for additional insight the user may want to consult a statistician.

Vinyl chloride

General Statistics

Total Number of Observations	69	Number of Distinct Observations	41

		Number of Missing Observations	0
Minimum	0.00307	Mean	0.11
Maximum	0.805	Median	0.035
SD	0.15	Std. Error of Mean	0.0181
Coefficient of Variation	1.364	Skewness	2.723

Normal GOF Test

Shapiro Wilk Test Statistic	0.628	**Shapiro Wilk GOF Test**
5% Shapiro Wilk P Value	0	Data Not Normal at 5% Significance Level
Lilliefors Test Statistic	0.268	**Lilliefors GOF Test**
5% Lilliefors Critical Value	0.107	Data Not Normal at 5% Significance Level

Data Not Normal at 5% Significance Level

Assuming Normal Distribution

95% Normal UCL		**95% UCLs (Adjusted for Skewness)**	
95% Student's-t UCL	0.14	95% Adjusted-CLT UCL (Chen-1995)	0.146
		95% Modified-t UCL (Johnson-1978)	0.141

Gamma GOF Test

A-D Test Statistic	4.519	**Anderson-Darling Gamma GOF Test**
5% A-D Critical Value	0.781	Data Not Gamma Distributed at 5% Significance Level
K-S Test Statistic	0.245	**Kolmogorov-Smirnov Gamma GOF Test**
5% K-S Critical Value	0.11	Data Not Gamma Distributed at 5% Significance Level

Data Not Gamma Distributed at 5% Significance Level

Gamma Statistics

k hat (MLE)	0.982	k star (bias corrected MLE)	0.949
Theta hat (MLE)	0.112	Theta star (bias corrected MLE)	0.116
nu hat (MLE)	135.5	nu star (bias corrected)	130.9
MLE Mean (bias corrected)	0.11	MLE Sd (bias corrected)	0.113
		Approximate Chi Square Value (0.05)	105.5

Adjusted Level of Significance	0.0465	Adjusted Chi Square Value	105

Assuming Gamma Distribution

95% Approximate Gamma UCL (use when n>=50))	0.137	95% Adjusted Gamma UCL (use when n<50)	0.137

Lognormal GOF Test

Shapiro Wilk Test Statistic	0.918	**Shapiro Wilk Lognormal GOF Test**	
5% Shapiro Wilk P Value	1.2706E-4	Data Not Lognormal at 5% Significance Level	
Lilliefors Test Statistic	0.224	**Lilliefors Lognormal GOF Test**	
5% Lilliefors Critical Value	0.107	Data Not Lognormal at 5% Significance Level	

Data Not Lognormal at 5% Significance Level

Lognormal Statistics

Minimum of Logged Data	-5.787	Mean of logged Data	-2.796
Maximum of Logged Data	-0.217	SD of logged Data	1.048

Assuming Lognormal Distribution

95% H-UCL	0.141	90% Chebyshev (MVUE) UCL	0.152
95% Chebyshev (MVUE) UCL	0.174	97.5% Chebyshev (MVUE) UCL	0.204
99% Chebyshev (MVUE) UCL	0.263		

Nonparametric Distribution Free UCL Statistics

Data do not follow a Discernible Distribution (0.05)

Nonparametric Distribution Free UCLs

95% CLT UCL	0.14	95% Jackknife UCL	0.14
95% Standard Bootstrap UCL	0.14	95% Bootstrap-t UCL	0.155
95% Hall's Bootstrap UCL	0.151	95% Percentile Bootstrap UCL	0.14
95% BCA Bootstrap UCL	0.147		
90% Chebyshev(Mean, Sd) UCL	0.164	95% Chebyshev(Mean, Sd) UCL	0.189
97.5% Chebyshev(Mean, Sd) UCL	0.223	99% Chebyshev(Mean, Sd) UCL	0.29

Suggested UCL to Use

95% Chebyshev (Mean, Sd) UCL	0.189

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
Recommendations are based upon data size, data distribution, and skewness.
These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).
However, simulations results will not cover all Real World data sets; for additional insight the user may want to consult a statistician.

Benzene

General Statistics

Total Number of Observations	69	Number of Distinct Observations	56
		Number of Missing Observations	0
Minimum	0.128	Mean	0.414
Maximum	0.936	Median	0.39
SD	0.15	Std. Error of Mean	0.0181
Coefficient of Variation	0.363	Skewness	0.751

Normal GOF Test

Shapiro Wilk Test Statistic	0.966	**Shapiro Wilk GOF Test**	
5% Shapiro Wilk P Value	0.15	Data appear Normal at 5% Significance Level	
Lilliefors Test Statistic	0.11	**Lilliefors GOF Test**	
5% Lilliefors Critical Value	0.107	Data Not Normal at 5% Significance Level	

Data appear Approximate Normal at 5% Significance Level

Assuming Normal Distribution

95% Normal UCL		**95% UCLs (Adjusted for Skewness)**	
95% Student's-t UCL	0.445	95% Adjusted-CLT UCL (Chen-1995)	0.446
		95% Modified-t UCL (Johnson-1978)	0.445

Gamma GOF Test

A-D Test Statistic	0.312	**Anderson-Darling Gamma GOF Test**
5% A-D Critical Value	0.752	Detected data appear Gamma Distributed at 5% Significance Level
K-S Test Statistic	0.0698	**Kolmogorov-Smirnov Gamma GOF Test**
5% K-S Critical Value	0.107	Detected data appear Gamma Distributed at 5% Significance Level

Detected data appear Gamma Distributed at 5% Significance Level

Gamma Statistics

k hat (MLE)	7.617	k star (bias corrected MLE)	7.296
Theta hat (MLE)	0.0544	Theta star (bias corrected MLE)	0.0568
nu hat (MLE)	1051	nu star (bias corrected)	1007
MLE Mean (bias corrected)	0.414	MLE Sd (bias corrected)	0.153
		Approximate Chi Square Value (0.05)	934.1
Adjusted Level of Significance	0.0465	Adjusted Chi Square Value	932.7

Assuming Gamma Distribution

95% Approximate Gamma UCL (use when n>=50))	0.447	95% Adjusted Gamma UCL (use when n<50)	0.447

Lognormal GOF Test

Shapiro Wilk Test Statistic	0.978	**Shapiro Wilk Lognormal GOF Test**
5% Shapiro Wilk P Value	0.565	Data appear Lognormal at 5% Significance Level
Lilliefors Test Statistic	0.0936	**Lilliefors Lognormal GOF Test**
5% Lilliefors Critical Value	0.107	Data appear Lognormal at 5% Significance Level

Data appear Lognormal at 5% Significance Level

Lognormal Statistics

Minimum of Logged Data	-2.055	Mean of logged Data	-0.948
Maximum of Logged Data	-0.0662	SD of logged Data	0.379

Assuming Lognormal Distribution

95% H-UCL	0.452	90% Chebyshev (MVUE) UCL	0.475
95% Chebyshev (MVUE) UCL	0.501	97.5% Chebyshev (MVUE) UCL	0.538
99% Chebyshev (MVUE) UCL	0.611		

Nonparametric Distribution Free UCL Statistics

Data appear to follow a Discernible Distribution at 5% Significance Level

Nonparametric Distribution Free UCLs

95% CLT UCL	0.444	95% Jackknife UCL	0.445
95% Standard Bootstrap UCL	0.444	95% Bootstrap-t UCL	0.448
95% Hall's Bootstrap UCL	0.447	95% Percentile Bootstrap UCL	0.446
95% BCA Bootstrap UCL	0.446		
90% Chebyshev(Mean, Sd) UCL	0.469	95% Chebyshev(Mean, Sd) UCL	0.493
97.5% Chebyshev(Mean, Sd) UCL	0.528	99% Chebyshev(Mean, Sd) UCL	0.595

Suggested UCL to Use

95% Student's-t UCL 0.445

When a data set follows an approximate (e.g., normal) distribution passing one of the GOF test

When applicable, it is suggested to use a UCL based upon a distribution (e.g., gamma) passing both GOF tests in ProUCL

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.

Recommendations are based upon data size, data distribution, and skewness.

These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).

However, simulations results will not cover all Real World data sets; for additional insight the user may want to consult a statistician.

Ethylbenzene

General Statistics

Total Number of Observations	69	Number of Distinct Observations	60

		Number of Missing Observations	0
Minimum	0.0178	Mean	0.0949
Maximum	0.86	Median	0.0612
SD	0.12	Std. Error of Mean	0.0145
Coefficient of Variation	1.266	Skewness	4.835

Normal GOF Test

Shapiro Wilk Test Statistic	0.501	**Shapiro Wilk GOF Test**
5% Shapiro Wilk P Value	0	Data Not Normal at 5% Significance Level
Lilliefors Test Statistic	0.261	**Lilliefors GOF Test**
5% Lilliefors Critical Value	0.107	Data Not Normal at 5% Significance Level

Data Not Normal at 5% Significance Level

Assuming Normal Distribution

95% Normal UCL		**95% UCLs (Adjusted for Skewness)**	
95% Student's-t UCL	0.119	95% Adjusted-CLT UCL (Chen-1995)	0.128
		95% Modified-t UCL (Johnson-1978)	0.12

Gamma GOF Test

A-D Test Statistic	2.709	**Anderson-Darling Gamma GOF Test**
5% A-D Critical Value	0.766	Data Not Gamma Distributed at 5% Significance Level
K-S Test Statistic	0.165	**Kolmogorov-Smirnov Gamma GOF Test**
5% K-S Critical Value	0.109	Data Not Gamma Distributed at 5% Significance Level

Data Not Gamma Distributed at 5% Significance Level

Gamma Statistics

k hat (MLE)	1.719	k star (bias corrected MLE)	1.654
Theta hat (MLE)	0.0552	Theta star (bias corrected MLE)	0.0574
nu hat (MLE)	237.2	nu star (bias corrected)	228.2
MLE Mean (bias corrected)	0.0949	MLE Sd (bias corrected)	0.0738
		Approximate Chi Square Value (0.05)	194.2

Adjusted Level of Significance	0.0465	Adjusted Chi Square Value	193.6

Assuming Gamma Distribution

95% Approximate Gamma UCL (use when n>=50))	0.111	95% Adjusted Gamma UCL (use when n<50)	0.112

Lognormal GOF Test

Shapiro Wilk Test Statistic	0.95	**Shapiro Wilk Lognormal GOF Test**	
5% Shapiro Wilk P Value	0.0192	Data Not Lognormal at 5% Significance Level	
Lilliefors Test Statistic	0.106	**Lilliefors Lognormal GOF Test**	
5% Lilliefors Critical Value	0.107	Data appear Lognormal at 5% Significance Level	

Data appear Approximate Lognormal at 5% Significance Level

Lognormal Statistics

Minimum of Logged Data	-4.028	Mean of logged Data	-2.674
Maximum of Logged Data	-0.151	SD of logged Data	0.705

Assuming Lognormal Distribution

95% H-UCL	0.105	90% Chebyshev (MVUE) UCL	0.113
95% Chebyshev (MVUE) UCL	0.124	97.5% Chebyshev (MVUE) UCL	0.14
99% Chebyshev (MVUE) UCL	0.17		

Nonparametric Distribution Free UCL Statistics

Data appear to follow a Discernible Distribution at 5% Significance Level

Nonparametric Distribution Free UCLs

95% CLT UCL	0.119	95% Jackknife UCL	0.119
95% Standard Bootstrap UCL	0.119	95% Bootstrap-t UCL	0.148
95% Hall's Bootstrap UCL	0.237	95% Percentile Bootstrap UCL	0.122
95% BCA Bootstrap UCL	0.132		
90% Chebyshev(Mean, Sd) UCL	0.138	95% Chebyshev(Mean, Sd) UCL	0.158
97.5% Chebyshev(Mean, Sd) UCL	0.185	99% Chebyshev(Mean, Sd) UCL	0.239

Suggested UCL to Use

95% H-UCL 0.105

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
Recommendations are based upon data size, data distribution, and skewness.
These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).
However, simulations results will not cover all Real World data sets; for additional insight the user may want to consult a statistician.

ProUCL computes and outputs H-statistic based UCLs for historical reasons only.
H-statistic often results in unstable (both high and low) values of UCL95 as shown in examples in the Technical Guide.
It is therefore recommended to avoid the use of H-statistic based 95% UCLs.
Use of nonparametric methods are preferred to compute UCL95 for skewed data sets which do not follow a gamma distribution.

Acrylonitrile

General Statistics

Total Number of Observations	69	Number of Distinct Observations	5
		Number of Missing Observations	0
Minimum	0	Mean	6.6983E-4
Maximum	0.02	Median	0
SD	0.00297	Std. Error of Mean	3.5766E-4
Coefficient of Variation	4.435	Skewness	5.091

Normal GOF Test

Shapiro Wilk Test Statistic	0.261	**Shapiro Wilk GOF Test**	
5% Shapiro Wilk P Value	0	Data Not Normal at 5% Significance Level	
Lilliefors Test Statistic	0.531	**Lilliefors GOF Test**	
5% Lilliefors Critical Value	0.107	Data Not Normal at 5% Significance Level	

Data Not Normal at 5% Significance Level

Assuming Normal Distribution

95% Normal UCL		95% UCLs (Adjusted for Skewness)	
95% Student's-t UCL	0.00127	95% Adjusted-CLT UCL (Chen-1995)	0.00149
		95% Modified-t UCL (Johnson-1978)	0.0013

Gamma Statistics Not Available

Lognormal Statistics Not Available

Nonparametric Distribution Free UCL Statistics

Data do not follow a Discernible Distribution (0.05)

Nonparametric Distribution Free UCLs

95% CLT UCL	0.00126	95% Jackknife UCL	0.00127
95% Standard Bootstrap UCL	0.00125	95% Bootstrap-t UCL	0.00197
95% Hall's Bootstrap UCL	0.00136	95% Percentile Bootstrap UCL	0.00131
95% BCA Bootstrap UCL	0.00152		
90% Chebyshev(Mean, Sd) UCL	0.00174	95% Chebyshev(Mean, Sd) UCL	0.00223
97.5% Chebyshev(Mean, Sd) UCL	0.0029	99% Chebyshev(Mean, Sd) UCL	0.00423

Suggested UCL to Use

95% Chebyshev (Mean, Sd) UCL	0.00223

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
Recommendations are based upon data size, data distribution, and skewness.
These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).
However, simulations results will not cover all Real World data sets; for additional insight the user may want to consult a statistician.

Ethylene dibromide

General Statistics

Total Number of Observations	69	Number of Distinct Observations	2

		Number of Missing Observations	0
Minimum	0	Mean	4.4536E-5
Maximum	0.00307	Median	0
SD	3.6995E-4	Std. Error of Mean	4.4536E-5
Coefficient of Variation	N/A	Skewness	8.307

Normal GOF Test

Shapiro Wilk Test Statistic	0.122	**Shapiro Wilk GOF Test**	
5% Shapiro Wilk P Value	0	Data Not Normal at 5% Significance Level	
Lilliefors Test Statistic	0.533	**Lilliefors GOF Test**	
5% Lilliefors Critical Value	0.107	Data Not Normal at 5% Significance Level	

Data Not Normal at 5% Significance Level

Assuming Normal Distribution

95% Normal UCL		**95% UCLs (Adjusted for Skewness)**	
95% Student's-t UCL	1.1880E-4	95% Adjusted-CLT UCL (Chen-1995)	1.6538E-4
		95% Modified-t UCL (Johnson-1978)	1.2623E-4

Gamma Statistics Not Available

Lognormal Statistics Not Available

Nonparametric Distribution Free UCL Statistics

Data do not follow a Discernible Distribution (0.05)

Nonparametric Distribution Free UCLs

95% CLT UCL	1.1779E-4	95% Jackknife UCL	N/A
95% Standard Bootstrap UCL	N/A	95% Bootstrap-t UCL	N/A
95% Hall's Bootstrap UCL	N/A	95% Percentile Bootstrap UCL	N/A
95% BCA Bootstrap UCL	N/A		
90% Chebyshev(Mean, Sd) UCL	1.7815E-4	95% Chebyshev(Mean, Sd) UCL	2.3867E-4
97.5% Chebyshev(Mean, Sd) UCL	3.2267E-4	99% Chebyshev(Mean, Sd) UCL	4.8767E-4

Suggested UCL to Use

95% Chebyshev (Mean, Sd) UCL 2.3867E-4

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
Recommendations are based upon data size, data distribution, and skewness.
These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).
However, simulations results will not cover all Real World data sets; for additional insight the user may want to consult a statistician.

10.3.2 Johnson-Riley Road

UCL Statistics for Uncensored Full Data Sets

User Selected Options	
Date/Time of Computation	ProUCL 5.16/14/2022 5:07:40 PM
From File	WorkSheet_a.xls
Full Precision	OFF
Confidence Coefficient	95%
Number of Bootstrap Operations	2000

1,3-Butadiene

General Statistics

Total Number of Observations	67	Number of Distinct Observations	54
		Number of Missing Observations	0
Minimum	0.00774	Mean	0.0353
Maximum	0.0933	Median	0.0363
SD	0.0208	Std. Error of Mean	0.00254

Coefficient of Variation	0.589	Skewness	1.049

Normal GOF Test

Shapiro Wilk Test Statistic	0.894	**Shapiro Wilk GOF Test**	
5% Shapiro Wilk P Value	4.2236E-6	Data Not Normal at 5% Significance Level	
Lilliefors Test Statistic	0.14	**Lilliefors GOF Test**	
5% Lilliefors Critical Value	0.108	Data Not Normal at 5% Significance Level	

Data Not Normal at 5% Significance Level

Assuming Normal Distribution

95% Normal UCL		**95% UCLs (Adjusted for Skewness)**	
95% Student's-t UCL	0.0395	95% Adjusted-CLT UCL (Chen-1995)	0.0398
		95% Modified-t UCL (Johnson-1978)	0.0395

Gamma GOF Test

A-D Test Statistic	0.61	**Anderson-Darling Gamma GOF Test**	
5% A-D Critical Value	0.758	Detected data appear Gamma Distributed at 5% Significance Level	
K-S Test Statistic	0.103	**Kolmogorov-Smirnov Gamma GOF Test**	
5% K-S Critical Value	0.11	Detected data appear Gamma Distributed at 5% Significance Level	

Detected data appear Gamma Distributed at 5% Significance Level

Gamma Statistics

k hat (MLE)	2.998	k star (bias corrected MLE)	2.874
Theta hat (MLE)	0.0118	Theta star (bias corrected MLE)	0.0123
nu hat (MLE)	401.7	nu star (bias corrected)	385.1
MLE Mean (bias corrected)	0.0353	MLE Sd (bias corrected)	0.0208
		Approximate Chi Square Value (0.05)	340.6
Adjusted Level of Significance	0.0464	Adjusted Chi Square Value	339.7

Assuming Gamma Distribution

95% Approximate Gamma UCL (use when n>=50)	0.0399	95% Adjusted Gamma UCL (use when n<50)	0.04

Lognormal GOF Test

Shapiro Wilk Test Statistic	0.955	**Shapiro Wilk Lognormal GOF Test**	
5% Shapiro Wilk P Value	0.0425	Data Not Lognormal at 5% Significance Level	
Lilliefors Test Statistic	0.137	**Lilliefors Lognormal GOF Test**	
5% Lilliefors Critical Value	0.108	Data Not Lognormal at 5% Significance Level	

Data Not Lognormal at 5% Significance Level

Lognormal Statistics

Minimum of Logged Data	-4.861	Mean of logged Data	-3.521
Maximum of Logged Data	-2.371	SD of logged Data	0.619

Assuming Lognormal Distribution

95% H-UCL	0.0416	90% Chebyshev (MVUE) UCL	0.0444
95% Chebyshev (MVUE) UCL	0.0484	97.5% Chebyshev (MVUE) UCL	0.0539
99% Chebyshev (MVUE) UCL	0.0647		

Nonparametric Distribution Free UCL Statistics

Data appear to follow a Discernible Distribution at 5% Significance Level

Nonparametric Distribution Free UCLs

95% CLT UCL	0.0394	95% Jackknife UCL	0.0395
95% Standard Bootstrap UCL	0.0394	95% Bootstrap-t UCL	0.0398
95% Hall's Bootstrap UCL	0.04	95% Percentile Bootstrap UCL	0.0394
95% BCA Bootstrap UCL	0.0398		
90% Chebyshev(Mean, Sd) UCL	0.0429	95% Chebyshev(Mean, Sd) UCL	0.0463
97.5% Chebyshev(Mean, Sd) UCL	0.0511	99% Chebyshev(Mean, Sd) UCL	0.0605

Suggested UCL to Use

95% Approximate Gamma UCL	0.0399

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
Recommendations are based upon data size, data distribution, and skewness.
These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).
However, simulations results will not cover all Real World data sets; for additional insight the user may want to consult a statistician.

Carbon tetrachloride

General Statistics

Total Number of Observations	67	Number of Distinct Observations	60
		Number of Missing Observations	0
Minimum	0.145	Mean	0.515
Maximum	0.874	Median	0.504
SD	0.0919	Std. Error of Mean	0.0112
Coefficient of Variation	0.178	Skewness	-0.226

Normal GOF Test

Shapiro Wilk Test Statistic	0.89	**Shapiro Wilk GOF Test**	
5% Shapiro Wilk P Value	2.0419E-6	Data Not Normal at 5% Significance Level	
Lilliefors Test Statistic	0.156	**Lilliefors GOF Test**	
5% Lilliefors Critical Value	0.108	Data Not Normal at 5% Significance Level	

Data Not Normal at 5% Significance Level

Assuming Normal Distribution

95% Normal UCL		**95% UCLs (Adjusted for Skewness)**	
95% Student's-t UCL	0.534	95% Adjusted-CLT UCL (Chen-1995)	0.533
		95% Modified-t UCL (Johnson-1978)	0.534

Gamma GOF Test

A-D Test Statistic	3.4	**Anderson-Darling Gamma GOF Test**
5% A-D Critical Value	0.749	Data Not Gamma Distributed at 5% Significance Level
K-S Test Statistic	0.193	**Kolmogorov-Smirnov Gamma GOF Test**
5% K-S Critical Value	0.109	Data Not Gamma Distributed at 5% Significance Level

Data Not Gamma Distributed at 5% Significance Level

Gamma Statistics

k hat (MLE)	25.62	k star (bias corrected MLE)	24.48
Theta hat (MLE)	0.0201	Theta star (bias corrected MLE)	0.021
nu hat (MLE)	3433	nu star (bias corrected)	3281
MLE Mean (bias corrected)	0.515	MLE Sd (bias corrected)	0.104
		Approximate Chi Square Value (0.05)	3148
Adjusted Level of Significance	0.0464	Adjusted Chi Square Value	3146

Assuming Gamma Distribution

95% Approximate Gamma UCL (use when n>=50))	0.537	95% Adjusted Gamma UCL (use when n<50)	0.537

Lognormal GOF Test

Shapiro Wilk Test Statistic	0.744	**Shapiro Wilk Lognormal GOF Test**
5% Shapiro Wilk P Value	1.110E-15	Data Not Lognormal at 5% Significance Level
Lilliefors Test Statistic	0.216	**Lilliefors Lognormal GOF Test**
5% Lilliefors Critical Value	0.108	Data Not Lognormal at 5% Significance Level

Data Not Lognormal at 5% Significance Level

Lognormal Statistics

Minimum of Logged Data	-1.929	Mean of logged Data	-0.683
Maximum of Logged Data	-0.134	SD of logged Data	0.218

Assuming Lognormal Distribution

95% H-UCL	0.542	90% Chebyshev (MVUE) UCL	0.559

95% Chebyshev (MVUE) UCL	0.578	97.5% Chebyshev (MVUE) UCL	0.604
99% Chebyshev (MVUE) UCL	0.656		

Nonparametric Distribution Free UCL Statistics

Data do not follow a Discernible Distribution (0.05)

Nonparametric Distribution Free UCLs

95% CLT UCL	0.534	95% Jackknife UCL	0.534
95% Standard Bootstrap UCL	0.534	95% Bootstrap-t UCL	0.534
95% Hall's Bootstrap UCL	0.535	95% Percentile Bootstrap UCL	0.533
95% BCA Bootstrap UCL	0.533		
90% Chebyshev(Mean, Sd) UCL	0.549	95% Chebyshev(Mean, Sd) UCL	0.564
97.5% Chebyshev(Mean, Sd) UCL	0.585	99% Chebyshev(Mean, Sd) UCL	0.627

Suggested UCL to Use

95% Student's-t UCL	0.534	or 95% Modified-t UCL	0.534

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
Recommendations are based upon data size, data distribution, and skewness.
These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).
However, simulations results will not cover all Real World data sets; for additional insight the user may want to consult a statistician.

Note: For highly negatively-skewed data, confidence limits (e.g., Chen, Johnson, Lognormal, and Gamma) may not be reliable. Chen's and Johnson's methods provide adjustments for positvely skewed data sets.

1,1-Dichloroethane

General Statistics

Total Number of Observations	67	Number of Distinct Observations	39
		Number of Missing Observations	0

Minimum	0.00486	Mean	0.0773
Maximum	1.376	Median	0.0457
SD	0.187	Std. Error of Mean	0.0229
Coefficient of Variation	2.422	Skewness	5.877

Normal GOF Test

Shapiro Wilk Test Statistic	0.334	**Shapiro Wilk GOF Test**
5% Shapiro Wilk P Value	0	Data Not Normal at 5% Significance Level
Lilliefors Test Statistic	0.407	**Lilliefors GOF Test**
5% Lilliefors Critical Value	0.108	Data Not Normal at 5% Significance Level

Data Not Normal at 5% Significance Level

Assuming Normal Distribution

95% Normal UCL		**95% UCLs (Adjusted for Skewness)**	
95% Student's-t UCL	0.115	95% Adjusted-CLT UCL (Chen-1995)	0.132
		95% Modified-t UCL (Johnson-1978)	0.118

Gamma GOF Test

A-D Test Statistic	6.555	**Anderson-Darling Gamma GOF Test**
5% A-D Critical Value	0.79	Data Not Gamma Distributed at 5% Significance Level
K-S Test Statistic	0.353	**Kolmogorov-Smirnov Gamma GOF Test**
5% K-S Critical Value	0.113	Data Not Gamma Distributed at 5% Significance Level

Data Not Gamma Distributed at 5% Significance Level

Gamma Statistics

k hat (MLE)	0.802	k star (bias corrected MLE)	0.776
Theta hat (MLE)	0.0963	Theta star (bias corrected MLE)	0.0995
nu hat (MLE)	107.5	nu star (bias corrected)	104
MLE Mean (bias corrected)	0.0773	MLE Sd (bias corrected)	0.0877
		Approximate Chi Square Value (0.05)	81.48
Adjusted Level of Significance	0.0464	Adjusted Chi Square Value	81.04

Assuming Gamma Distribution

95% Approximate Gamma UCL (use when n>=50))	0.0986	95% Adjusted Gamma UCL (use when n<50)	0.0992

Lognormal GOF Test

Shapiro Wilk Test Statistic	0.893	**Shapiro Wilk Lognormal GOF Test**	
5% Shapiro Wilk P Value	3.1945E-6	Data Not Lognormal at 5% Significance Level	
Lilliefors Test Statistic	0.253	**Lilliefors Lognormal GOF Test**	
5% Lilliefors Critical Value	0.108	Data Not Lognormal at 5% Significance Level	

Data Not Lognormal at 5% Significance Level

Lognormal Statistics

Minimum of Logged Data	-5.327	Mean of logged Data	-3.3
Maximum of Logged Data	0.319	SD of logged Data	1.022

Assuming Lognormal Distribution

95% H-UCL	0.0826	90% Chebyshev (MVUE) UCL	0.089
95% Chebyshev (MVUE) UCL	0.101	97.5% Chebyshev (MVUE) UCL	0.119
99% Chebyshev (MVUE) UCL	0.153		

Nonparametric Distribution Free UCL Statistics

Data do not follow a Discernible Distribution (0.05)

Nonparametric Distribution Free UCLs

95% CLT UCL	0.115	95% Jackknife UCL	0.115
95% Standard Bootstrap UCL	0.114	95% Bootstrap-t UCL	0.207
95% Hall's Bootstrap UCL	0.268	95% Percentile Bootstrap UCL	0.119
95% BCA Bootstrap UCL	0.137		
90% Chebyshev(Mean, Sd) UCL	0.146	95% Chebyshev(Mean, Sd) UCL	0.177
97.5% Chebyshev(Mean, Sd) UCL	0.22	99% Chebyshev(Mean, Sd) UCL	0.305

Suggested UCL to Use

95% Chebyshev (Mean, Sd) UCL	0.177

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
Recommendations are based upon data size, data distribution, and skewness.
These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).
However, simulations results will not cover all Real World data sets; for additional insight the user may want to consult a statistician.

Ethylene dichloride

General Statistics

Total Number of Observations	67	Number of Distinct Observations	63
		Number of Missing Observations	0
Minimum	0.0409	Mean	1.287
Maximum	15.42	Median	0.276
SD	2.661	Std. Error of Mean	0.325
Coefficient of Variation	2.067	Skewness	3.439

Normal GOF Test

Shapiro Wilk Test Statistic	0.524	**Shapiro Wilk GOF Test**	
5% Shapiro Wilk P Value	0	Data Not Normal at 5% Significance Level	
Lilliefors Test Statistic	0.32	**Lilliefors GOF Test**	
5% Lilliefors Critical Value	0.108	Data Not Normal at 5% Significance Level	

Data Not Normal at 5% Significance Level

Assuming Normal Distribution

95% Normal UCL		**95% UCLs (Adjusted for Skewness)**	
95% Student's-t UCL	1.83	95% Adjusted-CLT UCL (Chen-1995)	1.968
		95% Modified-t UCL (Johnson-1978)	1.853

Gamma GOF Test

A-D Test Statistic	4.264	**Anderson-Darling Gamma GOF Test**
5% A-D Critical Value	0.819	Data Not Gamma Distributed at 5% Significance Level
K-S Test Statistic	0.202	**Kolmogorov-Smirnov Gamma GOF Test**
5% K-S Critical Value	0.115	Data Not Gamma Distributed at 5% Significance Level

Data Not Gamma Distributed at 5% Significance Level

Gamma Statistics

k hat (MLE)	0.49	k star (bias corrected MLE)	0.478
Theta hat (MLE)	2.627	Theta star (bias corrected MLE)	2.693
nu hat (MLE)	65.68	nu star (bias corrected)	64.07
MLE Mean (bias corrected)	1.287	MLE Sd (bias corrected)	1.862
		Approximate Chi Square Value (0.05)	46.65
Adjusted Level of Significance	0.0464	Adjusted Chi Square Value	46.33

Assuming Gamma Distribution

95% Approximate Gamma UCL (use when n>=50))	1.768	95% Adjusted Gamma UCL (use when n<50)	1.78

Lognormal GOF Test

Shapiro Wilk Test Statistic	0.921	**Shapiro Wilk Lognormal GOF Test**
5% Shapiro Wilk P Value	2.5220E-4	Data Not Lognormal at 5% Significance Level
Lilliefors Test Statistic	0.109	**Lilliefors Lognormal GOF Test**
5% Lilliefors Critical Value	0.108	Data Not Lognormal at 5% Significance Level

Data Not Lognormal at 5% Significance Level

Lognormal Statistics

Minimum of Logged Data	-3.197	Mean of logged Data	-1.047
Maximum of Logged Data	2.736	SD of logged Data	1.538

Assuming Lognormal Distribution

95% H-UCL	1.812	90% Chebyshev (MVUE) UCL	1.954

95% Chebyshev (MVUE) UCL	2.34	97.5% Chebyshev (MVUE) UCL	2.875
99% Chebyshev (MVUE) UCL	3.926		

Nonparametric Distribution Free UCL Statistics

Data do not follow a Discernible Distribution (0.05)

Nonparametric Distribution Free UCLs

95% CLT UCL	1.822	95% Jackknife UCL	1.83
95% Standard Bootstrap UCL	1.821	95% Bootstrap-t UCL	2.081
95% Hall's Bootstrap UCL	2.088	95% Percentile Bootstrap UCL	1.855
95% BCA Bootstrap UCL	2.013		
90% Chebyshev(Mean, Sd) UCL	2.263	95% Chebyshev(Mean, Sd) UCL	2.705
97.5% Chebyshev(Mean, Sd) UCL	3.318	99% Chebyshev(Mean, Sd) UCL	4.522

Suggested UCL to Use

95% Chebyshev (Mean, Sd) UCL	2.705

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
Recommendations are based upon data size, data distribution, and skewness.
These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).
However, simulations results will not cover all Real World data sets; for additional insight the user may want to consult a statistician.

1,1,2-Trichloroethane

General Statistics

Total Number of Observations	67	Number of Distinct Observations	26
		Number of Missing Observations	0
Minimum	0.00764	Mean	0.0954
Maximum	0.584	Median	0.0937
SD	0.0843	Std. Error of Mean	0.0103

Coefficient of Variation	0.883	Skewness	4.011

Normal GOF Test

Shapiro Wilk Test Statistic	0.538	**Shapiro Wilk GOF Test**	
5% Shapiro Wilk P Value	0	Data Not Normal at 5% Significance Level	
Lilliefors Test Statistic	0.419	**Lilliefors GOF Test**	
5% Lilliefors Critical Value	0.108	Data Not Normal at 5% Significance Level	

Data Not Normal at 5% Significance Level

Assuming Normal Distribution

95% Normal UCL		**95% UCLs (Adjusted for Skewness)**	
95% Student's-t UCL	0.113	95% Adjusted-CLT UCL (Chen-1995)	0.118
		95% Modified-t UCL (Johnson-1978)	0.113

Gamma GOF Test

A-D Test Statistic	7.522	**Anderson-Darling Gamma GOF Test**	
5% A-D Critical Value	0.763	Data Not Gamma Distributed at 5% Significance Level	
K-S Test Statistic	0.328	**Kolmogorov-Smirnov Gamma GOF Test**	
5% K-S Critical Value	0.11	Data Not Gamma Distributed at 5% Significance Level	

Data Not Gamma Distributed at 5% Significance Level

Gamma Statistics

k hat (MLE)	2.074	k star (bias corrected MLE)	1.991
Theta hat (MLE)	0.046	Theta star (bias corrected MLE)	0.0479
nu hat (MLE)	277.9	nu star (bias corrected)	266.8
MLE Mean (bias corrected)	0.0954	MLE Sd (bias corrected)	0.0676
		Approximate Chi Square Value (0.05)	230
Adjusted Level of Significance	0.0464	Adjusted Chi Square Value	229.2

Assuming Gamma Distribution

95% Approximate Gamma UCL (use when n>=50))	0.111	95% Adjusted Gamma UCL (use when n<50)	0.111

Lognormal GOF Test

Shapiro Wilk Test Statistic	0.778	**Shapiro Wilk Lognormal GOF Test**	
5% Shapiro Wilk P Value	1.208E-13	Data Not Lognormal at 5% Significance Level	
Lilliefors Test Statistic	0.338	**Lilliefors Lognormal GOF Test**	
5% Lilliefors Critical Value	0.108	Data Not Lognormal at 5% Significance Level	

Data Not Lognormal at 5% Significance Level

Lognormal Statistics

Minimum of Logged Data	-4.875	Mean of logged Data	-2.61
Maximum of Logged Data	-0.538	SD of logged Data	0.769

Assuming Lognormal Distribution

95% H-UCL	0.12	90% Chebyshev (MVUE) UCL	0.129
95% Chebyshev (MVUE) UCL	0.143	97.5% Chebyshev (MVUE) UCL	0.163
99% Chebyshev (MVUE) UCL	0.201		

Nonparametric Distribution Free UCL Statistics

Data do not follow a Discernible Distribution (0.05)

Nonparametric Distribution Free UCLs

95% CLT UCL	0.112	95% Jackknife UCL	0.113
95% Standard Bootstrap UCL	0.112	95% Bootstrap-t UCL	0.125
95% Hall's Bootstrap UCL	0.203	95% Percentile Bootstrap UCL	0.113
95% BCA Bootstrap UCL	0.119		
90% Chebyshev(Mean, Sd) UCL	0.126	95% Chebyshev(Mean, Sd) UCL	0.14
97.5% Chebyshev(Mean, Sd) UCL	0.16	99% Chebyshev(Mean, Sd) UCL	0.198

Suggested UCL to Use

95% Chebyshev (Mean, Sd) UCL	0.14

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
Recommendations are based upon data size, data distribution, and skewness.
These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).
However, simulations results will not cover all Real World data sets; for additional insight the user may want to consult a statistician.

Vinyl chloride

General Statistics

Total Number of Observations	67	Number of Distinct Observations	59
		Number of Missing Observations	0
Minimum	0.00358	Mean	1.847
Maximum	13.75	Median	0.144
SD	3.217	Std. Error of Mean	0.393
Coefficient of Variation	1.742	Skewness	2.044

Normal GOF Test

Shapiro Wilk Test Statistic	0.639	**Shapiro Wilk GOF Test**	
5% Shapiro Wilk P Value	0	Data Not Normal at 5% Significance Level	
Lilliefors Test Statistic	0.311	**Lilliefors GOF Test**	
5% Lilliefors Critical Value	0.108	Data Not Normal at 5% Significance Level	

Data Not Normal at 5% Significance Level

Assuming Normal Distribution

95% Normal UCL		**95% UCLs (Adjusted for Skewness)**	
95% Student's-t UCL	2.503	95% Adjusted-CLT UCL (Chen-1995)	2.599
		95% Modified-t UCL (Johnson-1978)	2.519

Gamma GOF Test

A-D Test Statistic	3.214	**Anderson-Darling Gamma GOF Test**	
5% A-D Critical Value	0.857	Data Not Gamma Distributed at 5% Significance Level	

K-S Test Statistic	0.197	**Kolmogorov-Smirnov Gamma GOF Test**	
5% K-S Critical Value	0.118	Data Not Gamma Distributed at 5% Significance Level	

Data Not Gamma Distributed at 5% Significance Level

Gamma Statistics

k hat (MLE)	0.331	k star (bias corrected MLE)	0.327
Theta hat (MLE)	5.574	Theta star (bias corrected MLE)	5.658
nu hat (MLE)	44.41	nu star (bias corrected)	43.76
MLE Mean (bias corrected)	1.847	MLE Sd (bias corrected)	3.233
		Approximate Chi Square Value (0.05)	29.59
Adjusted Level of Significance	0.0464	Adjusted Chi Square Value	29.33

Assuming Gamma Distribution

95% Approximate Gamma UCL (use when n>=50))	2.732	95% Adjusted Gamma UCL (use when n<50)	2.756

Lognormal GOF Test

Shapiro Wilk Test Statistic	0.916	**Shapiro Wilk Lognormal GOF Test**	
5% Shapiro Wilk P Value	1.1689E-4	Data Not Lognormal at 5% Significance Level	
Lilliefors Test Statistic	0.141	**Lilliefors Lognormal GOF Test**	
5% Lilliefors Critical Value	0.108	Data Not Lognormal at 5% Significance Level	

Data Not Lognormal at 5% Significance Level

Lognormal Statistics

Minimum of Logged Data	-5.633	Mean of logged Data	-1.433
Maximum of Logged Data	2.621	SD of logged Data	2.317

Assuming Lognormal Distribution

95% H-UCL	8.533	90% Chebyshev (MVUE) UCL	7.209
95% Chebyshev (MVUE) UCL	9.089	97.5% Chebyshev (MVUE) UCL	11.7
99% Chebyshev (MVUE) UCL	16.83		

Nonparametric Distribution Free UCL Statistics

Data do not follow a Discernible Distribution (0.05)

Nonparametric Distribution Free UCLs

95% CLT UCL	2.494	95% Jackknife UCL	2.503
95% Standard Bootstrap UCL	2.496	95% Bootstrap-t UCL	2.624
95% Hall's Bootstrap UCL	2.599	95% Percentile Bootstrap UCL	2.534
95% BCA Bootstrap UCL	2.669		
90% Chebyshev(Mean, Sd) UCL	3.027	95% Chebyshev(Mean, Sd) UCL	3.561
97.5% Chebyshev(Mean, Sd) UCL	4.302	99% Chebyshev(Mean, Sd) UCL	5.758

Suggested UCL to Use

95% Chebyshev (Mean, Sd) UCL	3.561

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
Recommendations are based upon data size, data distribution, and skewness.
These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).
However, simulations results will not cover all Real World data sets; for additional insight the user may want to consult a statistician.

Benzene

General Statistics

Total Number of Observations	67	Number of Distinct Observations	58
		Number of Missing Observations	0
Minimum	0.136	Mean	0.459
Maximum	0.987	Median	0.434
SD	0.181	Std. Error of Mean	0.0221
Coefficient of Variation	0.394	Skewness	0.706

Normal GOF Test

Shapiro Wilk Test Statistic	0.955	**Shapiro Wilk GOF Test**	
5% Shapiro Wilk P Value	0.0407	Data Not Normal at 5% Significance Level	
Lilliefors Test Statistic	0.111	**Lilliefors GOF Test**	
5% Lilliefors Critical Value	0.108	Data Not Normal at 5% Significance Level	

Data Not Normal at 5% Significance Level

Assuming Normal Distribution

95% Normal UCL		**95% UCLs (Adjusted for Skewness)**	
95% Student's-t UCL	0.496	95% Adjusted-CLT UCL (Chen-1995)	0.498
		95% Modified-t UCL (Johnson-1978)	0.497

Gamma GOF Test

A-D Test Statistic	0.23	**Anderson-Darling Gamma GOF Test**	
5% A-D Critical Value	0.753	Detected data appear Gamma Distributed at 5% Significance Level	
K-S Test Statistic	0.072	**Kolmogorov-Smirnov Gamma GOF Test**	
5% K-S Critical Value	0.109	Detected data appear Gamma Distributed at 5% Significance Level	

Detected data appear Gamma Distributed at 5% Significance Level

Gamma Statistics

k hat (MLE)	6.494	k star (bias corrected MLE)	6.213
Theta hat (MLE)	0.0707	Theta star (bias corrected MLE)	0.0739
nu hat (MLE)	870.2	nu star (bias corrected)	832.6
MLE Mean (bias corrected)	0.459	MLE Sd (bias corrected)	0.184
		Approximate Chi Square Value (0.05)	766.6
Adjusted Level of Significance	0.0464	Adjusted Chi Square Value	765.2

Assuming Gamma Distribution

95% Approximate Gamma UCL (use when n>=50)	0.499	95% Adjusted Gamma UCL (use when n<50)	0.5

Lognormal GOF Test

Shapiro Wilk Test Statistic	0.979	**Shapiro Wilk Lognormal GOF Test**	

5% Shapiro Wilk P Value	0.58	Data appear Lognormal at 5% Significance Level	
Lilliefors Test Statistic	0.0757	**Lilliefors Lognormal GOF Test**	
5% Lilliefors Critical Value	0.108	Data appear Lognormal at 5% Significance Level	

Data appear Lognormal at 5% Significance Level

Lognormal Statistics

Minimum of Logged Data	-1.992	Mean of logged Data	-0.857
Maximum of Logged Data	-0.013	SD of logged Data	0.411

Assuming Lognormal Distribution

95% H-UCL	0.506	90% Chebyshev (MVUE) UCL	0.533
95% Chebyshev (MVUE) UCL	0.566	97.5% Chebyshev (MVUE) UCL	0.611
99% Chebyshev (MVUE) UCL	0.7		

Nonparametric Distribution Free UCL Statistics

Data appear to follow a Discernible Distribution at 5% Significance Level

Nonparametric Distribution Free UCLs

95% CLT UCL	0.496	95% Jackknife UCL	0.496
95% Standard Bootstrap UCL	0.495	95% Bootstrap-t UCL	0.497
95% Hall's Bootstrap UCL	0.498	95% Percentile Bootstrap UCL	0.495
95% BCA Bootstrap UCL	0.498		
90% Chebyshev(Mean, Sd) UCL	0.526	95% Chebyshev(Mean, Sd) UCL	0.556
97.5% Chebyshev(Mean, Sd) UCL	0.598	99% Chebyshev(Mean, Sd) UCL	0.68

Suggested UCL to Use

95% Approximate Gamma UCL	0.499

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.

Recommendations are based upon data size, data distribution, and skewness.

These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).

However, simulations results will not cover all Real World data sets; for additional insight the user may want to consult a statistician.

Acrylonitrile

General Statistics

Total Number of Observations	66	Number of Distinct Observations	6
		Number of Missing Observations	0
Minimum	0	Mean	0.00256
Maximum	0.0731	Median	0
SD	0.0106	Std. Error of Mean	0.0013
Coefficient of Variation	4.13	Skewness	5.283

Normal GOF Test

Shapiro Wilk Test Statistic	0.285	**Shapiro Wilk GOF Test**	
5% Shapiro Wilk P Value	0	Data Not Normal at 5% Significance Level	
Lilliefors Test Statistic	0.52	**Lilliefors GOF Test**	
5% Lilliefors Critical Value	0.109	Data Not Normal at 5% Significance Level	

Data Not Normal at 5% Significance Level

Assuming Normal Distribution

95% Normal UCL		**95% UCLs (Adjusted for Skewness)**	
95% Student's-t UCL	0.00473	95% Adjusted-CLT UCL (Chen-1995)	0.0056
		95% Modified-t UCL (Johnson-1978)	0.00487

Gamma Statistics Not Available

Lognormal Statistics Not Available

Nonparametric Distribution Free UCL Statistics

Data do not follow a Discernible Distribution (0.05)

Nonparametric Distribution Free UCLs

95% CLT UCL	0.0047	95% Jackknife UCL	0.00473

95% Standard Bootstrap UCL	0.00463	95% Bootstrap-t UCL	0.00764
95% Hall's Bootstrap UCL	0.00715	95% Percentile Bootstrap UCL	0.00482
95% BCA Bootstrap UCL	0.00606		
90% Chebyshev(Mean, Sd) UCL	0.00646	95% Chebyshev(Mean, Sd) UCL	0.00823
97.5% Chebyshev(Mean, Sd) UCL	0.0107	99% Chebyshev(Mean, Sd) UCL	0.0155

Suggested UCL to Use

95% Chebyshev (Mean, Sd) UCL	0.00823

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
Recommendations are based upon data size, data distribution, and skewness.
These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).
However, simulations results will not cover all Real World data sets; for additional insight the user may want to consult a statistician.

10.3.3 LWD

UCL Statistics for Uncensored Full Data Sets

User Selected Options	
Date/Time of Computation	ProUCL 5.16/14/2022 5:24:17 PM
From File	WorkSheet_b.xls
Full Precision	OFF
Confidence Coefficient	95%
Number of Bootstrap Operations	2000

1,3-Butadiene

General Statistics

Total Number of Observations	73	Number of Distinct Observations	61
		Number of Missing Observations	0
Minimum	0.00763	Mean	0.0478
Maximum	0.373	Median	0.0325
SD	0.0543	Std. Error of Mean	0.00635
Coefficient of Variation	1.137	Skewness	4.042

Normal GOF Test

Shapiro Wilk Test Statistic	0.589	**Shapiro Wilk GOF Test**	
5% Shapiro Wilk P Value	0	Data Not Normal at 5% Significance Level	
Lilliefors Test Statistic	0.235	**Lilliefors GOF Test**	
5% Lilliefors Critical Value	0.104	Data Not Normal at 5% Significance Level	

Data Not Normal at 5% Significance Level

Assuming Normal Distribution

95% Normal UCL		**95% UCLs (Adjusted for Skewness)**	
95% Student's-t UCL	0.0583	95% Adjusted-CLT UCL (Chen-1995)	0.0614
		95% Modified-t UCL (Johnson-1978)	0.0588

Gamma GOF Test

A-D Test Statistic	1.559	**Anderson-Darling Gamma GOF Test**	
5% A-D Critical Value	0.768	Data Not Gamma Distributed at 5% Significance Level	
K-S Test Statistic	0.11	**Kolmogorov-Smirnov Gamma GOF Test**	
5% K-S Critical Value	0.106	Data Not Gamma Distributed at 5% Significance Level	

Data Not Gamma Distributed at 5% Significance Level

Gamma Statistics

k hat (MLE)	1.646	k star (bias corrected MLE)	1.587
Theta hat (MLE)	0.029	Theta star (bias corrected MLE)	0.0301
nu hat (MLE)	240.3	nu star (bias corrected)	231.7

MLE Mean (bias corrected)	0.0478	MLE Sd (bias corrected)	0.0379
		Approximate Chi Square Value (0.05)	197.5
Adjusted Level of Significance	0.0467	Adjusted Chi Square Value	196.9

Assuming Gamma Distribution

95% Approximate Gamma UCL (use when n>=50))	0.056	95% Adjusted Gamma UCL (use when n<50)	0.0562

Lognormal GOF Test

Shapiro Wilk Test Statistic	0.969	**Shapiro Wilk Lognormal GOF Test**	
5% Shapiro Wilk P Value	0.197	Data appear Lognormal at 5% Significance Level	
Lilliefors Test Statistic	0.0617	**Lilliefors Lognormal GOF Test**	
5% Lilliefors Critical Value	0.104	Data appear Lognormal at 5% Significance Level	

Data appear Lognormal at 5% Significance Level

Lognormal Statistics

Minimum of Logged Data	-4.875	Mean of logged Data	-3.375
Maximum of Logged Data	-0.987	SD of logged Data	0.771

Assuming Lognormal Distribution

95% H-UCL	0.0555	90% Chebyshev (MVUE) UCL	0.0597
95% Chebyshev (MVUE) UCL	0.066	97.5% Chebyshev (MVUE) UCL	0.0747
99% Chebyshev (MVUE) UCL	0.0919		

Nonparametric Distribution Free UCL Statistics

Data appear to follow a Discernible Distribution at 5% Significance Level

Nonparametric Distribution Free UCLs

95% CLT UCL	0.0582	95% Jackknife UCL	0.0583
95% Standard Bootstrap UCL	0.0582	95% Bootstrap-t UCL	0.0653
95% Hall's Bootstrap UCL	0.0685	95% Percentile Bootstrap UCL	0.0586
95% BCA Bootstrap UCL	0.0616		

90% Chebyshev(Mean, Sd) UCL	0.0668	95% Chebyshev(Mean, Sd) UCL	0.0755
97.5% Chebyshev(Mean, Sd) UCL	0.0874	99% Chebyshev(Mean, Sd) UCL	0.111

Suggested UCL to Use

95% H-UCL 0.0555

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
Recommendations are based upon data size, data distribution, and skewness.
These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).
However, simulations results will not cover all Real World data sets; for additional insight the user may want to consult a statistician.

ProUCL computes and outputs H-statistic based UCLs for historical reasons only.
H-statistic often results in unstable (both high and low) values of UCL95 as shown in examples in the Technical Guide.
It is therefore recommended to avoid the use of H-statistic based 95% UCLs.
Use of nonparametric methods are preferred to compute UCL95 for skewed data sets which do not follow a gamma distribution.

Chloroform

General Statistics

Total Number of Observations	73	Number of Distinct Observations	73
		Number of Missing Observations	0
Minimum	0.0688	Mean	0.824
Maximum	15.43	Median	0.162
SD	2.131	Std. Error of Mean	0.249
Coefficient of Variation	2.586	Skewness	5.206

Normal GOF Test

Shapiro Wilk Test Statistic	0.398	**Shapiro Wilk GOF Test**	

5% Shapiro Wilk P Value	0	Data Not Normal at 5% Significance Level
Lilliefors Test Statistic	0.362	**Lilliefors GOF Test**
5% Lilliefors Critical Value	0.104	Data Not Normal at 5% Significance Level

Data Not Normal at 5% Significance Level

Assuming Normal Distribution

95% Normal UCL		**95% UCLs (Adjusted for Skewness)**	
95% Student's-t UCL	1.239	95% Adjusted-CLT UCL (Chen-1995)	1.397
		95% Modified-t UCL (Johnson-1978)	1.265

Gamma GOF Test

A-D Test Statistic	8.254	**Anderson-Darling Gamma GOF Test**
5% A-D Critical Value	0.813	Data Not Gamma Distributed at 5% Significance Level
K-S Test Statistic	0.258	**Kolmogorov-Smirnov Gamma GOF Test**
5% K-S Critical Value	0.11	Data Not Gamma Distributed at 5% Significance Level

Data Not Gamma Distributed at 5% Significance Level

Gamma Statistics

k hat (MLE)	0.54	k star (bias corrected MLE)	0.527
Theta hat (MLE)	1.526	Theta star (bias corrected MLE)	1.564
nu hat (MLE)	78.82	nu star (bias corrected)	76.92
MLE Mean (bias corrected)	0.824	MLE Sd (bias corrected)	1.135
		Approximate Chi Square Value (0.05)	57.72
Adjusted Level of Significance	0.0467	Adjusted Chi Square Value	57.38

Assuming Gamma Distribution

95% Approximate Gamma UCL (use when n>=50))	1.098	95% Adjusted Gamma UCL (use when n<50)	1.104

Lognormal GOF Test

Shapiro Wilk Test Statistic	0.834	**Shapiro Wilk Lognormal GOF Test**
5% Shapiro Wilk P Value	3.458E-11	Data Not Lognormal at 5% Significance Level
Lilliefors Test Statistic	0.189	**Lilliefors Lognormal GOF Test**
5% Lilliefors Critical Value	0.104	Data Not Lognormal at 5% Significance Level

Data Not Lognormal at 5% Significance Level

Lognormal Statistics

Minimum of Logged Data	-2.676	Mean of logged Data	-1.356
Maximum of Logged Data	2.736	SD of logged Data	1.266

Assuming Lognormal Distribution

95% H-UCL	0.837	90% Chebyshev (MVUE) UCL	0.883
95% Chebyshev (MVUE) UCL	1.028	97.5% Chebyshev (MVUE) UCL	1.23
99% Chebyshev (MVUE) UCL	1.626		

Nonparametric Distribution Free UCL Statistics

Data do not follow a Discernible Distribution (0.05)

Nonparametric Distribution Free UCLs

95% CLT UCL	1.234	95% Jackknife UCL	1.239
95% Standard Bootstrap UCL	1.243	95% Bootstrap-t UCL	1.66
95% Hall's Bootstrap UCL	2.616	95% Percentile Bootstrap UCL	1.278
95% BCA Bootstrap UCL	1.512		
90% Chebyshev(Mean, Sd) UCL	1.572	95% Chebyshev(Mean, Sd) UCL	1.911
97.5% Chebyshev(Mean, Sd) UCL	2.381	99% Chebyshev(Mean, Sd) UCL	3.305

Suggested UCL to Use

95% Chebyshev (Mean, Sd) UCL	1.911

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
Recommendations are based upon data size, data distribution, and skewness.
These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).
However, simulations results will not cover all Real World data sets; for additional insight the user may want to consult a statistician.

Carbon tetrachloride

General Statistics

Total Number of Observations	73	Number of Distinct Observations	69
		Number of Missing Observations	0
Minimum	0.0981	Mean	0.748
Maximum	5.523	Median	0.543
SD	0.729	Std. Error of Mean	0.0853
Coefficient of Variation	0.975	Skewness	4.722

Normal GOF Test

Shapiro Wilk Test Statistic	0.485	**Shapiro Wilk GOF Test**	
5% Shapiro Wilk P Value	0	Data Not Normal at 5% Significance Level	
Lilliefors Test Statistic	0.335	**Lilliefors GOF Test**	
5% Lilliefors Critical Value	0.104	Data Not Normal at 5% Significance Level	

Data Not Normal at 5% Significance Level

Assuming Normal Distribution

95% Normal UCL		**95% UCLs (Adjusted for Skewness)**	
95% Student's-t UCL	0.89	95% Adjusted-CLT UCL (Chen-1995)	0.938
		95% Modified-t UCL (Johnson-1978)	0.898

Gamma GOF Test

A-D Test Statistic	8.352	**Anderson-Darling Gamma GOF Test**	
5% A-D Critical Value	0.759	Data Not Gamma Distributed at 5% Significance Level	
K-S Test Statistic	0.258	**Kolmogorov-Smirnov Gamma GOF Test**	
5% K-S Critical Value	0.105	Data Not Gamma Distributed at 5% Significance Level	

Data Not Gamma Distributed at 5% Significance Level

Gamma Statistics

k hat (MLE)	2.709	k star (bias corrected MLE)	2.607
Theta hat (MLE)	0.276	Theta star (bias corrected MLE)	0.287
nu hat (MLE)	395.6	nu star (bias corrected)	380.6
MLE Mean (bias corrected)	0.748	MLE Sd (bias corrected)	0.463
		Approximate Chi Square Value (0.05)	336.4
Adjusted Level of Significance	0.0467	Adjusted Chi Square Value	335.6

Assuming Gamma Distribution

95% Approximate Gamma UCL (use when n>=50))	0.846	95% Adjusted Gamma UCL (use when n<50)	0.848

Lognormal GOF Test

Shapiro Wilk Test Statistic	0.81	**Shapiro Wilk Lognormal GOF Test**	
5% Shapiro Wilk P Value	6.150E-13	Data Not Lognormal at 5% Significance Level	
Lilliefors Test Statistic	0.211	**Lilliefors Lognormal GOF Test**	
5% Lilliefors Critical Value	0.104	Data Not Lognormal at 5% Significance Level	

Data Not Lognormal at 5% Significance Level

Lognormal Statistics

Minimum of Logged Data	-2.321	Mean of logged Data	-0.487
Maximum of Logged Data	1.709	SD of logged Data	0.547

Assuming Lognormal Distribution

95% H-UCL	0.806	90% Chebyshev (MVUE) UCL	0.857
95% Chebyshev (MVUE) UCL	0.923	97.5% Chebyshev (MVUE) UCL	1.014

99% Chebyshev (MVUE) UCL	1.194

Nonparametric Distribution Free UCL Statistics

Data do not follow a Discernible Distribution (0.05)

Nonparametric Distribution Free UCLs

95% CLT UCL	0.888	95% Jackknife UCL	0.89
95% Standard Bootstrap UCL	0.892	95% Bootstrap-t UCL	1.029
95% Hall's Bootstrap UCL	1.442	95% Percentile Bootstrap UCL	0.912
95% BCA Bootstrap UCL	0.962		
90% Chebyshev(Mean, Sd) UCL	1.003	95% Chebyshev(Mean, Sd) UCL	1.119
97.5% Chebyshev(Mean, Sd) UCL	1.28	99% Chebyshev(Mean, Sd) UCL	1.596

Suggested UCL to Use

95% Chebyshev (Mean, Sd) UCL	1.119

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
Recommendations are based upon data size, data distribution, and skewness.
These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).
However, simulations results will not cover all Real World data sets; for additional insight the user may want to consult a statistician.

1,1-Dichloroethane

General Statistics

Total Number of Observations	73	Number of Distinct Observations	60
		Number of Missing Observations	0
Minimum	0.00142	Mean	0.776
Maximum	16.01	Median	0.0773
SD	2.158	Std. Error of Mean	0.253
Coefficient of Variation	2.782	Skewness	5.54

Normal GOF Test

Shapiro Wilk Test Statistic	0.397	**Shapiro Wilk GOF Test**	
5% Shapiro Wilk P Value	0	Data Not Normal at 5% Significance Level	
Lilliefors Test Statistic	0.36	**Lilliefors GOF Test**	
5% Lilliefors Critical Value	0.104	Data Not Normal at 5% Significance Level	

Data Not Normal at 5% Significance Level

Assuming Normal Distribution

95% Normal UCL		**95% UCLs (Adjusted for Skewness)**	
95% Student's-t UCL	1.197	95% Adjusted-CLT UCL (Chen-1995)	1.366
		95% Modified-t UCL (Johnson-1978)	1.224

Gamma GOF Test

A-D Test Statistic	3.924	**Anderson-Darling Gamma GOF Test**	
5% A-D Critical Value	0.849	Data Not Gamma Distributed at 5% Significance Level	
K-S Test Statistic	0.201	**Kolmogorov-Smirnov Gamma GOF Test**	
5% K-S Critical Value	0.112	Data Not Gamma Distributed at 5% Significance Level	

Data Not Gamma Distributed at 5% Significance Level

Gamma Statistics

k hat (MLE)	0.368	k star (bias corrected MLE)	0.362
Theta hat (MLE)	2.109	Theta star (bias corrected MLE)	2.144
nu hat (MLE)	53.69	nu star (bias corrected)	52.82
MLE Mean (bias corrected)	0.776	MLE Sd (bias corrected)	1.29
		Approximate Chi Square Value (0.05)	37.12
Adjusted Level of Significance	0.0467	Adjusted Chi Square Value	36.86

Assuming Gamma Distribution

95% Approximate Gamma UCL (use when n>=50))	1.104	95% Adjusted Gamma UCL (use when n<50)	1.112

Lognormal GOF Test

Shapiro Wilk Test Statistic	0.974	**Shapiro Wilk Lognormal GOF Test**	
5% Shapiro Wilk P Value	0.354	Data appear Lognormal at 5% Significance Level	
Lilliefors Test Statistic	0.129	**Lilliefors Lognormal GOF Test**	
5% Lilliefors Critical Value	0.104	Data Not Lognormal at 5% Significance Level	

Data appear Approximate Lognormal at 5% Significance Level

Lognormal Statistics

Minimum of Logged Data	-6.56	Mean of logged Data	-2.068
Maximum of Logged Data	2.773	SD of logged Data	1.935

Assuming Lognormal Distribution

95% H-UCL	1.758	90% Chebyshev (MVUE) UCL	1.556
95% Chebyshev (MVUE) UCL	1.912	97.5% Chebyshev (MVUE) UCL	2.408
99% Chebyshev (MVUE) UCL	3.38		

Nonparametric Distribution Free UCL Statistics

Data appear to follow a Discernible Distribution at 5% Significance Level

Nonparametric Distribution Free UCLs

95% CLT UCL	1.191	95% Jackknife UCL	1.197
95% Standard Bootstrap UCL	1.172	95% Bootstrap-t UCL	1.733
95% Hall's Bootstrap UCL	2.867	95% Percentile Bootstrap UCL	1.229
95% BCA Bootstrap UCL	1.412		
90% Chebyshev(Mean, Sd) UCL	1.534	95% Chebyshev(Mean, Sd) UCL	1.877
97.5% Chebyshev(Mean, Sd) UCL	2.353	99% Chebyshev(Mean, Sd) UCL	3.289

Suggested UCL to Use

95% H-UCL	1.758

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.

Recommendations are based upon data size, data distribution, and skewness.

These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).

However, simulations results will not cover all Real World data sets; for additional insight the user may want to consult a statistician.

ProUCL computes and outputs H-statistic based UCLs for historical reasons only.

H-statistic often results in unstable (both high and low) values of UCL95 as shown in examples in the Technical Guide.

It is therefore recommended to avoid the use of H-statistic based 95% UCLs.

Use of nonparametric methods are preferred to compute UCL95 for skewed data sets which do not follow a gamma distribution.

Ethylene dichloride

General Statistics

Total Number of Observations	73	Number of Distinct Observations	71
		Number of Missing Observations	0
Minimum	0.0429	Mean	21.8
Maximum	221	Median	2.193
SD	45.95	Std. Error of Mean	5.378
Coefficient of Variation	2.108	Skewness	2.894

Normal GOF Test

Shapiro Wilk Test Statistic	0.532	**Shapiro Wilk GOF Test**	
5% Shapiro Wilk P Value	0	Data Not Normal at 5% Significance Level	
Lilliefors Test Statistic	0.318	**Lilliefors GOF Test**	
5% Lilliefors Critical Value	0.104	Data Not Normal at 5% Significance Level	

Data Not Normal at 5% Significance Level

Assuming Normal Distribution

95% Normal UCL		**95% UCLs (Adjusted for Skewness)**	
95% Student's-t UCL	30.76	95% Adjusted-CLT UCL (Chen-1995)	32.59
		95% Modified-t UCL (Johnson-1978)	31.06

Gamma GOF Test

A-D Test Statistic	2.351	**Anderson-Darling Gamma GOF Test**
5% A-D Critical Value	0.865	Data Not Gamma Distributed at 5% Significance Level
K-S Test Statistic	0.128	**Kolmogorov-Smirnov Gamma GOF Test**
5% K-S Critical Value	0.113	Data Not Gamma Distributed at 5% Significance Level

Data Not Gamma Distributed at 5% Significance Level

Gamma Statistics

k hat (MLE)	0.302	k star (bias corrected MLE)	0.298
Theta hat (MLE)	72.3	Theta star (bias corrected MLE)	73.09
nu hat (MLE)	44.02	nu star (bias corrected)	43.55
MLE Mean (bias corrected)	21.8	MLE Sd (bias corrected)	39.92
		Approximate Chi Square Value (0.05)	29.41
Adjusted Level of Significance	0.0467	Adjusted Chi Square Value	29.18

Assuming Gamma Distribution

95% Approximate Gamma UCL (use when n>=50))	32.27	95% Adjusted Gamma UCL (use when n<50)	32.53

Lognormal GOF Test

Shapiro Wilk Test Statistic	0.916	**Shapiro Wilk Lognormal GOF Test**
5% Shapiro Wilk P Value	5.2942E-5	Data Not Lognormal at 5% Significance Level
Lilliefors Test Statistic	0.145	**Lilliefors Lognormal GOF Test**
5% Lilliefors Critical Value	0.104	Data Not Lognormal at 5% Significance Level

Data Not Lognormal at 5% Significance Level

Lognormal Statistics

Minimum of Logged Data	-3.149	Mean of logged Data	0.797
Maximum of Logged Data	5.398	SD of logged Data	2.547

Assuming Lognormal Distribution

95% H-UCL	196.7	90% Chebyshev (MVUE) UCL	119.8
95% Chebyshev (MVUE) UCL	152.3	97.5% Chebyshev (MVUE) UCL	197.4
99% Chebyshev (MVUE) UCL	286		

Nonparametric Distribution Free UCL Statistics

Data do not follow a Discernible Distribution (0.05)

Nonparametric Distribution Free UCLs

95% CLT UCL	30.64	95% Jackknife UCL	30.76
95% Standard Bootstrap UCL	30.52	95% Bootstrap-t UCL	34.14
95% Hall's Bootstrap UCL	32.11	95% Percentile Bootstrap UCL	30.68
95% BCA Bootstrap UCL	34.08		
90% Chebyshev(Mean, Sd) UCL	37.93	95% Chebyshev(Mean, Sd) UCL	45.24
97.5% Chebyshev(Mean, Sd) UCL	55.38	99% Chebyshev(Mean, Sd) UCL	75.3

Suggested UCL to Use

95% Chebyshev (Mean, Sd) UCL	45.24

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
Recommendations are based upon data size, data distribution, and skewness.
These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).
However, simulations results will not cover all Real World data sets; for additional insight the user may want to consult a statistician.

Bromomethane

General Statistics

Total Number of Observations	73	Number of Distinct Observations	54
		Number of Missing Observations	0
Minimum	0.0124	Mean	0.0464
Maximum	0.707	Median	0.0311

SD	0.0806	Std. Error of Mean	0.00944
Coefficient of Variation	1.736	Skewness	7.853

Normal GOF Test

Shapiro Wilk Test Statistic	0.262	**Shapiro Wilk GOF Test**
5% Shapiro Wilk P Value	0	Data Not Normal at 5% Significance Level
Lilliefors Test Statistic	0.351	**Lilliefors GOF Test**
5% Lilliefors Critical Value	0.104	Data Not Normal at 5% Significance Level

Data Not Normal at 5% Significance Level

Assuming Normal Distribution

95% Normal UCL		**95% UCLs (Adjusted for Skewness)**	
95% Student's-t UCL	0.0622	95% Adjusted-CLT UCL (Chen-1995)	0.0712
		95% Modified-t UCL (Johnson-1978)	0.0636

Gamma GOF Test

A-D Test Statistic	9.178	**Anderson-Darling Gamma GOF Test**
5% A-D Critical Value	0.763	Data Not Gamma Distributed at 5% Significance Level
K-S Test Statistic	0.277	**Kolmogorov-Smirnov Gamma GOF Test**
5% K-S Critical Value	0.106	Data Not Gamma Distributed at 5% Significance Level

Data Not Gamma Distributed at 5% Significance Level

Gamma Statistics

k hat (MLE)	2.028	k star (bias corrected MLE)	1.954
Theta hat (MLE)	0.0229	Theta star (bias corrected MLE)	0.0238
nu hat (MLE)	296.1	nu star (bias corrected)	285.3
MLE Mean (bias corrected)	0.0464	MLE Sd (bias corrected)	0.0332
		Approximate Chi Square Value (0.05)	247.2
Adjusted Level of Significance	0.0467	Adjusted Chi Square Value	246.4

Assuming Gamma Distribution

95% Approximate Gamma UCL (use when n>=50))	0.0536	95% Adjusted Gamma UCL (use when n<50)	0.0537

Lognormal GOF Test

Shapiro Wilk Test Statistic	0.772	**Shapiro Wilk Lognormal GOF Test**	
5% Shapiro Wilk P Value	1.110E-15	Data Not Lognormal at 5% Significance Level	
Lilliefors Test Statistic	0.199	**Lilliefors Lognormal GOF Test**	
5% Lilliefors Critical Value	0.104	Data Not Lognormal at 5% Significance Level	

Data Not Lognormal at 5% Significance Level

Lognormal Statistics

Minimum of Logged Data	-4.388	Mean of logged Data	-3.336
Maximum of Logged Data	-0.347	SD of logged Data	0.526

Assuming Lognormal Distribution

95% H-UCL	0.0459	90% Chebyshev (MVUE) UCL	0.0488
95% Chebyshev (MVUE) UCL	0.0524	97.5% Chebyshev (MVUE) UCL	0.0574
99% Chebyshev (MVUE) UCL	0.0672		

Nonparametric Distribution Free UCL Statistics

Data do not follow a Discernible Distribution (0.05)

Nonparametric Distribution Free UCLs

95% CLT UCL	0.062	95% Jackknife UCL	0.0622
95% Standard Bootstrap UCL	0.0621	95% Bootstrap-t UCL	0.11
95% Hall's Bootstrap UCL	0.115	95% Percentile Bootstrap UCL	0.0651
95% BCA Bootstrap UCL	0.076		
90% Chebyshev(Mean, Sd) UCL	0.0747	95% Chebyshev(Mean, Sd) UCL	0.0876
97.5% Chebyshev(Mean, Sd) UCL	0.105	99% Chebyshev(Mean, Sd) UCL	0.14

Suggested UCL to Use

95% Chebyshev (Mean, Sd) UCL	0.0876

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
Recommendations are based upon data size, data distribution, and skewness.
These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).
However, simulations results will not cover all Real World data sets; for additional insight the user may want to consult a statistician.

1,1,2-Trichloroethane

General Statistics

Total Number of Observations	73	Number of Distinct Observations	56
		Number of Missing Observations	0
Minimum	0.0115	Mean	0.494
Maximum	10.61	Median	0.0937
SD	1.347	Std. Error of Mean	0.158
Coefficient of Variation	2.724	Skewness	6.309

Normal GOF Test

Shapiro Wilk Test Statistic	0.359	**Shapiro Wilk GOF Test**	
5% Shapiro Wilk P Value	0	Data Not Normal at 5% Significance Level	
Lilliefors Test Statistic	0.36	**Lilliefors GOF Test**	
5% Lilliefors Critical Value	0.104	Data Not Normal at 5% Significance Level	

Data Not Normal at 5% Significance Level

Assuming Normal Distribution

95% Normal UCL		**95% UCLs (Adjusted for Skewness)**	
95% Student's-t UCL	0.757	95% Adjusted-CLT UCL (Chen-1995)	0.878
		95% Modified-t UCL (Johnson-1978)	0.776

Gamma GOF Test

A-D Test Statistic	5.586	**Anderson-Darling Gamma GOF Test**	

5% A-D Critical Value	0.811	Data Not Gamma Distributed at 5% Significance Level
K-S Test Statistic	0.223	**Kolmogorov-Smirnov Gamma GOF Test**
5% K-S Critical Value	0.11	Data Not Gamma Distributed at 5% Significance Level

Data Not Gamma Distributed at 5% Significance Level

Gamma Statistics

k hat (MLE)	0.564	k star (bias corrected MLE)	0.55
Theta hat (MLE)	0.876	Theta star (bias corrected MLE)	0.899
nu hat (MLE)	82.38	nu star (bias corrected)	80.33
MLE Mean (bias corrected)	0.494	MLE Sd (bias corrected)	0.667
		Approximate Chi Square Value (0.05)	60.68
Adjusted Level of Significance	0.0467	Adjusted Chi Square Value	60.33

Assuming Gamma Distribution

95% Approximate Gamma UCL (use when n>=50))	0.655	95% Adjusted Gamma UCL (use when n<50)	0.658

Lognormal GOF Test

Shapiro Wilk Test Statistic	0.941	**Shapiro Wilk Lognormal GOF Test**
5% Shapiro Wilk P Value	0.00351	Data Not Lognormal at 5% Significance Level
Lilliefors Test Statistic	0.192	**Lilliefors Lognormal GOF Test**
5% Lilliefors Critical Value	0.104	Data Not Lognormal at 5% Significance Level

Data Not Lognormal at 5% Significance Level

Lognormal Statistics

Minimum of Logged Data	-4.469	Mean of logged Data	-1.809
Maximum of Logged Data	2.362	SD of logged Data	1.304

Assuming Lognormal Distribution

95% H-UCL	0.568	90% Chebyshev (MVUE) UCL	0.597
95% Chebyshev (MVUE) UCL	0.698	97.5% Chebyshev (MVUE) UCL	0.837
99% Chebyshev (MVUE) UCL	1.112		

Nonparametric Distribution Free UCL Statistics

Data do not follow a Discernible Distribution (0.05)

Nonparametric Distribution Free UCLs

95% CLT UCL	0.754	95% Jackknife UCL	0.757
95% Standard Bootstrap UCL	0.761	95% Bootstrap-t UCL	1.14
95% Hall's Bootstrap UCL	1.688	95% Percentile Bootstrap UCL	0.786
95% BCA Bootstrap UCL	0.951		
90% Chebyshev(Mean, Sd) UCL	0.967	95% Chebyshev(Mean, Sd) UCL	1.181
97.5% Chebyshev(Mean, Sd) UCL	1.479	99% Chebyshev(Mean, Sd) UCL	2.063

Suggested UCL to Use

95% Chebyshev (Mean, Sd) UCL	1.181

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
Recommendations are based upon data size, data distribution, and skewness.
These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).
However, simulations results will not cover all Real World data sets; for additional insight the user may want to consult a statistician.

Trichloroethylene

General Statistics

Total Number of Observations	73	Number of Distinct Observations	59
		Number of Missing Observations	0
Minimum	0.00564	Mean	0.0574
Maximum	0.37	Median	0.0438
SD	0.0533	Std. Error of Mean	0.00624
Coefficient of Variation	0.929	Skewness	3.72

Normal GOF Test

Shapiro Wilk Test Statistic	0.636	**Shapiro Wilk GOF Test**	
5% Shapiro Wilk P Value	0	Data Not Normal at 5% Significance Level	
Lilliefors Test Statistic	0.234	**Lilliefors GOF Test**	
5% Lilliefors Critical Value	0.104	Data Not Normal at 5% Significance Level	

Data Not Normal at 5% Significance Level

Assuming Normal Distribution

95% Normal UCL		**95% UCLs (Adjusted for Skewness)**	
95% Student's-t UCL	0.0677	95% Adjusted-CLT UCL (Chen-1995)	0.0705
		95% Modified-t UCL (Johnson-1978)	0.0682

Gamma GOF Test

A-D Test Statistic	2.187	**Anderson-Darling Gamma GOF Test**	
5% A-D Critical Value	0.762	Data Not Gamma Distributed at 5% Significance Level	
K-S Test Statistic	0.133	**Kolmogorov-Smirnov Gamma GOF Test**	
5% K-S Critical Value	0.106	Data Not Gamma Distributed at 5% Significance Level	

Data Not Gamma Distributed at 5% Significance Level

Gamma Statistics

k hat (MLE)	2.254	k star (bias corrected MLE)	2.17
Theta hat (MLE)	0.0254	Theta star (bias corrected MLE)	0.0264
nu hat (MLE)	329	nu star (bias corrected)	316.8
MLE Mean (bias corrected)	0.0574	MLE Sd (bias corrected)	0.0389
		Approximate Chi Square Value (0.05)	276.6
Adjusted Level of Significance	0.0467	Adjusted Chi Square Value	275.9

Assuming Gamma Distribution

95% Approximate Gamma UCL (use when n>=50))	0.0657	95% Adjusted Gamma UCL (use when n<50)	0.0659

Lognormal GOF Test

Shapiro Wilk Test Statistic	0.972	**Shapiro Wilk Lognormal GOF Test**	
5% Shapiro Wilk P Value	0.283	Data appear Lognormal at 5% Significance Level	
Lilliefors Test Statistic	0.0846	**Lilliefors Lognormal GOF Test**	
5% Lilliefors Critical Value	0.104	Data appear Lognormal at 5% Significance Level	

Data appear Lognormal at 5% Significance Level

Lognormal Statistics

Minimum of Logged Data	-5.178	Mean of logged Data	-3.097
Maximum of Logged Data	-0.994	SD of logged Data	0.653

Assuming Lognormal Distribution

95% H-UCL	0.065	90% Chebyshev (MVUE) UCL	0.0696
95% Chebyshev (MVUE) UCL	0.0759	97.5% Chebyshev (MVUE) UCL	0.0847
99% Chebyshev (MVUE) UCL	0.102		

Nonparametric Distribution Free UCL Statistics

Data appear to follow a Discernible Distribution at 5% Significance Level

Nonparametric Distribution Free UCLs

95% CLT UCL	0.0676	95% Jackknife UCL	0.0677
95% Standard Bootstrap UCL	0.0672	95% Bootstrap-t UCL	0.0743
95% Hall's Bootstrap UCL	0.0794	95% Percentile Bootstrap UCL	0.0682
95% BCA Bootstrap UCL	0.0714		
90% Chebyshev(Mean, Sd) UCL	0.0761	95% Chebyshev(Mean, Sd) UCL	0.0845
97.5% Chebyshev(Mean, Sd) UCL	0.0963	99% Chebyshev(Mean, Sd) UCL	0.119

Suggested UCL to Use

95% H-UCL	0.065

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.

Recommendations are based upon data size, data distribution, and skewness.

These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).
However, simulations results will not cover all Real World data sets; for additional insight the user may want to consult a statistician.

ProUCL computes and outputs H-statistic based UCLs for historical reasons only.
H-statistic often results in unstable (both high and low) values of UCL95 as shown in examples in the Technical Guide.
It is therefore recommended to avoid the use of H-statistic based 95% UCLs.
Use of nonparametric methods are preferred to compute UCL95 for skewed data sets which do not follow a gamma distribution.

Chloroprene

General Statistics

Total Number of Observations	73	Number of Distinct Observations	22
		Number of Missing Observations	0
Minimum	0.00652	Mean	0.0855
Maximum	0.567	Median	0.0984
SD	0.069	Std. Error of Mean	0.00808
Coefficient of Variation	0.807	Skewness	5.001

Normal GOF Test

Shapiro Wilk Test Statistic	0.543	**Shapiro Wilk GOF Test**	
5% Shapiro Wilk P Value	0	Data Not Normal at 5% Significance Level	
Lilliefors Test Statistic	0.357	**Lilliefors GOF Test**	
5% Lilliefors Critical Value	0.104	Data Not Normal at 5% Significance Level	

Data Not Normal at 5% Significance Level

Assuming Normal Distribution

95% Normal UCL		**95% UCLs (Adjusted for Skewness)**	
95% Student's-t UCL	0.099	95% Adjusted-CLT UCL (Chen-1995)	0.104
		95% Modified-t UCL (Johnson-1978)	0.0998

Gamma GOF Test

A-D Test Statistic	6.076	**Anderson-Darling Gamma GOF Test**
5% A-D Critical Value	0.762	Data Not Gamma Distributed at 5% Significance Level
K-S Test Statistic	0.262	**Kolmogorov-Smirnov Gamma GOF Test**
5% K-S Critical Value	0.106	Data Not Gamma Distributed at 5% Significance Level

Data Not Gamma Distributed at 5% Significance Level

Gamma Statistics

k hat (MLE)	2.319	k star (bias corrected MLE)	2.233
Theta hat (MLE)	0.0369	Theta star (bias corrected MLE)	0.0383
nu hat (MLE)	338.6	nu star (bias corrected)	326.1
MLE Mean (bias corrected)	0.0855	MLE Sd (bias corrected)	0.0572
		Approximate Chi Square Value (0.05)	285.2
Adjusted Level of Significance	0.0467	Adjusted Chi Square Value	284.5

Assuming Gamma Distribution

95% Approximate Gamma UCL (use when n>=50))	0.0978	95% Adjusted Gamma UCL (use when n<50)	0.098

Lognormal GOF Test

Shapiro Wilk Test Statistic	0.775	**Shapiro Wilk Lognormal GOF Test**
5% Shapiro Wilk P Value	1.998E-15	Data Not Lognormal at 5% Significance Level
Lilliefors Test Statistic	0.281	**Lilliefors Lognormal GOF Test**
5% Lilliefors Critical Value	0.104	Data Not Lognormal at 5% Significance Level

Data Not Lognormal at 5% Significance Level

Lognormal Statistics

Minimum of Logged Data	-5.033	Mean of logged Data	-2.69
Maximum of Logged Data	-0.568	SD of logged Data	0.76

Assuming Lognormal Distribution

95% H-UCL	0.109	90% Chebyshev (MVUE) UCL	0.117

95% Chebyshev (MVUE) UCL	0.129	97.5% Chebyshev (MVUE) UCL	0.146
99% Chebyshev (MVUE) UCL	0.179		

Nonparametric Distribution Free UCL Statistics

Data do not follow a Discernible Distribution (0.05)

Nonparametric Distribution Free UCLs

95% CLT UCL	0.0988	95% Jackknife UCL	0.099
95% Standard Bootstrap UCL	0.0984	95% Bootstrap-t UCL	0.11
95% Hall's Bootstrap UCL	0.166	95% Percentile Bootstrap UCL	0.1
95% BCA Bootstrap UCL	0.105		
90% Chebyshev(Mean, Sd) UCL	0.11	95% Chebyshev(Mean, Sd) UCL	0.121
97.5% Chebyshev(Mean, Sd) UCL	0.136	99% Chebyshev(Mean, Sd) UCL	0.166

Suggested UCL to Use

95% Chebyshev (Mean, Sd) UCL	0.121

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
Recommendations are based upon data size, data distribution, and skewness.
These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).
However, simulations results will not cover all Real World data sets; for additional insight the user may want to consult a statistician.

Vinyl chloride

General Statistics

Total Number of Observations	73	Number of Distinct Observations	70
		Number of Missing Observations	0
Minimum	0.00332	Mean	1.059
Maximum	8.23	Median	0.718
SD	1.34	Std. Error of Mean	0.157

Coefficient of Variation	1.265	Skewness	2.965

Normal GOF Test

Shapiro Wilk Test Statistic	0.715	**Shapiro Wilk GOF Test**	
5% Shapiro Wilk P Value	0	Data Not Normal at 5% Significance Level	
Lilliefors Test Statistic	0.215	**Lilliefors GOF Test**	
5% Lilliefors Critical Value	0.104	Data Not Normal at 5% Significance Level	

Data Not Normal at 5% Significance Level

Assuming Normal Distribution

95% Normal UCL		**95% UCLs (Adjusted for Skewness)**	
95% Student's-t UCL	1.32	95% Adjusted-CLT UCL (Chen-1995)	1.375
		95% Modified-t UCL (Johnson-1978)	1.329

Gamma GOF Test

A-D Test Statistic	0.301	**Anderson-Darling Gamma GOF Test**	
5% A-D Critical Value	0.799	Detected data appear Gamma Distributed at 5% Significance Level	
K-S Test Statistic	0.0551	**Kolmogorov-Smirnov Gamma GOF Test**	
5% K-S Critical Value	0.109	Detected data appear Gamma Distributed at 5% Significance Level	

Detected data appear Gamma Distributed at 5% Significance Level

Gamma Statistics

k hat (MLE)	0.685	k star (bias corrected MLE)	0.666
Theta hat (MLE)	1.545	Theta star (bias corrected MLE)	1.589
nu hat (MLE)	100.1	nu star (bias corrected)	97.28
MLE Mean (bias corrected)	1.059	MLE Sd (bias corrected)	1.297
		Approximate Chi Square Value (0.05)	75.53
Adjusted Level of Significance	0.0467	Adjusted Chi Square Value	75.14

Assuming Gamma Distribution

95% Approximate Gamma UCL (use when n>=50)	1.364	95% Adjusted Gamma UCL (use when n<50)	1.371

Lognormal GOF Test

Shapiro Wilk Test Statistic	0.914	**Shapiro Wilk Lognormal GOF Test**	
5% Shapiro Wilk P Value	3.6040E-5	Data Not Lognormal at 5% Significance Level	
Lilliefors Test Statistic	0.127	**Lilliefors Lognormal GOF Test**	
5% Lilliefors Critical Value	0.104	Data Not Lognormal at 5% Significance Level	

Data Not Lognormal at 5% Significance Level

Lognormal Statistics

Minimum of Logged Data	-5.707	Mean of logged Data	-0.827
Maximum of Logged Data	2.108	SD of logged Data	1.689

Assuming Lognormal Distribution

95% H-UCL	3.323	90% Chebyshev (MVUE) UCL	3.216
95% Chebyshev (MVUE) UCL	3.884	97.5% Chebyshev (MVUE) UCL	4.811
99% Chebyshev (MVUE) UCL	6.633		

Nonparametric Distribution Free UCL Statistics

Data appear to follow a Discernible Distribution at 5% Significance Level

Nonparametric Distribution Free UCLs

95% CLT UCL	1.317	95% Jackknife UCL	1.32
95% Standard Bootstrap UCL	1.316	95% Bootstrap-t UCL	1.418
95% Hall's Bootstrap UCL	1.524	95% Percentile Bootstrap UCL	1.33
95% BCA Bootstrap UCL	1.418		
90% Chebyshev(Mean, Sd) UCL	1.529	95% Chebyshev(Mean, Sd) UCL	1.742
97.5% Chebyshev(Mean, Sd) UCL	2.038	99% Chebyshev(Mean, Sd) UCL	2.619

Suggested UCL to Use

95% Approximate Gamma UCL	1.364

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
Recommendations are based upon data size, data distribution, and skewness.
These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).
However, simulations results will not cover all Real World data sets; for additional insight the user may want to consult a statistician.

Benzene

General Statistics

Total Number of Observations	73	Number of Distinct Observations	66
		Number of Missing Observations	0
Minimum	0.107	Mean	0.459
Maximum	1.465	Median	0.406
SD	0.238	Std. Error of Mean	0.0278
Coefficient of Variation	0.518	Skewness	2.166

Normal GOF Test

Shapiro Wilk Test Statistic	0.822	**Shapiro Wilk GOF Test**	
5% Shapiro Wilk P Value	4.960E-12	Data Not Normal at 5% Significance Level	
Lilliefors Test Statistic	0.167	**Lilliefors GOF Test**	
5% Lilliefors Critical Value	0.104	Data Not Normal at 5% Significance Level	

Data Not Normal at 5% Significance Level

Assuming Normal Distribution

95% Normal UCL		**95% UCLs (Adjusted for Skewness)**	
95% Student's-t UCL	0.505	95% Adjusted-CLT UCL (Chen-1995)	0.512
		95% Modified-t UCL (Johnson-1978)	0.506

Gamma GOF Test

A-D Test Statistic	0.903	**Anderson-Darling Gamma GOF Test**	
5% A-D Critical Value	0.755	Data Not Gamma Distributed at 5% Significance Level	

K-S Test Statistic	0.105	**Kolmogorov-Smirnov Gamma GOF Test**	
5% K-S Critical Value	0.105	Data Not Gamma Distributed at 5% Significance Level	

Data Not Gamma Distributed at 5% Significance Level

Gamma Statistics

k hat (MLE)	4.848	k star (bias corrected MLE)	4.658
Theta hat (MLE)	0.0947	Theta star (bias corrected MLE)	0.0985
nu hat (MLE)	707.8	nu star (bias corrected)	680.1
MLE Mean (bias corrected)	0.459	MLE Sd (bias corrected)	0.213
		Approximate Chi Square Value (0.05)	620.6
Adjusted Level of Significance	0.0467	Adjusted Chi Square Value	619.4

Assuming Gamma Distribution

95% Approximate Gamma UCL (use when n>=50))	0.503	95% Adjusted Gamma UCL (use when n<50)	0.504

Lognormal GOF Test

Shapiro Wilk Test Statistic	0.981	**Shapiro Wilk Lognormal GOF Test**	
5% Shapiro Wilk P Value	0.664	Data appear Lognormal at 5% Significance Level	
Lilliefors Test Statistic	0.0795	**Lilliefors Lognormal GOF Test**	
5% Lilliefors Critical Value	0.104	Data appear Lognormal at 5% Significance Level	

Data appear Lognormal at 5% Significance Level

Lognormal Statistics

Minimum of Logged Data	-2.235	Mean of logged Data	-0.885
Maximum of Logged Data	0.382	SD of logged Data	0.459

Assuming Lognormal Distribution

95% H-UCL	0.506	90% Chebyshev (MVUE) UCL	0.535
95% Chebyshev (MVUE) UCL	0.57	97.5% Chebyshev (MVUE) UCL	0.618
99% Chebyshev (MVUE) UCL	0.713		

Nonparametric Distribution Free UCL Statistics

Data appear to follow a Discernible Distribution at 5% Significance Level

Nonparametric Distribution Free UCLs

95% CLT UCL	0.505	95% Jackknife UCL	0.505
95% Standard Bootstrap UCL	0.504	95% Bootstrap-t UCL	0.512
95% Hall's Bootstrap UCL	0.52	95% Percentile Bootstrap UCL	0.508
95% BCA Bootstrap UCL	0.512		
90% Chebyshev(Mean, Sd) UCL	0.542	95% Chebyshev(Mean, Sd) UCL	0.58
97.5% Chebyshev(Mean, Sd) UCL	0.633	99% Chebyshev(Mean, Sd) UCL	0.736

Suggested UCL to Use

95% Student's-t UCL	0.505	or 95% Modified-t UCL	0.506
or 95% H-UCL	0.506		

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.

Recommendations are based upon data size, data distribution, and skewness.

These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).

However, simulations results will not cover all Real World data sets; for additional insight the user may want to consult a statistician.

ProUCL computes and outputs H-statistic based UCLs for historical reasons only.

H-statistic often results in unstable (both high and low) values of UCL95 as shown in examples in the Technical Guide.

It is therefore recommended to avoid the use of H-statistic based 95% UCLs.

Use of nonparametric methods are preferred to compute UCL95 for skewed data sets which do not follow a gamma distribution.

Ethylene dibromide

General Statistics

Total Number of Observations	73	Number of Distinct Observations	2
		Number of Missing Observations	0
Minimum	0	Mean	2.2627E-4

Maximum	0.0165	Median	0
SD	0.00193	Std. Error of Mean	2.2627E-4
Coefficient of Variation	8.544	Skewness	8.544

Normal GOF Test

Shapiro Wilk Test Statistic	0.118	**Shapiro Wilk GOF Test**	
5% Shapiro Wilk P Value	0	Data Not Normal at 5% Significance Level	
Lilliefors Test Statistic	0.533	**Lilliefors GOF Test**	
5% Lilliefors Critical Value	0.104	Data Not Normal at 5% Significance Level	

Data Not Normal at 5% Significance Level

Assuming Normal Distribution

95% Normal UCL		**95% UCLs (Adjusted for Skewness)**	
95% Student's-t UCL	6.0329E-4	95% Adjusted-CLT UCL (Chen-1995)	8.4021E-4
		95% Modified-t UCL (Johnson-1978)	6.4100E-4

Gamma Statistics Not Available

Lognormal Statistics Not Available

Nonparametric Distribution Free UCL Statistics

Data do not follow a Discernible Distribution (0.05)

Nonparametric Distribution Free UCLs

95% CLT UCL	5.9844E-4	95% Jackknife UCL	N/A
95% Standard Bootstrap UCL	N/A	95% Bootstrap-t UCL	N/A
95% Hall's Bootstrap UCL	N/A	95% Percentile Bootstrap UCL	N/A
95% BCA Bootstrap UCL	N/A		
90% Chebyshev(Mean, Sd) UCL	9.0506E-4	95% Chebyshev(Mean, Sd) UCL	0.00121
97.5% Chebyshev(Mean, Sd) UCL	0.00164	99% Chebyshev(Mean, Sd) UCL	0.00248

Suggested UCL to Use

95% Chebyshev (Mean, Sd) UCL	0.00121

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
Recommendations are based upon data size, data distribution, and skewness.
These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).
However, simulations results will not cover all Real World data sets; for additional insight the user may want to consult a statistician.

Acrylonitrile

General Statistics

Total Number of Observations	72	Number of Distinct Observations	8
		Number of Missing Observations	0
Minimum	0	Mean	0.00128
Maximum	0.0358	Median	0
SD	0.00513	Std. Error of Mean	6.0453E-4
Coefficient of Variation	4.01	Skewness	5.27

Normal GOF Test

Shapiro Wilk Test Statistic	0.298	**Shapiro Wilk GOF Test**	
5% Shapiro Wilk P Value	0	Data Not Normal at 5% Significance Level	
Lilliefors Test Statistic	0.501	**Lilliefors GOF Test**	
5% Lilliefors Critical Value	0.104	Data Not Normal at 5% Significance Level	

Data Not Normal at 5% Significance Level

Assuming Normal Distribution

95% Normal UCL		**95% UCLs (Adjusted for Skewness)**	
95% Student's-t UCL	0.00229	95% Adjusted-CLT UCL (Chen-1995)	0.00267
		95% Modified-t UCL (Johnson-1978)	0.00235

Gamma Statistics Not Available

Lognormal Statistics Not Available

Nonparametric Distribution Free UCL Statistics

Data do not follow a Discernible Distribution (0.05)

Nonparametric Distribution Free UCLs

95% CLT UCL	0.00227	95% Jackknife UCL	0.00229
95% Standard Bootstrap UCL	0.00225	95% Bootstrap-t UCL	0.00354
95% Hall's Bootstrap UCL	0.00527	95% Percentile Bootstrap UCL	0.00237
95% BCA Bootstrap UCL	0.00277		
90% Chebyshev(Mean, Sd) UCL	0.00309	95% Chebyshev(Mean, Sd) UCL	0.00391
97.5% Chebyshev(Mean, Sd) UCL	0.00505	99% Chebyshev(Mean, Sd) UCL	0.00729

Suggested UCL to Use

95% Chebyshev (Mean, Sd) UCL	0.00391

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
Recommendations are based upon data size, data distribution, and skewness.
These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).
However, simulations results will not cover all Real World data sets; for additional insight the user may want to consult a statistician.

10.3.4 Grayson Lake

UCL Statistics for Uncensored Full Data Sets

User Selected Options	
Date/Time of Computation	ProUCL 5.16/14/2022 5:53:06 PM
From File	WorkSheet_c.xls
Full Precision	OFF
Confidence Coefficient	95%
Number of Bootstrap Operations	2000

1,3-Butadiene

General Statistics

Total Number of Observations	69	Number of Distinct Observations	48
		Number of Missing Observations	0
Minimum	0.00531	Mean	0.0291
Maximum	0.109	Median	0.0239
SD	0.0184	Std. Error of Mean	0.00221
Coefficient of Variation	0.633	Skewness	1.461

Normal GOF Test

Shapiro Wilk Test Statistic	0.862	**Shapiro Wilk GOF Test**	
5% Shapiro Wilk P Value	1.5327E-8	Data Not Normal at 5% Significance Level	
Lilliefors Test Statistic	0.14	**Lilliefors GOF Test**	
5% Lilliefors Critical Value	0.107	Data Not Normal at 5% Significance Level	

Data Not Normal at 5% Significance Level

Assuming Normal Distribution

95% Normal UCL		**95% UCLs (Adjusted for Skewness)**	
95% Student's-t UCL	0.0328	95% Adjusted-CLT UCL (Chen-1995)	0.0331
		95% Modified-t UCL (Johnson-1978)	0.0328

Gamma GOF Test

A-D Test Statistic	1.671	**Anderson-Darling Gamma GOF Test**	
5% A-D Critical Value	0.759	Data Not Gamma Distributed at 5% Significance Level	
K-S Test Statistic	0.175	**Kolmogorov-Smirnov Gamma GOF Test**	
5% K-S Critical Value	0.108	Data Not Gamma Distributed at 5% Significance Level	

Data Not Gamma Distributed at 5% Significance Level

Gamma Statistics

k hat (MLE)	2.687	k star (bias corrected MLE)	2.58

Theta hat (MLE)	0.0108	Theta star (bias corrected MLE)	0.0113
nu hat (MLE)	370.9	nu star (bias corrected)	356.1
MLE Mean (bias corrected)	0.0291	MLE Sd (bias corrected)	0.0181
		Approximate Chi Square Value (0.05)	313.4
Adjusted Level of Significance	0.0465	Adjusted Chi Square Value	312.5

Assuming Gamma Distribution

95% Approximate Gamma UCL (use when n>=50))	0.033	95% Adjusted Gamma UCL (use when n<50)	0.0331

Lognormal GOF Test

Shapiro Wilk Test Statistic	0.943	**Shapiro Wilk Lognormal GOF Test**	
5% Shapiro Wilk P Value	0.00682	Data Not Lognormal at 5% Significance Level	
Lilliefors Test Statistic	0.182	**Lilliefors Lognormal GOF Test**	
5% Lilliefors Critical Value	0.107	Data Not Lognormal at 5% Significance Level	

Data Not Lognormal at 5% Significance Level

Lognormal Statistics

Minimum of Logged Data	-5.238	Mean of logged Data	-3.736
Maximum of Logged Data	-2.212	SD of logged Data	0.654

Assuming Lognormal Distribution

95% H-UCL	0.0346	90% Chebyshev (MVUE) UCL	0.037
95% Chebyshev (MVUE) UCL	0.0404	97.5% Chebyshev (MVUE) UCL	0.0452
99% Chebyshev (MVUE) UCL	0.0545		

Nonparametric Distribution Free UCL Statistics

Data do not follow a Discernible Distribution (0.05)

Nonparametric Distribution Free UCLs

95% CLT UCL	0.0327	95% Jackknife UCL	0.0328
95% Standard Bootstrap UCL	0.0328	95% Bootstrap-t UCL	0.0333

95% Hall's Bootstrap UCL	0.0335	95% Percentile Bootstrap UCL	0.0329
95% BCA Bootstrap UCL	0.0332		
90% Chebyshev(Mean, Sd) UCL	0.0357	95% Chebyshev(Mean, Sd) UCL	0.0387
97.5% Chebyshev(Mean, Sd) UCL	0.0429	99% Chebyshev(Mean, Sd) UCL	0.0511

Suggested UCL to Use

95% Chebyshev (Mean, Sd) UCL	0.0387

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
Recommendations are based upon data size, data distribution, and skewness.
These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).
However, simulations results will not cover all Real World data sets; for additional insight the user may want to consult a statistician.

Acetonitrile

General Statistics

Total Number of Observations	69	Number of Distinct Observations	64
		Number of Missing Observations	0
Minimum	0.579	Mean	30.05
Maximum	126.6	Median	19.98
SD	26.43	Std. Error of Mean	3.182
Coefficient of Variation	0.88	Skewness	1.059

Normal GOF Test

Shapiro Wilk Test Statistic	0.886	**Shapiro Wilk GOF Test**	
5% Shapiro Wilk P Value	6.9766E-7	Data Not Normal at 5% Significance Level	
Lilliefors Test Statistic	0.166	**Lilliefors GOF Test**	
5% Lilliefors Critical Value	0.107	Data Not Normal at 5% Significance Level	

Data Not Normal at 5% Significance Level

Assuming Normal Distribution

95% Normal UCL		95% UCLs (Adjusted for Skewness)	
95% Student's-t UCL	35.35	95% Adjusted-CLT UCL (Chen-1995)	35.71
		95% Modified-t UCL (Johnson-1978)	35.42

Gamma GOF Test

A-D Test Statistic	0.86	**Anderson-Darling Gamma GOF Test**	
5% A-D Critical Value	0.78	Data Not Gamma Distributed at 5% Significance Level	
K-S Test Statistic	0.111	**Kolmogorov-Smirnov Gamma GOF Test**	
5% K-S Critical Value	0.11	Data Not Gamma Distributed at 5% Significance Level	

Data Not Gamma Distributed at 5% Significance Level

Gamma Statistics

k hat (MLE)	1.001	k star (bias corrected MLE)	0.967
Theta hat (MLE)	30.02	Theta star (bias corrected MLE)	31.08
nu hat (MLE)	138.1	nu star (bias corrected)	133.4
MLE Mean (bias corrected)	30.05	MLE Sd (bias corrected)	30.56
		Approximate Chi Square Value (0.05)	107.7
Adjusted Level of Significance	0.0465	Adjusted Chi Square Value	107.2

Assuming Gamma Distribution

95% Approximate Gamma UCL (use when n>=50))	37.21	95% Adjusted Gamma UCL (use when n<50)	37.38

Lognormal GOF Test

Shapiro Wilk Test Statistic	0.895	**Shapiro Wilk Lognormal GOF Test**	
5% Shapiro Wilk P Value	2.9780E-6	Data Not Lognormal at 5% Significance Level	
Lilliefors Test Statistic	0.131	**Lilliefors Lognormal GOF Test**	
5% Lilliefors Critical Value	0.107	Data Not Lognormal at 5% Significance Level	

Data Not Lognormal at 5% Significance Level

Lognormal Statistics

Minimum of Logged Data	-0.546	Mean of logged Data	2.826
Maximum of Logged Data	4.841	SD of logged Data	1.315

Assuming Lognormal Distribution

95% H-UCL	56.17	90% Chebyshev (MVUE) UCL	63.3
95% Chebyshev (MVUE) UCL	74.22	97.5% Chebyshev (MVUE) UCL	89.37
99% Chebyshev (MVUE) UCL	119.1		

Nonparametric Distribution Free UCL Statistics

Data do not follow a Discernible Distribution (0.05)

Nonparametric Distribution Free UCLs

95% CLT UCL	35.28	95% Jackknife UCL	35.35
95% Standard Bootstrap UCL	35.09	95% Bootstrap-t UCL	35.84
95% Hall's Bootstrap UCL	36.07	95% Percentile Bootstrap UCL	35.37
95% BCA Bootstrap UCL	35.56		
90% Chebyshev(Mean, Sd) UCL	39.59	95% Chebyshev(Mean, Sd) UCL	43.92
97.5% Chebyshev(Mean, Sd) UCL	49.92	99% Chebyshev(Mean, Sd) UCL	61.71

Suggested UCL to Use

95% Chebyshev (Mean, Sd) UCL	43.92

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.

Recommendations are based upon data size, data distribution, and skewness.

These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).

However, simulations results will not cover all Real World data sets; for additional insight the user may want to consult a statistician.

Carbon tetrachloride

General Statistics

Total Number of Observations	69	Number of Distinct Observations	62
		Number of Missing Observations	0
Minimum	0.0723	Mean	0.509
Maximum	0.654	Median	0.517
SD	0.0914	Std. Error of Mean	0.011
Coefficient of Variation	0.179	Skewness	-2.126

Normal GOF Test

Shapiro Wilk Test Statistic	0.839	**Shapiro Wilk GOF Test**
5% Shapiro Wilk P Value	4.348E-10	Data Not Normal at 5% Significance Level
Lilliefors Test Statistic	0.159	**Lilliefors GOF Test**
5% Lilliefors Critical Value	0.107	Data Not Normal at 5% Significance Level

Data Not Normal at 5% Significance Level

Assuming Normal Distribution

95% Normal UCL		**95% UCLs (Adjusted for Skewness)**	
95% Student's-t UCL	0.528	95% Adjusted-CLT UCL (Chen-1995)	0.524
		95% Modified-t UCL (Johnson-1978)	0.527

Gamma GOF Test

A-D Test Statistic	5.489	**Anderson-Darling Gamma GOF Test**
5% A-D Critical Value	0.75	Data Not Gamma Distributed at 5% Significance Level
K-S Test Statistic	0.231	**Kolmogorov-Smirnov Gamma GOF Test**
5% K-S Critical Value	0.107	Data Not Gamma Distributed at 5% Significance Level

Data Not Gamma Distributed at 5% Significance Level

Gamma Statistics

k hat (MLE)	17.7	k star (bias corrected MLE)	16.94
Theta hat (MLE)	0.0288	Theta star (bias corrected MLE)	0.0301
nu hat (MLE)	2442	nu star (bias corrected)	2337
MLE Mean (bias corrected)	0.509	MLE Sd (bias corrected)	0.124
		Approximate Chi Square Value (0.05)	2226
Adjusted Level of Significance	0.0465	Adjusted Chi Square Value	2224

Assuming Gamma Distribution

95% Approximate Gamma UCL (use when n>=50))	0.535	95% Adjusted Gamma UCL (use when n<50)	0.535

Lognormal GOF Test

Shapiro Wilk Test Statistic	0.565	**Shapiro Wilk Lognormal GOF Test**	
5% Shapiro Wilk P Value	0	Data Not Lognormal at 5% Significance Level	
Lilliefors Test Statistic	0.266	**Lilliefors Lognormal GOF Test**	
5% Lilliefors Critical Value	0.107	Data Not Lognormal at 5% Significance Level	

Data Not Lognormal at 5% Significance Level

Lognormal Statistics

Minimum of Logged Data	-2.626	Mean of logged Data	-0.703
Maximum of Logged Data	-0.424	SD of logged Data	0.291

Assuming Lognormal Distribution

95% H-UCL	0.549	90% Chebyshev (MVUE) UCL	0.571
95% Chebyshev (MVUE) UCL	0.596	97.5% Chebyshev (MVUE) UCL	0.631
99% Chebyshev (MVUE) UCL	0.699		

Nonparametric Distribution Free UCL Statistics

Data do not follow a Discernible Distribution (0.05)

Nonparametric Distribution Free UCLs

95% CLT UCL	0.527	95% Jackknife UCL	0.528

95% Standard Bootstrap UCL	0.527	95% Bootstrap-t UCL	0.525
95% Hall's Bootstrap UCL	0.525	95% Percentile Bootstrap UCL	0.526
95% BCA Bootstrap UCL	0.525		
90% Chebyshev(Mean, Sd) UCL	0.542	95% Chebyshev(Mean, Sd) UCL	0.557
97.5% Chebyshev(Mean, Sd) UCL	0.578	99% Chebyshev(Mean, Sd) UCL	0.619

Suggested UCL to Use

95% Student's-t UCL	0.528	or 95% Modified-t UCL	0.527

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
Recommendations are based upon data size, data distribution, and skewness.
These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).
However, simulations results will not cover all Real World data sets; for additional insight the user may want to consult a statistician.

Note: For highly negatively-skewed data, confidence limits (e.g., Chen, Johnson, Lognormal, and Gamma) may not be reliable. Chen's and Johnson's methods provide adjustments for positvely skewed data sets.

Ethylene dichloride

General Statistics

Total Number of Observations	69	Number of Distinct Observations	49
		Number of Missing Observations	0
Minimum	0.0287	Mean	0.0645
Maximum	0.163	Median	0.0676
SD	0.0189	Std. Error of Mean	0.00227
Coefficient of Variation	0.293	Skewness	2.009

Normal GOF Test

Shapiro Wilk Test Statistic	0.842	**Shapiro Wilk GOF Test**	
5% Shapiro Wilk P Value	6.245E-10	Data Not Normal at 5% Significance Level	

Lilliefors Test Statistic	0.154	**Lilliefors GOF Test**	
5% Lilliefors Critical Value	0.107	Data Not Normal at 5% Significance Level	

Data Not Normal at 5% Significance Level

Assuming Normal Distribution

95% Normal UCL		**95% UCLs (Adjusted for Skewness)**	
95% Student's-t UCL	0.0683	95% Adjusted-CLT UCL (Chen-1995)	0.0688
		95% Modified-t UCL (Johnson-1978)	0.0684

Gamma GOF Test

A-D Test Statistic	1.951	**Anderson-Darling Gamma GOF Test**	
5% A-D Critical Value	0.75	Data Not Gamma Distributed at 5% Significance Level	
K-S Test Statistic	0.133	**Kolmogorov-Smirnov Gamma GOF Test**	
5% K-S Critical Value	0.107	Data Not Gamma Distributed at 5% Significance Level	

Data Not Gamma Distributed at 5% Significance Level

Gamma Statistics

k hat (MLE)	13.27	k star (bias corrected MLE)	12.7
Theta hat (MLE)	0.00486	Theta star (bias corrected MLE)	0.00508
nu hat (MLE)	1831	nu star (bias corrected)	1753
MLE Mean (bias corrected)	0.0645	MLE Sd (bias corrected)	0.0181
		Approximate Chi Square Value (0.05)	1657
Adjusted Level of Significance	0.0465	Adjusted Chi Square Value	1655

Assuming Gamma Distribution

95% Approximate Gamma UCL (use when n>=50))	0.0682	95% Adjusted Gamma UCL (use when n<50)	0.0683

Lognormal GOF Test

Shapiro Wilk Test Statistic	0.928	**Shapiro Wilk Lognormal GOF Test**	
5% Shapiro Wilk P Value	6.5506E-4	Data Not Lognormal at 5% Significance Level	
Lilliefors Test Statistic	0.14	**Lilliefors Lognormal GOF Test**	

5% Lilliefors Critical Value	0.107	Data Not Lognormal at 5% Significance Level

Data Not Lognormal at 5% Significance Level

Lognormal Statistics

Minimum of Logged Data	-3.55	Mean of logged Data	-2.78
Maximum of Logged Data	-1.813	SD of logged Data	0.278

Assuming Lognormal Distribution

95% H-UCL	0.0684	90% Chebyshev (MVUE) UCL	0.0711
95% Chebyshev (MVUE) UCL	0.0741	97.5% Chebyshev (MVUE) UCL	0.0782
99% Chebyshev (MVUE) UCL	0.0864		

Nonparametric Distribution Free UCL Statistics

Data do not follow a Discernible Distribution (0.05)

Nonparametric Distribution Free UCLs

95% CLT UCL	0.0682	95% Jackknife UCL	0.0683
95% Standard Bootstrap UCL	0.0683	95% Bootstrap-t UCL	0.0691
95% Hall's Bootstrap UCL	0.0708	95% Percentile Bootstrap UCL	0.0685
95% BCA Bootstrap UCL	0.0685		
90% Chebyshev(Mean, Sd) UCL	0.0713	95% Chebyshev(Mean, Sd) UCL	0.0744
97.5% Chebyshev(Mean, Sd) UCL	0.0787	99% Chebyshev(Mean, Sd) UCL	0.0871

Suggested UCL to Use

95% Student's-t UCL	0.0683	or 95% Modified-t UCL	0.0684

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.

Recommendations are based upon data size, data distribution, and skewness.

These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).

However, simulations results will not cover all Real World data sets; for additional insight the user may want to consult a statistician.

Hexachlorobutadiene

General Statistics

Total Number of Observations	69	Number of Distinct Observations	5
		Number of Missing Observations	0
Minimum	0.00213	Mean	0.283
Maximum	0.319	Median	0.319
SD	0.1	Std. Error of Mean	0.0121
Coefficient of Variation	0.354	Skewness	-2.465

Normal GOF Test

Shapiro Wilk Test Statistic	0.374	**Shapiro Wilk GOF Test**
5% Shapiro Wilk P Value	0	Data Not Normal at 5% Significance Level
Lilliefors Test Statistic	0.524	**Lilliefors GOF Test**
5% Lilliefors Critical Value	0.107	Data Not Normal at 5% Significance Level

Data Not Normal at 5% Significance Level

Assuming Normal Distribution

95% Normal UCL		**95% UCLs (Adjusted for Skewness)**	
95% Student's-t UCL	0.303	95% Adjusted-CLT UCL (Chen-1995)	0.299
		95% Modified-t UCL (Johnson-1978)	0.302

Gamma GOF Test

A-D Test Statistic	22.75	**Anderson-Darling Gamma GOF Test**
5% A-D Critical Value	0.771	Data Not Gamma Distributed at 5% Significance Level
K-S Test Statistic	0.549	**Kolmogorov-Smirnov Gamma GOF Test**
5% K-S Critical Value	0.109	Data Not Gamma Distributed at 5% Significance Level

Data Not Gamma Distributed at 5% Significance Level

Gamma Statistics

k hat (MLE)	1.426	k star (bias corrected MLE)	1.374
Theta hat (MLE)	0.198	Theta star (bias corrected MLE)	0.206
nu hat (MLE)	196.8	nu star (bias corrected)	189.6
MLE Mean (bias corrected)	0.283	MLE Sd (bias corrected)	0.241
		Approximate Chi Square Value (0.05)	158.8
Adjusted Level of Significance	0.0465	Adjusted Chi Square Value	158.2

Assuming Gamma Distribution

95% Approximate Gamma UCL (use when n>=50))	0.338	95% Adjusted Gamma UCL (use when n<50)	0.339

Lognormal GOF Test

Shapiro Wilk Test Statistic	0.375	**Shapiro Wilk Lognormal GOF Test**	
5% Shapiro Wilk P Value	0	Data Not Lognormal at 5% Significance Level	
Lilliefors Test Statistic	0.52	**Lilliefors Lognormal GOF Test**	
5% Lilliefors Critical Value	0.107	Data Not Lognormal at 5% Significance Level	

Data Not Lognormal at 5% Significance Level

Lognormal Statistics

Minimum of Logged Data	-6.15	Mean of logged Data	-1.653
Maximum of Logged Data	-1.143	SD of logged Data	1.462

Assuming Lognormal Distribution

95% H-UCL	0.834	90% Chebyshev (MVUE) UCL	0.925
95% Chebyshev (MVUE) UCL	1.099	97.5% Chebyshev (MVUE) UCL	1.34
99% Chebyshev (MVUE) UCL	1.814		

Nonparametric Distribution Free UCL Statistics

Data do not follow a Discernible Distribution (0.05)

Nonparametric Distribution Free UCLs

95% CLT UCL	0.303	95% Jackknife UCL	0.303

95% Standard Bootstrap UCL	0.303	95% Bootstrap-t UCL	0.299
95% Hall's Bootstrap UCL	0.3	95% Percentile Bootstrap UCL	0.301
95% BCA Bootstrap UCL	0.3		
90% Chebyshev(Mean, Sd) UCL	0.319	95% Chebyshev(Mean, Sd) UCL	0.335
97.5% Chebyshev(Mean, Sd) UCL	0.358	99% Chebyshev(Mean, Sd) UCL	0.403

Suggested UCL to Use

95% Chebyshev (Mean, Sd) UCL	0.335

Recommended UCL exceeds the maximum observation

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
Recommendations are based upon data size, data distribution, and skewness.
These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).
However, simulations results will not cover all Real World data sets; for additional insight the user may want to consult a statistician.

Note: For highly negatively-skewed data, confidence limits (e.g., Chen, Johnson, Lognormal, and Gamma) may not be reliable. Chen's and Johnson's methods provide adjustments for positvely skewed data sets.

Benzene

General Statistics

Total Number of Observations	69	Number of Distinct Observations	65
		Number of Missing Observations	0
Minimum	0.149	Mean	0.36
Maximum	0.878	Median	0.345
SD	0.139	Std. Error of Mean	0.0167
Coefficient of Variation	0.384	Skewness	1.009

Normal GOF Test

Shapiro Wilk Test Statistic	0.943	**Shapiro Wilk GOF Test**
5% Shapiro Wilk P Value	0.00659	Data Not Normal at 5% Significance Level
Lilliefors Test Statistic	0.0792	**Lilliefors GOF Test**
5% Lilliefors Critical Value	0.107	Data appear Normal at 5% Significance Level

Data appear Approximate Normal at 5% Significance Level

Assuming Normal Distribution

95% Normal UCL		**95% UCLs (Adjusted for Skewness)**	
95% Student's-t UCL	0.388	95% Adjusted-CLT UCL (Chen-1995)	0.39
		95% Modified-t UCL (Johnson-1978)	0.389

Gamma GOF Test

A-D Test Statistic	0.235	**Anderson-Darling Gamma GOF Test**
5% A-D Critical Value	0.753	Detected data appear Gamma Distributed at 5% Significance Level
K-S Test Statistic	0.0707	**Kolmogorov-Smirnov Gamma GOF Test**
5% K-S Critical Value	0.107	Detected data appear Gamma Distributed at 5% Significance Level

Detected data appear Gamma Distributed at 5% Significance Level

Gamma Statistics

k hat (MLE)	7.231	k star (bias corrected MLE)	6.926
Theta hat (MLE)	0.0498	Theta star (bias corrected MLE)	0.052
nu hat (MLE)	997.8	nu star (bias corrected)	955.8
MLE Mean (bias corrected)	0.36	MLE Sd (bias corrected)	0.137
		Approximate Chi Square Value (0.05)	885
Adjusted Level of Significance	0.0465	Adjusted Chi Square Value	883.6

Assuming Gamma Distribution

95% Approximate Gamma UCL (use when n>=50))	0.389	95% Adjusted Gamma UCL (use when n<50)	0.39

Lognormal GOF Test

Shapiro Wilk Test Statistic	0.979	**Shapiro Wilk Lognormal GOF Test**

5% Shapiro Wilk P Value	0.602	Data appear Lognormal at 5% Significance Level	
Lilliefors Test Statistic	0.0766	**Lilliefors Lognormal GOF Test**	
5% Lilliefors Critical Value	0.107	Data appear Lognormal at 5% Significance Level	

Data appear Lognormal at 5% Significance Level

Lognormal Statistics

Minimum of Logged Data	-1.907	Mean of logged Data	-1.091
Maximum of Logged Data	-0.13	SD of logged Data	0.382

Assuming Lognormal Distribution

95% H-UCL	0.393	90% Chebyshev (MVUE) UCL	0.412
95% Chebyshev (MVUE) UCL	0.435	97.5% Chebyshev (MVUE) UCL	0.468
99% Chebyshev (MVUE) UCL	0.531		

Nonparametric Distribution Free UCL Statistics

Data appear to follow a Discernible Distribution at 5% Significance Level

Nonparametric Distribution Free UCLs

95% CLT UCL	0.388	95% Jackknife UCL	0.388
95% Standard Bootstrap UCL	0.388	95% Bootstrap-t UCL	0.391
95% Hall's Bootstrap UCL	0.391	95% Percentile Bootstrap UCL	0.389
95% BCA Bootstrap UCL	0.389		
90% Chebyshev(Mean, Sd) UCL	0.41	95% Chebyshev(Mean, Sd) UCL	0.433
97.5% Chebyshev(Mean, Sd) UCL	0.465	99% Chebyshev(Mean, Sd) UCL	0.526

Suggested UCL to Use

95% Student's-t UCL	0.388

When a data set follows an approximate (e.g., normal) distribution passing one of the GOF test

When applicable, it is suggested to use a UCL based upon a distribution (e.g., gamma) passing both GOF tests in ProUCL

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
Recommendations are based upon data size, data distribution, and skewness.
These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).
However, simulations results will not cover all Real World data sets; for additional insight the user may want to consult a statistician.

10.4 APPENDIX D: Chemical – Specific Health Effects

Calvert City, KY VOC Study
Chemical-specific Health Effects

The chemical-specific health effect information provided below is limited to the chemicals that were the largest contributor to the cancer risks and noncancer hazard. Additionally, citations are provided to facilitate access to extended information relative to the remaining chemicals from the study.

Ethylene Dichloride

Exposure to low levels of ethylene dichloride can occur from breathing ambient or workplace air. Inhalation of concentrated ethylene dichloride vapor can induce effects on the human nervous system, liver, and kidneys, as well as respiratory distress, cardiac arrhythmia, nausea, and vomiting. Chronic (long-term) inhalation exposure to ethylene dichloride produced effects on the liver and kidneys in animals. No information is available on the reproductive or developmental effects of ethylene dichloride in humans. Decreased fertility and increased embryo mortality have been observed in inhalation studies of rats. Epidemiological studies are not conclusive regarding the carcinogenic effects of ethylene dichloride, due to concomitant exposure to other chemicals. Following treatment by gavage (experimentally placing the chemical in the stomach), several tumor types were induced in rats and mice. EPA has classified ethylene dichloride as a Group B2, probable human carcinogen.

A full discussion of ethylene dichloride can be found at https://www.epa.gov/sites/default/files/2016-09/documents/ethylene-dichloride.pdf and in the literature (see: (ATSDR, Toxicological Profile for 1,2-Dichloroethane, U.S. Department of Health and Human Services, see:, 2022) and (WHO, Environmental Health Criteria 62: Ethylene dichloride, International Programme on Chemical Safety, see:, 1987)).

Carbon Tetrachloride

Carbon tetrachloride may be found in both ambient outdoor and indoor air. The primary effects of carbon tetrachloride in humans are on the liver, kidneys, and central nervous system (CNS). Human symptoms of acute (short-term) inhalation and oral exposures to carbon tetrachloride include headache, weakness, lethargy, nausea, and vomiting. Acute exposures to higher levels and chronic (long-term) inhalation or oral exposure to carbon tetrachloride produces liver and kidney damage in humans. Human data on the carcinogenic effects of carbon tetrachloride are limited. Studies in animals have shown that ingestion of carbon tetrachloride increases the risk of liver cancer. EPA has classified carbon tetrachloride as a Group B2, probable human carcinogen.

A full discussion of carbon tetrachloride can be found at https://www.epa.gov/sites/default/files/2016-09/documents/carbon-tetrachloride.pdf and in the literature (see: (ATSDR, Toxicological Profile for Carbon Tetrachloride, U.S. Department of Health and Human Services, see: , 2005) and (WHO, Environmental Health Criteria 208: Carbon tetrachloride, International Programme on Chemical Safety, see: , 1999)).

Benzene
Benzene is found in the air from emissions from burning coal and oil, gasoline service stations, and motor vehicle exhaust. Acute (short-term) inhalation exposure of humans to benzene may cause drowsiness, dizziness, headaches, as well as eye, skin, and respiratory tract irritation, and, at high levels, unconsciousness. Chronic (long-term) inhalation exposure has caused various disorders in the blood, including reduced numbers of red blood cells and aplastic anemia, in occupational settings. Reproductive effects have been reported for women exposed by inhalation to high levels, and adverse effects on the developing fetus have been observed in animal tests. Increased incidence of leukemia (cancer of the tissues that form white blood cells) have been observed in humans occupationally exposed to benzene. EPA has classified benzene as known human carcinogen for all routes of exposure.

A full discussion of benzene can be found at https://www.epa.gov/sites/default/files/2016-09/documents/benzene.pdf and in the literature (see: (ATSDR, Toxicological Profile for Benzene, U.S. Department of Health and Human Services, see: , 2007) and (WHO, Environmental Health Criteria 150: Benzene, International Programme on Chemical Safety, see: , 1993)).

Vinyl Chloride
Most vinyl chloride is used to make polyvinyl chloride (PVC) plastic and vinyl products. Acute (short-term) exposure to high levels of vinyl chloride in air has resulted in central nervous system (CNS) effects, such as dizziness, drowsiness, and headaches in humans. Chronic (long-term) exposure to vinyl chloride through inhalation and oral exposure in humans has resulted in CNS effects and liver damage. Animal studies have reported effects on the liver, kidney, and CNS from chronic exposure to vinyl chloride. Vinyl chloride exposure, via inhalation, has been shown to increase the risk of a rare form of liver cancer, angiosarcoma of the liver, in humans. EPA has concluded that vinyl chloride is carcinogenic to humans by the inhalation and oral routes of exposure, and highly likely to be carcinogenic by the dermal route of exposure.

A full discussion of vinyl chloride can be found at https://www.epa.gov/sites/default/files/2020-05/documents/vinyl_chloride_march_26_2020.pdf and in the literature (see: (ATSDR, Toxicological Profile for Vinyl Chloride, U.S. Department of Health and Human Services, see: , 2006) and (WHO, Environmental Health Criteria 215: Vinyl Chloride, International Programme on Chemical Safety, see: , 1999)).

Acetonitrile
Acetonitrile has many uses, including as a solvent, for spinning fibers, and in lithium batteries. It is primarily found in air from automobile exhaust and manufacturing facilities. Acute (short-term) inhalation exposure results in irritation of mucous membranes. Chronic (long-term) exposure results in central nervous system effects, such as headaches, numbness, and tremors. No data are available on its carcinogenic

effects in humans; EPA has classified it as a Group D, not classifiable as to human carcinogenicity.

A full discussion of acetonitrile can be found at https://www.epa.gov/sites/default/files/2016-09/documents/acetonitrile.pdf and in the literature (see: (WHO, Environmental Health Criteria 154: Acetonitrile, International Programme on Chemical Safety, see: , 1993)).

1,1,2-Trichloroethane

A full discussion of 1,1,2-Trichloroethanecan be found at https://www.epa.gov/sites/default/files/2016-09/documents/1-1-2-trichloroethane.pdf and in the literature (see: (ATSDR, Toxicological Profile for 1,12-Trichloroethane, U.S. Department of Health and Human Services, see: , 2021) and (WHO, Environmental Health Criteria 136: 1,1,2- Trichloroethane, International Programme on Chemical Safety, see: , 1992)).

1,1-Dichloroethane

A full discussion of 1,1-Dichloroethane can be found at https://www.epa.gov/sites/default/files/2016-09/documents/ethylidene-dichloride.pdf and in the literature (see: (ATSDR, Toxicological Profile for 1,1-Dichloroethane, U.S. Department of Health and Human Services, see:, 2013) and (WHO, Environmental Health Criteria 176: 1,1-Dichloroethane, International Programme on Chemical Safety, see: , 1995)).

1,3-Butadiene

A full discussion of 1,3-Butadiene can be found at https://www.epa.gov/sites/default/files/2016-08/documents/13-butadiene.pdf and in the literature (see: (ATSDR, Toxicological Profile for 1,3-Butadiene, U.S. Department of Health and Human Services, see: , 2012)).

Acrylonitrile

A full discussion of Acrylonitrile can be found at https://www.epa.gov/sites/default/files/2016-09/documents/acrylonitrile.pdf and in the literature (see: (ATSDR, Toxicological Profile for Acrylonitrile, U.S. Department of Health and Human Services, see: , 1990) and (WHO, Environmental Health Criteria 28: Acrylonitrile, International Programme on Chemical Safety, see: , 1983)).

Chloroform

A full discussion of Chloroform can be found at https://www.epa.gov/sites/default/files/2016-09/documents/chloroform.pdf and in the literature (see: (ATSDR, Toxicological Profile for Chloroform, U.S. Department of Health and Human Services, see: , 1997) and (WHO, Environmental Health Criteria 163: Chloroform, International Programme on Chemical Safety, see: , 1994)).

Chloroprene

A full discussion of Chloroprene can be found at https://www.epa.gov/sites/default/files/2016-10/documents/chloroprene.pdf and in the literature.

Ethylbenzene

A full discussion of Ethylbenzene can be found at https://www.epa.gov/sites/default/files/2016-09/documents/ethylbenzene.pdf and in the literature (see: (ATSDR, Toxicological Profile for Ethylbenzene, U.S. Department of Health and Human Services, see: , 2010) and (WHO, Environmental Health Criteria 186: Ethylbenzene, International Programme on Chemical Safety, see: , 1996)).

Ethylene dibromide

A full discussion of Ethylene dibromide can be found at https://www.epa.gov/sites/default/files/2016-09/documents/ethylene-dibromide.pdf and in the literature (see: (ATSDR, Toxicological Profile for 1,2-Dibromoethane, U.S. Department of Health and Human Services, see:, 2018)).

Hexachlorobutadiene

A full discussion of Hexachlorobutadiene can be found at https://www.epa.gov/sites/default/files/2016-09/documents/hexachlorobutadeine.pdf and in the literature (see: (ATSDR, Toxicological Profile for Hexachlorobutadiene, U.S. Department of Health and Human Services, see: , 2021) and (WHO, Environmental Health Criteria 156: Hexachlorobutadiene, International Programme on Chemical Safety, see: , 1994)).

Trichloroethylene

A full discussion of Trichloroethylene can be found at https://www.epa.gov/sites/default/files/2016-09/documents/trichloroethylene.pdf and in the literature (see: (ATSDR, Toxicological Profile for Trichloroethylene, U.S. Department

of Health and Human Services, see: , 2019) and (WHO, Environmental Health Criteria 50: Trichloroethylene, International Programme on Chemical Safety, see: , 1985)).

10.5 APPENDIX E: Quality Assurance Project Plan

Calvert City, KY VOC Study
Quality Assurance Project Plan

10.6 APPENDIX F: KDAQ Calvert City, KY Monitoring Study Final Report

KDAQ Calvert City Special Study
Final Report