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Environmental Protection
Agency

Electrical & Electronic Components (40 CFR Part 469) Detailed Study Report

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Abbreviations

BAT	Best Available Technology Economically Achievable
BCT	Best Conventional Pollutant Control Technology
BOD_5	five-day biological oxygen demand
BPT	Best Practicable Control Technology Currently Available
C4	controlled collapse chip connection
CFR	Code of Federal Regulations
CIUs	categorical industrial users
COD	chemical oxygen demand
CMP	chemical mechanical planarization
CP	chemical precipitation
CRTs	cathode ray tubes
CVD	chemical vapor deposition
DMR	discharge monitoring report
E&EC	Electrical & Electronic Components
ELG	effluent limitations guidelines and standards
EPA	Environmental Protection Agency
ERG	Eastern Research Group, Inc.
LCD	liquid crystal display
LED	light-emitting diode
MGD	million gallons per day
NACWA	National Association of Clean Water Agencies
NPDES	National Pollutant Discharge Elimination System
NSPS	New Source Performance Standards
OLED	organic light-emitting diode
PFAS	per- and polyfluoroalkyl substances
PFBS	perfluorobutane sulfonic acid
PFOA	perfluorooctanoic acid
PFOS	perfluorooctane sulfonic acid
POTW	publicly owned treatment works
PSES	Pretreatment Standards for Existing Sources

PSNS	Pretreatment Standards for New Sources
SIC	Standard Industrial Classification
TFT-LCD	thin-film transistor liquid crystal display
TRI	Toxics Release Inventory
TSS	Total Suspended Solids

1. Electrical and Electronic Components (40 CFR Part 469)

As part of the 2015 Annual Review, EPA initiated a preliminary review of the Electrical and Electronic Components (E&EC) Category in response to stakeholder comments received during a 2014 National Association of Clean Water Agencies (NACWA) conference regarding the applicability of the effluent limitations guidelines and standards (ELGs) to the manufacture of sapphire crystals. Stakeholders expressed concerns about potential new pollutants of concern in the wastewater discharges from the manufacture of sapphire crystals (now commonly used in electronic devices), which they believe EPA did not consider during the development of the E&EC ELGs.

While the E&EC ELGs do not specifically mention sapphire crystals, from the 2015 Annual Review EPA determined that Subpart B - Electronic Crystals covers wastewater discharges generated from growing sapphire crystals and producing sapphire crystal wafers. Sapphire crystals are a crystal or crystalline material used in the manufacture of electronic devices because of their unique structural and electronic properties, and therefore, meet the applicability requirements of Subpart B. Additionally, EPA determined that sapphire-crystal wafer production likely generates wastewater in the form of slurries and acids and confirmed that nanodiamonds (the manufacture of which could also be covered by this rule) are used in sapphire crystal polishing slurries. In addition, EPA, at that time, identified several facilities in the U.S. that are currently manufacturing sapphire crystals and wafers. Following these preliminary findings, EPA determined that further review of the E&EC ELGs was appropriate.

EPA promulgated the E&EC ELGs (40 CFR part 469) in 1983. Given the age of the ELGs and the changes that have occurred in the industry since their promulgation, EPA expanded the 2016 Annual Review to include the entire E&EC Category, not just sapphire crystal manufacturing. The 1983 ELGs set limitations for four subcategories: semiconductors, electronic crystals, cathode ray tubes (CRTs), and luminescent materials. EPA further evaluated each of the four subcategories to:

- Understand the current U.S. E&EC industry and the extent to which it has changed since the promulgation of the ELGs.
- Identify which E&EC manufacturers discharge wastewater, whether they discharge directly or indirectly, what pollutants are discharged, and what electronics and electrical components they manufacture.
- Further understand and identify changes to the manufacturing steps associated with new E&EC operations since the 1983 rulemaking that may impact wastewater characteristics or management.
- Evaluate advancements in wastewater treatment technologies employed by facilities in the E&EC industry.

Section 1.1 provides details on the E&EC ELGs. Section 1.2 describes the industry profile, including facility types, process operations, and wastewater discharge practices in 1983 and the present.

1.1 Overview of Existing E&EC Effluent Limitations Guidelines and Standards (ELGs)

EPA promulgated the existing E&EC ELGs (40 CFR part 469) in 1983, which established the Best Practicable Control Technology (BPT), Best Available Technology Economically Achievable (BAT), Best Conventional Pollutant Control Technology (BCT), Pretreatment Standards for Existing Sources (PSES), New Source Performance Standards (NSPS), and Pretreatment Standards for New Sources (PSNS) for the E&EC industry. EPA divided the E&EC Industry into four subcategories based on manufacture of the following products: semiconductors, electronic crystals, CRTs, and luminescent materials. EPA promulgated the E&EC ELGs in two phases: Phase I, published in April 1983, contains the ELGs for Subparts A (semiconductors) and B (electronic crystals) (U.S. EPA, 1983a); and Phase II, published in

December 1983, contains the ELGs for Subparts C (CRTs) and D (luminescent materials) (U.S. EPA, 1983b). Table 1 lists the regulated pollutants by subcategory for the 1983 E&EC ELGs.

Table 1. Regulated Pollutants for E&EC Category

Subpart	Subcategory	Total Toxic Organics[a]	Antimony	Arsenic[b]	Cadmium	Chromium	Fluoride	Lead	pH	TSS	Zinc
BPT (Best Practicable Control Technology)											
A	Semiconductors	✓							✓		
B	Electronic Crystals	✓		✓			✓		✓	✓	
BAT (Best Available Technology Economically Achievable)											
A	Semiconductors	✓					✓				
B	Electronic Crystals	✓		✓			✓				
BCT (Best Conventional Pollutant Control Technology)											
A	Semiconductors								✓		
B	Electronic Crystals								✓	✓	
PSES (Pretreatment Standards for Existing Sources)											
A	Semiconductors	✓									
B	Electronic Crystals	✓		✓							
C	Cathode Ray Tubes	✓			✓	✓	✓	✓			✓
NSPS (New Source Performance Standards)											
A	Semiconductors	✓					✓		✓		
B	Electronic Crystals	✓		✓			✓		✓	✓	
C	Cathode Ray Tubes	✓			✓	✓	✓	✓	✓	✓	✓
D	Luminescent Materials		✓		✓		✓		✓	✓	✓
PSNS (Pretreatment Standards for New Sources)											
A	Semiconductors	✓									
B	Electronic Crystals	✓		✓							

Table 1. Regulated Pollutants for E&EC Category

Subpart	Subcategory	Total Toxic Organics[a]	Antimony	Arsenic[b]	Cadmium	Chromium	Fluoride	Lead	pH	TSS	Zinc
C	Cathode Ray Tubes	✓			✓	✓	✓	✓			✓
D	Luminescent Materials		✓		✓		✓				✓

Sources: U.S. EPA, 1983a; U.S. EPA, 1983b.

TSS – Total Suspended Solids

[a] Total toxic organics (TTO) indicates the sum of the concentrations for each of the toxic organic compounds which are found in the wastewater discharge at a concentration greater than 10 µg/L. Table 2 and Table 3 provide the list of regulated toxic organic compounds for Subparts A, B, and C.

[b] For Subpart B the arsenic limitation only applies for facilities manufacturing gallium-, or indium-arsenide crystals.

EPA established the E&EC ELGs specific to each subcategory based on their different raw materials, final products, manufacturing processes, geographical location, plant-size and age, wastewater characteristics, non-water quality environmental impacts, treatment costs, energy costs, and solid waste generation (U.S. EPA, 1983a; U.S. EPA, 1983b). The following subsections describe the two phases of the E&EC ELG development in more detail, the wastewater treatment technology bases for the ELGs, and other point source categories related to E&EC.

1.1.1 Phase I: Semiconductors and Electronic Crystals

In April 1983, EPA promulgated the Phase I E&EC ELGs for Subpart A (Semiconductors) and Subpart B (Electronic Crystals) (U.S. EPA, 1983a). As part of this rulemaking, EPA gathered industry analytical data to characterize wastewater discharges from semiconductor and electronic crystal manufacturing facilities. EPA excluded 95 pollutants from regulation because they were 1) non-detectable with 1983 EPA analytical methods (82 pollutants), 2) present in concentrations too small to be effectively treated (antimony, beryllium, cadmium, mercury, selenium, thallium, zinc, and cyanide), or 3) subject to Metal Finishing ELGs (nickel, copper, chromium, and lead).[1] In addition to the exclusion of the ninety-five pollutants for both subparts, another toxic pollutant was excluded for the Semiconductor subpart only. This pollutant was arsenic and was excluded as it was present in concentrations too small to be effectively treated. EPA ultimately established limitations for fluoride (Subpart B only), toxic organics, arsenic (Subpart B only), pH, and total suspended solids (subpart B only).[2] Since semiconductor and electronic crystal manufacturers use a wide variety of solvents, EPA identified several toxic organics that may be present in the untreated wastewater. Therefore, EPA established limitations for total toxic organics (TTO). EPA defined TTO, for Subparts A and B, as the sum of the concentrations of toxic organics listed in Table 2 with discharge concentrations greater than ten (10) micrograms per liter (µg/L) per pollutant (U.S. EPA, 1983a).

[1] See Section 1.1.4 for a discussion on the overlap between the E&EC and Metal Finishing ELGs.

[2] The E&EC ELGs reference the regulated pollutants for each subpart as the only pollutants of concern identified during the rulemaking (U.S. EPA 1983a; U.S. 1983b).

Table 2. TTO Pollutants for Subpart A (Semiconductors) and Subpart B (Electronic Crystals)

List of TTO Pollutants for Semiconductors and Electronic Crystals			
anthracene	1,3-dichlorobenzene	Isophorone	toluene
bis(2-ethylhexyl)phthalate	1,4-dichlorobenzene	methylene chloride	1,2,4-trichlorobenzene
butyl benzyl phthalate	Dichlorobromoethane	Naphthalene	1,1,1-trichloroethane
carbon tetrachloride	1,2-dichloroethane	2-nitrophenol	1,1,2-trichloroethane
chloroform	1,1-dichloroethylene	4-nitrophenol	trichloroethylene
2-chlorophenol	2,4-dichlorophenol	pentachlorophenol	2,4,6-trichlorophenol
di-n-butyl phthalate	1,2-diphenylhydrazine	Phenol	
1,2-dichlorobenzene	ethyl benzene	tetrachloroethylene	

Source: U.S. EPA, 1983a.

1.1.2 Phase II: Cathode Ray Tubes and Luminescent Materials

In December 1983, EPA promulgated the Phase II E&EC ELGs for Subpart C (CRTs) and Subpart D (Luminescent Materials) (U.S. EPA, 1983b). EPA gathered industry analytical data to characterize wastewater discharged from the manufacture of CRTs and luminescent materials. EPA originally divided the Electron Tube subcategory into CRTs and Receiving and Transmitting Tubes (RTT) subcategories; however, EPA determined RTT manufacturing operations do not discharge wastewaters and only promulgated limitations for CRTs. Further, EPA did not establish limitations for existing source direct dischargers in the CRT subcategory. Only one facility directly discharged, and it operated a chemical precipitation plus filtration treatment system and the discharge of toxic pollutants was less than two pounds per day after treatment. Similarly, EPA did not establish limitations or pretreatment standards for existing dischargers in the Luminescent Materials subcategory due to the small number of facilities in the subcategory (five) and because the amount of toxic metals discharged to surface water (less than one pound per facility per day) and toxic pollutants introduced to publicly operated treatment works (POTWs) was insignificant at the time of promulgation (U.S. EPA, 1983b).

For CRT manufacturing, EPA excluded 116 pollutants from regulation because they were either non-detectable by 1983 EPA analytical methods (106 pollutants) or present in concentrations too small to be effectively treated (antimony, arsenic, beryllium, copper, mercury, nickel, selenium, silver, thallium, cyanide) (U.S. EPA, 1983b). EPA established limitations for cadmium, chromium, lead, zinc, TTO, fluoride, pH, and total suspended solids for the CRT manufacturing subcategory. Similar to semiconductors and electronic crystals, CRT manufacturers use a wide variety of solvents, and EPA identified several toxic organics that may be present in the untreated wastewater. Therefore, EPA established limitations for TTO. For the CRT subcategory, EPA defined TTO as the sum of the concentrations of the toxic organics listed in Table 3 with concentrations greater than ten (10) micrograms per liter (µg/L) per pollutant (U.S. EPA, 1983b).

Table 3. TTO Pollutants for Subpart C (CRTs)

List of TTO Pollutants for CRTs		
Chloroform	methylene chloride	1,1,1-trichloroethane
bis(2-ethylhexyl)pthalate	Toluene	trichloroethylene

Source: U.S. EPA, 1983b.

For luminescent material manufacturing, EPA excluded 123 pollutants from regulation because they were either non-detectable with 1983 EPA analytical methods (114 pollutants) or present in concentrations too small to be effectively treated (arsenic, beryllium, copper, mercury, nickel, selenium, silver, thallium, cyanide). EPA established limitations for cadmium, antimony, zinc, fluoride, pH, and total suspended solids for the luminescent material subcategory (U.S. EPA, 1983b). No limitations were established for TTO.

1.1.3 Wastewater Treatment Technology Bases for Pollutant Limitations in the E&EC Category

The E&EC ELGs established pollutant limitations for the E&EC Category generally based on solvent management[3] (to control TTO), neutralization, chemical precipitation with clarification (hydroxide), in-process control for specific pollutants,[4] and filtration. EPA only established limitations for CRT manufacturing operations for PSES, NSPS, and PSNS. For luminescent materials manufacturing, limitations were established for NSPS and PSNS. Table 4 presents the general wastewater treatment technology basis by subcategory and level of control.

Table 4. Wastewater Treatment Technology Bases for the E&EC Category

Subpart	Subcategory	Solvent Management	Neutralization	Chemical Precipitation with Clarification[a]	In Process Control for Lead and Chromium	Filtration
BPT (Best Practicable Control Technology)						
A	Semiconductors	✓	✓			
B	Electronic Crystals	✓	✓	✓		
BAT (Best Available Technology Economically Achievable)						
A	Semiconductors	✓	✓	✓		
B	Electronic Crystals	✓	✓	✓		
BCT (Best Conventional Pollutant Control Technology)						
A	Semiconductors	✓	✓			
B	Electronic Crystals	✓	✓	✓		
PSES (Pretreatment Standards for Existing Sources)						
A	Semiconductors	✓				
B	Electronic Crystals	✓	✓	✓		
C	Cathode Ray Tubes	✓	✓	✓	✓	

[3] In the E&EC ELGs, EPA defined solvent management as a practice of preventing spent solvent baths (containing TTO) from entering other process wastewater. While the ELGs allow for some solvent bath contamination (e.g., drag out), plants are required to transfer solvent baths to drums or tanks for disposal.

[4] In-process control includes the collection of lead- and chromium- bearing wastes for resale, reuse, or disposal.

Table 4. Wastewater Treatment Technology Bases for the E&EC Category

Subpart	Subcategory	Solvent Management	Neutralization	Chemical Precipitation with Clarification[a]	In-Process Control for Lead and Chromium	Filtration
NSPS (New Source Performance Standards)						
A	Semiconductors	✓	✓	✓		
B	Electronic Crystals	✓	✓	✓		
C	Cathode Ray Tubes	✓	✓	✓	✓	✓
D	Luminescent Materials		✓	✓		
PSNS (Pretreatment Standards for New Sources)						
A	Semiconductors	✓				
B	Electronic Crystals	✓	✓	✓		
C	Cathode Ray Tubes	✓	✓	✓	✓	✓
D	Luminescent Materials		✓	✓		

Source: U.S. EPA 1983a; U.S. EPA, 1983b.

[a] EPA based all subparts on end-of-pipe or final effluent chemical precipitation with clarification except Subpart A (Semiconductors), which was based on in-plant chemical precipitation and clarification of the concentrated fluoride stream. In addition, contract hauling of the concentrated fluoride stream was considered an acceptable alternative for compliance.

1.1.4 Other Point Source Categories Related to E&EC

As stated previously, EPA promulgated the existing E&EC ELGs (40 CFR part 469) in 1983. EPA promulgated the Electroplating ELGs in 1974 and amended them in 1977, 1979, 1981 and 1983 (40 CFR part 413) and promulgated the Metal Finishing ELGs in 1983 (40 CFR part 433). During promulgation of the E&EC and Metal Finishing ELGs and the amendments of the Electroplating ELGs, EPA considered that some facilities may generate wastewater from metal finishing and/or electroplating operations as well as E&EC operations; therefore, facilities may be covered under multiple ELGs.

The Metal Finishing ELGs apply to discharges resulting from six core process operations, and 40 additional process operations for those facilities using at least one of the six core process operations (U.S. EPA, 1983c). The six core metal finishing process operations are electroplating, electroless plating, anodizing, coating, etching and chemical milling, and printed circuit board manufacturing (U.S. EPA, 1983c). Following the amendments of the Electroplating ELGs, EPA limited the applicability of the Electroplating Category ELGs to facilities that apply metal coatings via electrodeposition that began operation before July 15, 1983, and discharge wastes to POTWs. All other facilities performing electroplating operations are subject to regulations under the Metal Finishing Category (U.S. EPA, 1983c).

Most semiconductor manufacturing facilities use one or more of the six core metal finishing operations while processing silicon wafers. The *Development Document for Effluent Limitations Guidelines and New Source Performance Standards for the Metal Finishing Point Source Category* states that the ELGs for the Metal Finishing Category, the Electroplating Category, and/or the E&EC Category cover all industries listed under SIC Major Group 36.[5] Specifically, the E&EC ELGs cover processes unique to electronics manufacturing (e.g., semiconductor manufacturing, electronic crystal production), while the Metal Finishing and Electroplating ELGs cover the remaining processes used to manufacture the products in SIC Major Group 36 (U.S. EPA, 1983c).

As described in the *Development Document for Effluent Limitations Guidelines and New Source Performance Standards for the Metal Finishing Point Source Category*, when overlap occurs between the Metal Finishing or Electroplating ELGs and E&EC ELGs, the Metal Finishing ELGs apply for the discharge of four pollutants (nickel, copper, chromium, and lead) (U.S. EPA, 1983c). For example, for a semiconductor manufacturing facility generating electroplating wastewater, the subpart A E&EC ELGs would apply for pollutants provided in Table 1 and the Metal Finishing ELGs would apply for four pollutants associated with metal finishing processes (nickel, copper, chromium, and lead).

1.2 E&EC Industry Profile

As part of the 2016 Annual Review, EPA reviewed the 1983 E&EC industry profile and updated the characteristics of the current E&EC industry. This section presents the facility type, wastewater discharge practices, and process operations for E&EC facilities in 1983 and currently.

EPA developed an industry profile for the E&EC industry as part of the development of the Phase I and Phase II E&EC ELGs in 1983. To complete the industry profile, EPA gathered information through literature searches, EPA regional office contacts, wastewater treatment technology vendors, and plant surveys and evaluations. This section describes the 1983 facility information EPA gained from its data collection efforts.

1.2.1 Facilities and Wastewater Discharge Practices

During the 1983 E&EC rulemaking, EPA determined that the majority of facilities under the E&EC Category manufactured semiconductors (Subpart A) (approximately 72 percent). EPA estimated that about 20 percent of facilities within the E&EC Category manufactured electronic crystals (Subpart B), leaving the remaining 8 percent of facilities under the combined totals for Subparts C (CRTs) and D (luminescent materials). Table 5 provides the facility count and discharge type determined during the 1983 E&EC rulemaking.

Table 5. Facility Information for 1983 Industry Profile

Subpart	Manufacturing Process	Facility Count[a]	Dischargers	
			Direct	*Indirect*
A	Semiconductor Manufacturing	257	77	180
B	Electronic Crystals	70	6	64
C	Cathode Ray Tubes	24	1	23

[5] SIC Major Group 36 includes Semiconductor and Related Manufacturing (SIC code 3674), Electron Tube Manufacturing (SIC code 3671), and Electronic Component Manufacturing (SIC code 3679).

Table 5. Facility Information for 1983 Industry Profile

Subpart	Manufacturing Process	Facility Count[a]	Dischargers	
			Direct	*Indirect*
D	Luminescent Materials	5[b]	2	2
	Total	356	86	269

Source: U.S. EPA, 1983a; U.S. EPA, 1983b

[a] EPA determined the number of facilities using a Semiconductor Industry Association (SIA) listing of plants involved in manufacturing semiconductor products in August 1979.

[b] EPA identified one facility with zero discharges.

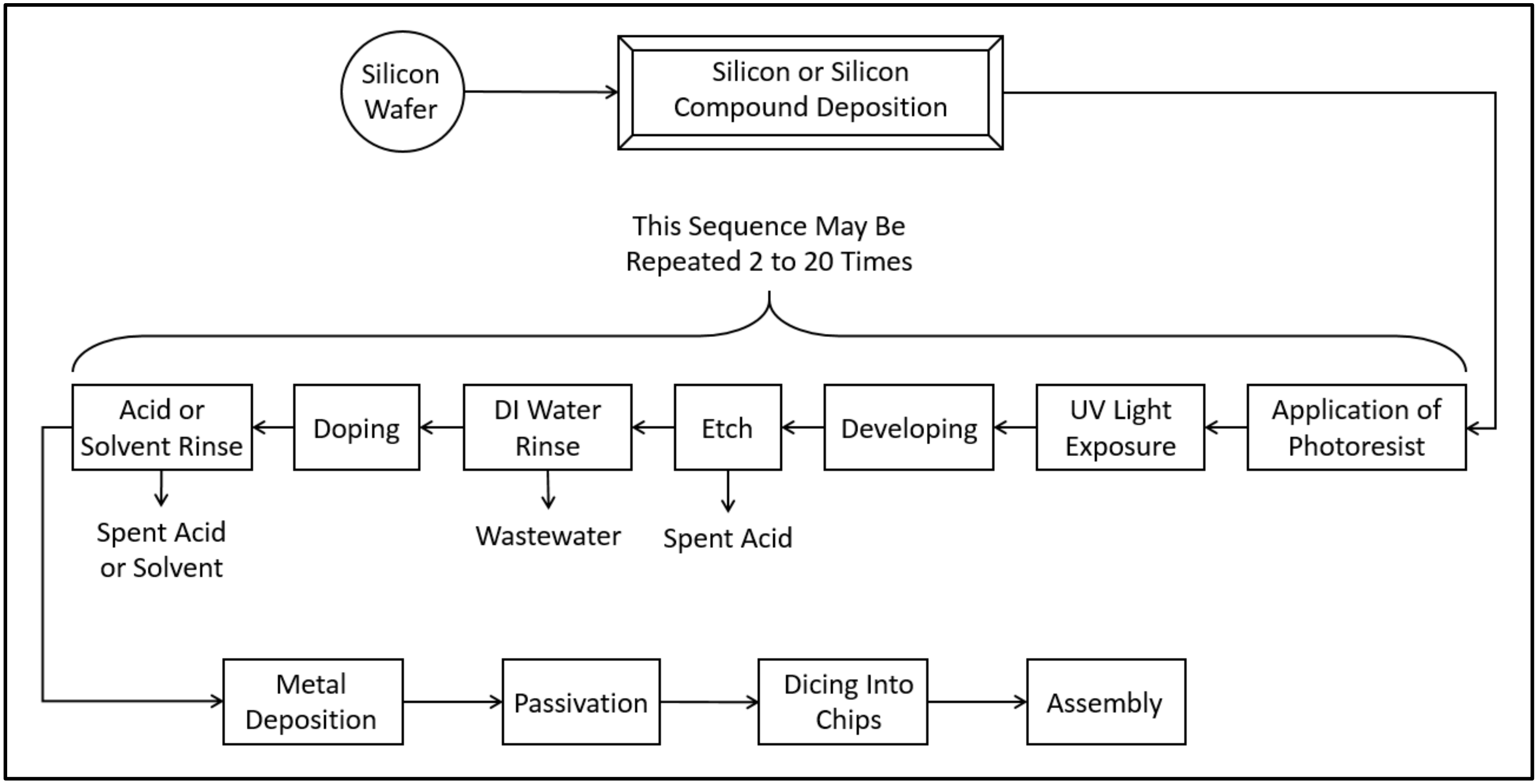
As shown in Table 5, in 1983, 76 percent of all facilities in the E&EC industry discharged to POTWs, including 70 percent of semiconductor manufacturing facilities, 91 percent of electronic crystal manufacturers, and 96 percent of CRT manufacturing facilities. EPA only reviewed five luminescent materials manufacturers, where 40 percent discharged to surface waters and 40 percent discharged to POTWs, while 20 percent achieved zero discharge (U.S. EPA, 1983a; U.S. EPA, 1983b).

1.2.2 1983 E&EC Process Operations

EPA reviewed information on the process operations for the four subcategories established in 1983: semiconductor manufacturing, electronic crystal manufacturing, cathode ray tube manufacturing, and luminescent materials manufacturing. The following sections summarize EPA's findings by subcategory.

1.2.2.1 Semiconductor Manufacturing

In general, semiconductor manufacturing facilities coat and chemically etch/pattern silicon (or other semiconducting materials) wafers for the desired E&EC products. In 1983, semiconductor manufacturing involved a series of processes, possibly repeated two to 20 times, starting from a raw silicon wafer (silicon was the primary wafer type, although other composition wafers were used) and ending in a microchip designed for assembly in a specific electronic product. Figure 1 presents the sequence of process operations for manufacturing silicon integrated circuits (a semiconductor type), as identified in 1983.

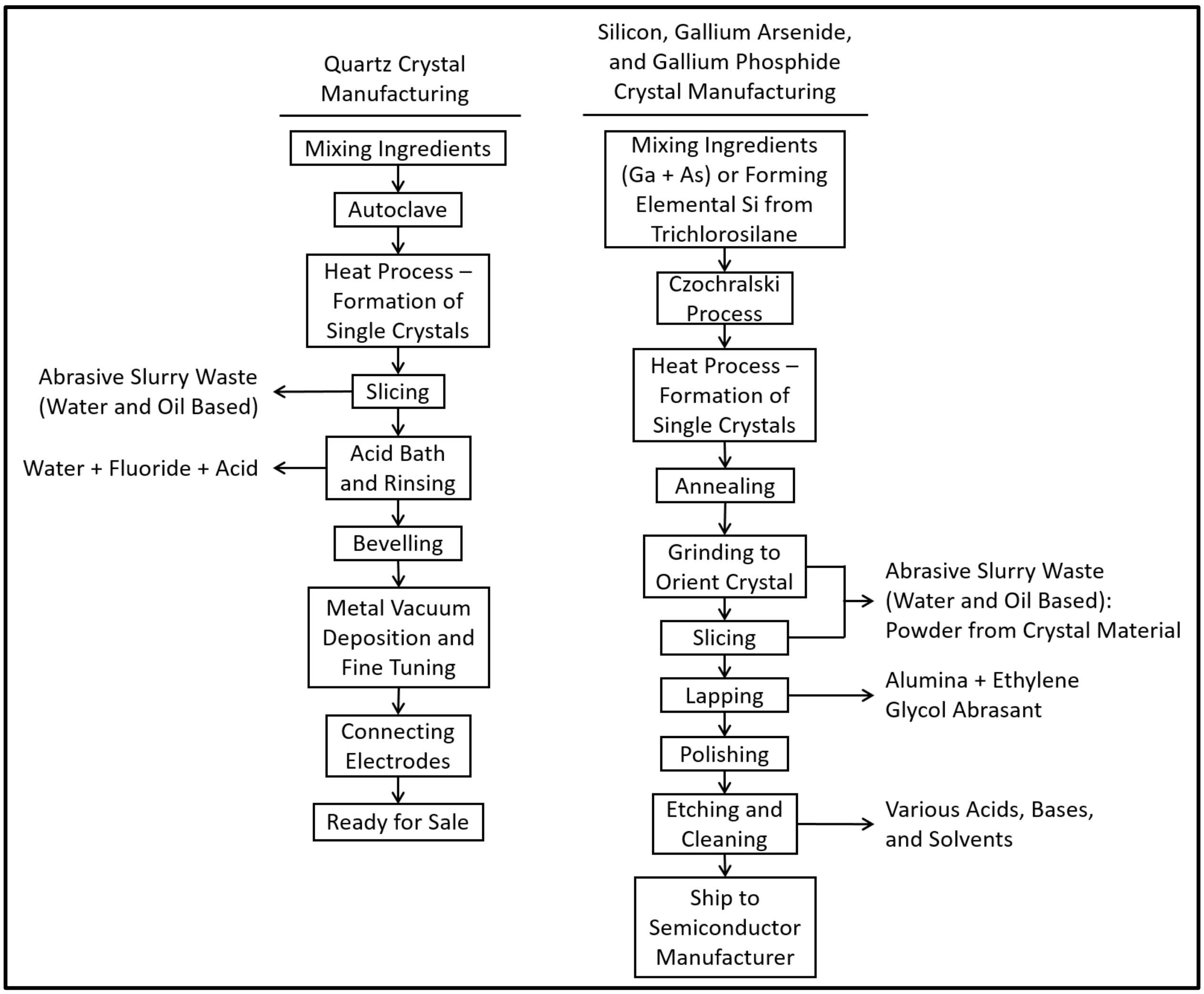


Source: Adapted from U.S. EPA 1983a and ERG, 2016a.

Figure 1. 1983 Silicon Integrated Circuit Production

1.2.2.2 Electronic Crystals Manufacturing

As part of the 1983 regulations EPA defined electronic crystal manufacturing as "the growing of crystals and/or production of crystal wafers for use in the manufacture of electronic devices". In general, electronic crystal manufacturing involves forming a crystalline boule and then slicing, rinsing, lapping (e.g., grinding), polishing, etching, and cleaning the crystal prior to shipping to a semiconductor manufacturer or other electronics customers. Figure 2 shows diagrams of typical manufacturing process flows in 1983 for the manufacture of quartz crystals (a type of piezoelectric crystal), and three types of semiconducting crystals: silicon, gallium arsenide, and gallium phosphide. EPA only identified one sapphire crystal producer in 1983; therefore, sapphire crystal manufacturing was not a focus of the rulemaking. EPA reviewed sapphire crystal manufacturing as part of the 2015 Annual Review. That review suggested that sapphire crystals are currently a common type of electronic crystal manufactured and used in the E&EC industry (U.S. EPA, 1983a, U.S. EPA, 2016a).



Source: Adapted from U.S. EPA, 1983a.

Figure 2. Basic Manufacturing Processes for Electronic Crystals in 1983

1.2.2.3 Cathode Ray Tubes and Luminescent Materials Manufacturing

In 1983, CRT manufacturing operations differed depending on the type of CRT (e.g., color television (TV) tubes, single phosphor tubes) being manufactured. The manufacture of each type of CRT was highly complex and often automated (U.S. EPA, 1983b). The 1983 E&EC ELGs define luminescent materials as "those that emit electromagnetic radiation (light) upon excitation by such energy sources as photons, electrons, applied voltage, chemical reactions, or mechanical energy. These luminescent materials are used for a variety of applications, including fluorescent lamps, high-pressure mercury vapor lamps, color TV picture tubes and single phosphor tubes, lasers, instrument panels, postage stamps, laundry whiteners, and specialty paints" (U.S. EPA, 1983b). EPA based its 1983 analyses related to these two subcategories on those materials used as coatings in fluorescent lamps and color TV picture tubes and single phosphor tubes (U.S. EPA, 1983b).

1.2.3 Current E&EC Process Operations

Since 1983, EPA has observed changes in E&EC process operations in all four subcategories. EPA evaluated economic census data, analyzed DMR and TRI data, performed a literature search, searched for available NPDES reports, reviewed IBISWorld reports, met with industry trade associations and NACWA members, contacted individual facilities, and attended industry conferences, to determine the nature of current E&EC process operations. The following sections summarize EPA's findings by subcategory.

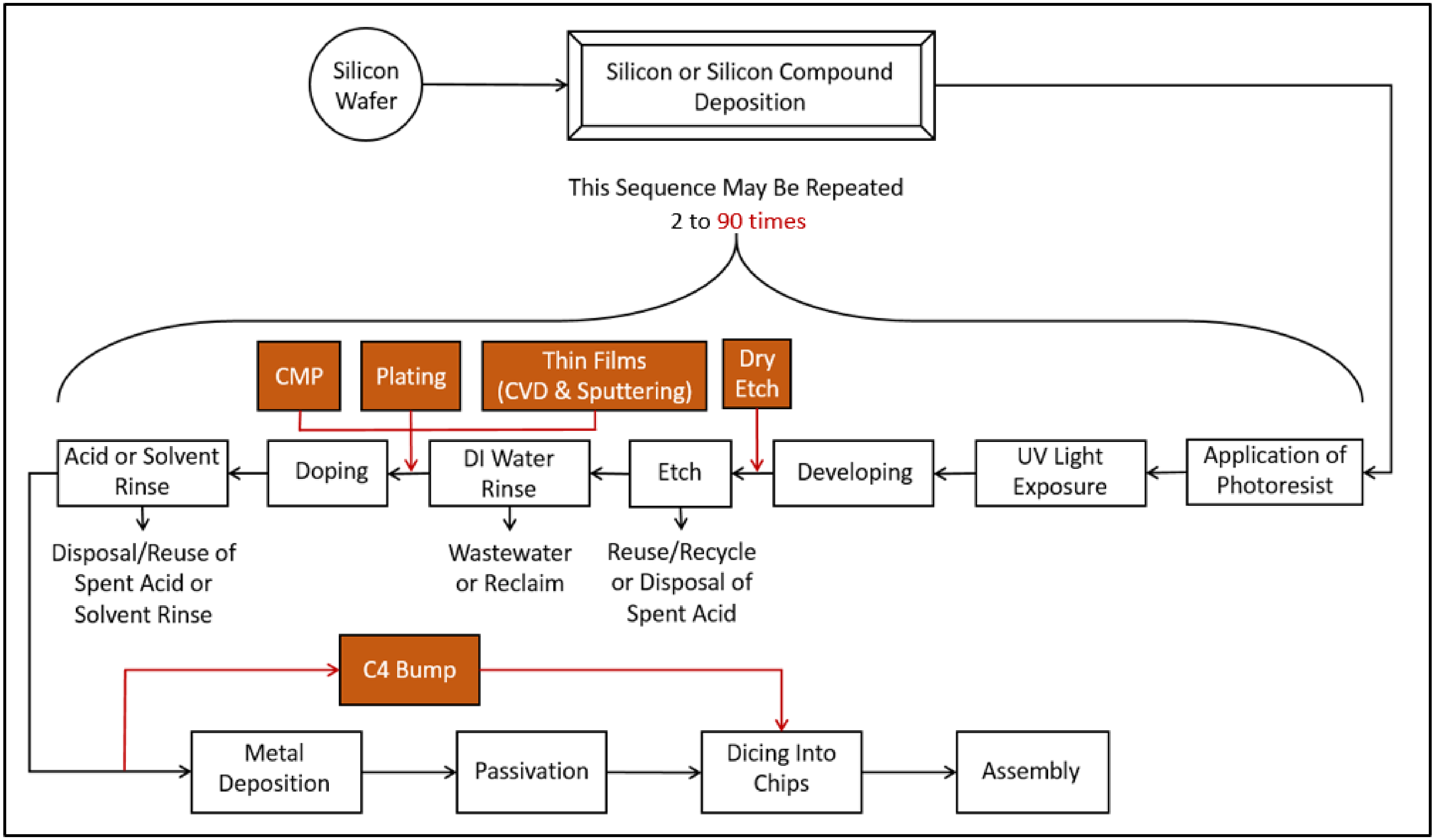
1.2.3.1 Semiconductor Manufacturing

Discussion with the Semiconductor Industry Association (SIA) indicated that while the semiconductor manufacturing (Subpart A) process sequence in general has not changed significantly, semiconductor manufacturing facilities (the semiconductor manufacturing industry refers to these facilities as fabrication plants or "fabs") have added several process steps over the past 30 years to optimize semiconductor manufacturing, incorporate newer technologies, and achieve smaller node size. The node size, which indicates how densely individual transistors can be packed on a chip, has decreased roughly three orders of magnitude since 1970, to the point where the industry can produce microchips with over one-billion transistors per square centimeter. When the number of transistors on a chip increases, the computational capabilities increase, speed increases, and energy consumption decreases. Since 2010, the node size decreased from 32 nanometers (nm) to less than 3 nm (estimated for 2022 operations) (ERG, 2016a; ERG, 2016b).

In addition to the node size decreasing, the semiconductor industry has increased the silicon wafer size over the past 30 years, from a diameter of 125 millimeters (mm) to 300mm (ERG, 2016a; ERG, 2016b). Furthermore, as the technology advances (smaller nodes, larger wafers), semiconductor manufacturing facilities must replace machines, tools, and monitoring systems to support new processes.

More specifically, to increase the number of microprocessors obtainable from a single wafer over the past 30 years, semiconductor manufacturing facilities have integrated new steps within the semiconductor manufacturing process sequence including dry etching, metal deposition processes (e.g., plating, chemical vapor deposition (CVD), copper metallization), chemical mechanical planarization (CMP), and controlled collapse chip connection (C4) bump. SIA indicated that wastewater is generated from these new processes but did not provide further details. In addition to new process steps, SIA stated that the existing semiconductor process sequence could be repeated up to 90 times, whereas in 1983 the sequence was repeated only up to 20 times. Figure 3 provides the 1983 process flow diagram from the E&EC ELGs with updated semiconductor manufacturing operations based on EPA's discussions with SIA (ERG, 2016a; U.S. EPA, 1998; U.S. EPA 1983a).

To further understand existing processes, EPA contacted six semiconductor facilities with significant discharges based on reported 2014 DMR and TRI data. EPA inquired about the facility's age, size, manufacturing processes, end-products, process chemistries, wastewater generation, and wastewater treatment technologies. Table 6 presents a summary of information EPA obtained from these facility contacts. The facility contacts generally stated that the final products in semiconductor manufacturing have continued to shrink in size causing some fabrication processes to change (e.g., tooling, lithography patterns, new coating layers, CVD) (McCoy, 2016; Heironimus, 2016; Aldrich, 2016). Most of the contacts indicated that process chemistries (i.e., chemicals used in E&EC processes) have not changed substantially over the past 30 years; however, one facility stated that the chemistry changes would likely involve trading out one acid for another acid (McCoy, 2016).



Source: Adapted from ERG, 2016a.

Note: Process steps in black writing and grey boxes represent the 1983 semiconductor manufacturing operations and process steps in white/red writing and red boxes represent updated semiconductor manufacturing operations since 1983.

Figure 3. Updated Silicon Integrated Circuit Production

Table 6. Summary of Facility Contacts for the Semiconductor Industry

Facility Name	Location	Manufacturing Process	Year	Size[a]	Type	Wastewater Generation Processes	Wastewater Treatment[b]
East Fishkill Facility	Hopewell Junction, NY	Semiconductor 300 mm fab	1963	40 MGD 168,000 wafers/yr	Direct	• Ultrapure water reject • Photolithography (i.e., solvents, rinses) • Polishing	• Clarifiers • CP (polymer) • Microfiltration • Acid base slurry treatment • Calcium hydroxide precipitation (Fluoride treatment) • Recycle 10 to 11 million gal/month (i.e., for use in 2nd/3rd rinses)
Powerex, Inc.	Youngwood, PA	Semiconductor	1965	0.1 MGD	Indirect	• Rinsing after etching • Cleaning products throughout process	• Contact did not provide wastewater treatment information.
Micron Technology, Inc.	Manassas, VA	Semiconductor 300 mm fab	1997	5 MGD	Indirect	• Throughout manufacturing process (rinse water)	• Clarifiers • pH adjustment • Chloride treatment • Lime addition with filter tank
Samsung Austin Semiconductor	Austin, TX	Semiconductor	1996	1.3 billion gal/yr	Indirect	• Ultrapure water reject • Rinsing after etching • Cleaning products throughout process	• Clarifiers • CP (sodium hydroxide, lime, caustic, sulfuric acid, ferric chloride) • Filter presses • *Future Wastewater Treatment:* Ion Exchange (Cu Treatment)[c]
Freescale Semiconductor – Oak Hill Facility	Austin, TX	Semiconductor	1991	240,000 wafers/yr	Indirect	• Ultrapure water reject • Rinsing after etching	• pH adjustment • Recycle a portion of rinse water (i.e., for use in cooling tower, scrubber)
Intel Corporation	Chandler, AZ	Semiconductor 12 in wafer	1994	5.4 MGD	Indirect	• Wet edging • Abatement technologies • Rinsing after etching • Cleaning products throughout process	• Fluoride Treatment (i.e., creates calcium fluoride cake) • Stripper scrubber (NH_3 Treatment) • Zeolite resin (NH_3 Treatment) • Electrowinning System (Cu Treatment)

Source: Aldrich, 2016; Heironimus, 2016; Kang, 2016; Marone, 2016; McCoy, 2016; Wasielewski, 2016.

[a] MGD – million gallons per day discharged; Production rate (i.e., number of wafers).

[b] CP – Chemical Precipitation.

[c] Future Wastewater Treatment – The facility is considering installing ion exchange for copper treatment in effluent (i.e., performing pilot studies).

1.2.3.2 Electronic Crystals Manufacturing

EPA reviewed electronic crystal manufacturing as part of the 2015 Annual Review and determined sapphire crystal manufacturing has likely increased in the U.S. since the 1983 E&EC rulemaking. EPA also determined that sapphire crystal wafer production generates wastewater in the form of slurries and acids from processing steps including wafer lapping, wafer grinding, and polishing similar to the processing steps for the production of other types of electronic crystals. Wafer lapping involves using an abrasive liquid slurry mixture to form a smooth, polished surface, while wafer grinding uses oil- or water-based slurries for coarse removal of material. Polishing slurries are used for surface polishing and removing abrasives; however, these slurries may introduce water, oil, and acid-based additives, as well as harsh chemicals, to the process wastewater. However, EPA's information on the wastewater constituents associated with sapphire crystal manufacturing is limited as the chemicals used in the preparation of sapphire wafers have not been thoroughly studied (U.S. EPA, 2016a).

For its 2016 Annual Review, EPA conducted a targeted literature review using the keyword list (U.S. EPA, 2018), and did not identify any further information with regards sapphire crystal manufacturing. However, EPA identified one paper with specific information regarding treatment of wastewater from electronic crystal polishing (Sturgill, 2000). Sturgill primarily discusses pollution prevention and recycling of gallium and arsenic from gallium arsenide (GaAs) polishing wastes, but the introduction provides a general description of GaAs crystal manufacturing. Sturgill states that boules (i.e., ingots of crystalline GaAs) are cut into wafers, and then the wafers are etched, lapped, and polished (Sturgill, 2000). Sturgill's GaAs crystal manufacturing process steps are similar to electronic crystal manufacturing process steps depicted in Figure 2 identified during the 1983 rulemaking. This information suggests the electronic crystal manufacturing process steps have not changed substantially over the past 30 years; however, as identified during the 2015 Annual Review, sapphire crystal manufacturing has likely increased.

1.2.3.3 Cathode Ray Tubes and Luminescent Materials Manufacturing

EPA reviewed existing manufacturing operations for Subpart C, CRTs, and Subpart D, luminescent materials, through internet searches and the literature review. The research indicates that CRT manufacturing has decreased dramatically due to their replacement with newer technologies, such as liquid crystal display (LCD), thin-film transistor liquid crystal display (TFT-LCD), plasma display, and organic light-emitting diode (OLED) for TV and other electronic applications (IBISWorld, 2016; Sood, 2005). Similarly, luminescent materials consisted of fluorescent lamp phosphors in 1983 (i.e., used in TV, video game displays, and lamp applications); however, most of these applications have been replaced with other technologies, such as light-emitting diode (LED) lamps and the CRT replacement technologies listed previously (IBISWorld, 2016; ERG, 2016a; Sood, 2005). In addition, NACWA members confirmed that CRT and luminescent materials are phasing out of production (U.S. EPA, 2016b).

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2. Discharge Regulatory Framework

E&EC facilities commonly are indirect dischargers (i.e., they discharge their wastewater to a POTW) but some are direct dischargers (i.e., they discharge treated wastewater to waters of the US. The regulatory framework applicable to each type of discharger is described below.

2.1 Indirect Dischargers Subject to the Pretreatment Standards Under the National Pretreatment Program

The majority of facilities are indirect dischargers that discharge their wastewater to a local or regional publicly owned treatment works (POTW). These facilities are subject to the national pretreatment program in 40 CFR Part 403. The national pretreatment program is a component of the NPDES program. It is a cooperative effort of federal, state, and local environmental regulatory agencies established to protect water quality. Similar to how EPA authorizes the NPDES permit program to state, tribal, and territorial governments to perform permitting, administrative, and enforcement tasks for discharges to surface waters (NPDES program), EPA and authorized NPDES state pretreatment programs approve local municipalities to perform permitting, administrative, and enforcement tasks for discharges into the municipalities' POTWs.

The national pretreatment program is designed to protect POTWs infrastructure and reduce conventional and toxic pollutant levels discharged by industries and other nondomestic wastewater sources into municipal sewer systems and into the environment.

2.1.1 Pretreatment Standards

Pretreatment standards are pollutant discharge limits which apply to industrial users (IUs). Pretreatment requirements are substantive or procedural requirements applied to IUs. ELGs are uniform national standards developed by EPA for specific industrial categories. The standards applicable to indirect dischargers (also called categorical pretreatment standards) are listed under each ELG as pretreatment standards for existing sources (PSES) and pretreatment standards for new sources (PSNS). The E&EC ELG establishes PSES and PSNS for the E&EC industrial category. These technology-based standards apply regardless of whether or not the POTW has an approved pretreatment program or whether or not the nondomestic discharger has been issued a control mechanism or permit. Nondomestic dischargers subject to categorical pretreatment standards are categorical industrial users (CIUs). Thus, all indirect discharging E&EC facilities are CIUs.

2.1.2 Pretreatment Control Authorities

Where a POTW has an approved local pretreatment program, the POTW is the control authority. Where a POTW has not received approval, the control authority is the approved state or, in unapproved states, the EPA.

The control authorities:

- Develop legal authority for their jurisdiction, local limits, standard operating procedures, and an enforcement response plan to establish and maintain an approved pretreatment program.
- Regulate IUs by:
  - issuing control mechanisms,
  - conducting monitoring and inspections,
  - receiving and reviewing reports and notifications,
  - reviewing requests for net/gross variances,

- evaluating compliance with program requirements, and taking enforcement as appropriate, and
- submitting regular reports to approval authorities to describe the implementation of their pretreatment program.

The control authority is responsible for administering and enforcing pretreatment standards and requirements. The control authority's primary goals are: to prevent the discharge of pollutants into the POTW that would result in interference and pass through at the POTW's wastewater treatment plant; and to ensure that IUs comply with all applicable pretreatment program requirements.

2.1.3 Local limits and other potentially applicable pretretment standards

The federal regulations in 40 CFR 403.5(c)(1) require POTWs with approved pretreatment programs or POTWs developing a pretreatment program to develop local limits that enforce the general and specific prohibitions in 40 CFR 403.5 (a)(1) and (b). Additionally, some states and EPA Regions may have additional requirements for the development of local limits for specific parameters. EPA's Local Limits Development Guidance (U.S. EPA, 2004) provides a detailed outline of the process for developing local limits. Additionally, some states may have additional requirements for the development of local limits for specific parameters.

While 40 CFR Part 469 does not have a pH limit for indirect dischargers, many POTWs do include pH requirements in their permits for indirect dischargers. The federal regulations in 40 CFR 403.5(b)(2) prohibits indirects dischargers from discharging "pollutants which will cause corrosive structural damage to the POTW, but in no case Discharges with pH lower than 5.0, unless the works is specifically designed to accommodate such Discharge." Note that if the POTW's collection system is designed to handle a lower pH, the control authortity may accept wastewater with a pH less than 5.0 as long as the control authority has an approved and adopted local limit for the lower pH. Additionally, 40 CFR Part 403 does not contain an upper pH limit; however, discharges with a pH greater than 12.5 will require the industrial user to meet the hazardous waste reporting requirements in 40 CFR 403.12(p). As a result, most control authorities set their upper pH limit below 12.5.

E&EC indirect dischargers are required to conduct self-monitoring and submit monitoring reports to the pretreatment control authority. The federal regulations in 40 CFR 403.12(g)(1) require self-monitoring to be performed at least twice a year, but more frequent monitoring may be required by the control authority.

2.2 Direct Dischargers Subject to NPDES Permitting

Any E&EC facility that directly discharges pollutants from a point source to a water of the US is subject to the NPDES permit program. NPDES permits are issued by the EPA or authorized states. Most NPDES permits are issued by the authorized state. These permits must include applicable technology-based effluent limits from the E&EC ELG (40 CFR part 469) based on Best Practicable Control Technology (BPT), Best Available Technology Economically Achievable (BAT), Best Conventional Pollutant Control Technology (BCT), or New Source Performance Standards (NSPS) for the E&EC industrial subcategory.

Additionally, the NPDES permit is required to include permit limits and conditions where necessary that protect water quality in the receiving stream. As a result, more stringent water quality-based effluent limitations and/or limits for additional pollutants and/or other requirements may be included in the NPDES permit compared to the requirements in the ELG.

E&EC direct dischargers must submit DMRs to the permitting authority in compliance with the NPDES permit.

2.3 E&EC Facility Discharge Requirements

EPA contacted permitting agencies (states, EPA regions, and pretreatment control authorities) to better understand permits and pretreatment requirements applicable for direct and indirect discharging E&EC facilities. As a follow-up to these conversations, the permitting agencies and control authorities provided copies of the permits and associated documents, including the permit applications, fact sheets, and solvent management plans. Additionally, EPA reviewed public databases for copies of this information. EPA developed a permit summary database to track the various permit conditions included in E&EC permits, implementing the quality control procedures described in Section 2.3.4 to ensure data were transcribed accurately. While the database is not a census of all permitted E&EC facilities, it is a robust representation of the E&EC industry. All collected documents as well as the final permit database are available in the supporting docket.[6]

Table 7 shows the number of direct and indirect permitted facilities in the E&EC permit database by E&EC subcategory, includings those facilities that are subject to multiple subcategories or are also permitted under additional ELGs (i.e., 40 CFR part 433 and/or 40 CFR part 471). This distribution shows that the E&EC industry is comprised primarily of indirect dischargers (97%) and a few direct dischargers (3%). E&EC facilities are also predominantly semiconductor manufacturers (65%), followed by crystal manufacturers (10%), and several integrated plants manufacturing both electronic crystals and semiconductors or performing both E&EC and other manufacturing operations (24%). EPA did not collect any permits from any cathode ray tube manufacturing facilities and collected permits from only two luminescent materials manufacturing facilities; this is consistent with the decline in the cathode ray tube and fluorescent lamps industries since the early 1980s when the E&EC regulations were promulgated.

Table 7. E&EC Permitted Facilities in E&EC Study Permit Database

Point Source Category and Subcategory	Number of Facilities Permitted		
	Existing Source	New Source	Unknown
Indirect Dischargers			
469 A	6	58	9
469 B	3	6	2
469 D	0	2	0
469 A, 469 B	0	4	2
469 A, 433	4	11	0
469 B, 433	1	1	0
469 A, 469 B, 433	0	1	0
469 B, 433, 471	0	1	0
Research and Development Facility	0	0	1
Total	14	84	14
Direct Dischargers			
469 A	0	1	1

[6] https://www.regulations.gov/docket/EPA-HQ-OW-2021-0547

Table 7. E&EC Permitted Facilities in E&EC Study Permit Database

Point Source Category and Subcategory	Number of Facilities Permitted		
	Existing Source	New Source	Unknown
469 B	1	0	0
469 A, 433	0	1	0
Total	**1**	**2**	**1**

40 CFR 469 A – E&EC Semiconductor Subcategory
40 CFR 469 B – E&EC Electronic Crystals Subcategory
40 CFR 469 D – E&EC Luminescent Materials Subcategory
40 CFR 433 – Metal Finishing Point Source Category
40 CFR 471 – Nonferrous Metals Forming and Metal Powders Point Source Category

For each E&EC permit reviewed, the study database also captured the list of pollutants included in the permit, the limit for each pollutant, and the monitoring frequency for each pollutant. Where either stated in the permit, stated in the fact sheet, or otherwise determined by reviewing the permit documents, the basis of the permit limits (ELG, local limits, or water quality criteria) was also noted in the permit database. A summary of the pollutants listed in E&EC permits is included in Table A-1 through Table A-4 of Attachment A.

2.3.1 Indirect Dischargers

Table A-1 and Table A-2 in Attachment A summarize permit information for E&EC indirect discharge facilities that are permitted either solely under the ELG at 40 CFR part 469 or under both 40 CFR part 469 and 40 CFR part 433, respectively. Some observations on the data are described below.

With respect to inclusion of the E&EC ELGs, all indirect discharge permits included limits for the pollutants regulated at 40 CFR part 469 where applicable (i.e., arsenic for certain 40 CFR Subpart B facilities and additional metals for 40 CFR Subpart C and D facilities) with one exception. All of the indirect discharge permits EPA reviewed, that should contain a limit for TTO (40 CFR 469 Subparts A, B, and C facilities), had a limit except for one. The one permit that did not include a TTO limit was for a facility that submitted a solvent management plan and was submitting certification statements in lieu of monitoring for TTO. Note that the TTO limit should have been included in the permit for this facility because the facility was still subject to the limit in the event a sample was collected by either the facility or the Control Authority.

Most of the permits for indirect discharge facilities contain limits for parameters in addition to those required in 40 CFR Part 469. For those facilities that are subject to multiple ELGs (Table A-2), permit writers included limits for all pollutants in each of the ELGs. In some cases, the permit writer adjusted the limit using the combined wastestream formula to account for the comingling of wastestreams prior to treatment and discharge.

In addition, as discussed in Section 2.1 above, Control Authorities are required to calculate local limits to protect the POTW and collection system. Because the calculations are based on site specific conditions, the pollutants regulated by local limits varies by Control Authority. As a result, permit writers may use local limits to control discharges from indirect dischargers when the ELG(s) does not include a limit for the pollutant.

Several of the indirect discharging facilities have local limits for TTO in their permits, and six of these facilities are subject to a TTO local limit that is more stringent that the TTO limit in 40 CFR Part 469. Using the criteria outlined in Section 2.1 above, Control Authorities may develop TTO local limits as needed to protect their POTWs and collection systems from all industrial discharges.

Of the 112 indirect discharge permits EPA reviewed, 105 included a local limit for pH. The pH limits ranged from a lower limit of 5.0 S.U. to an upper limit of 12.5 S.U. As discussed in Section 2.1, these pH limits are consistent with both Federal pretreatment program requirements and local limits developed by Control Authorities.

Additionally, the permit writer for each Control Authority may use best professional judgement when determining the monitoring frequency for each pollutant. The federal regulations at 40 CFR 403.12(h) require indirect dischargers to monitor for pollutants regulated in the ELG at least once every six months. Permit writers may use best professional judgement to place a more frequent monitoring frequency in the permit. Additionally, permit writers may require "monitoring only" of some parameters. This is usually done when the permit writer wants to gather additional information about the industrial user's discharge, for example to characterize a new or changed operation, gather additional data for calculating limits in the future, or verify that a pollutant is not present in an industrial user's discharge.

2.3.2 Direct Dischargers

Table A-3 and Table A-4 of Attachment A include information about the parameters included in the permits for direct dischargers. As discussed in more detail in Section 4 of this report, the parameters included in these permits are site specific and are often based on water quality criteria.

2.3.3 Solvent Management Plans in Lieu of Monitoring

The E&EC regulations allow a facility to submit a solvent management plan and submit certification statements in lieu of monitoring for TTO. However, this option must be included as a permit condition. Based on the documents reviewed, 77 of the 112 indirect discharging facilitities have submitted a solvent management plan. Additionally, one of the the four direct discharging facilities has submitted a solvent management plan. A summary of the solvent management plans by E&EC subcategory is provided in Table 8. As noted in Table 8, 23 of the solvent managent plans reviewed by EPA covered the disposal of all toxic organics and not just the toxic organics listed in the ELG.

Table 8. Solvent Management Plans E&EC Permitted Facilities in E&EC Study Permit Database

Point Source Category and Subcategory	Number of Facilities Submitting Solvent Management Plans	Number of Solvent Management Plans Covering all Toxic Organics
Indirect Dischargers		
469 A	51	13
469 B	7	3
469 D	1	1
469 A, 469 B	4	0
469 A, 433	10	4
469 B, 433	2	2
469 A, 469 B, 433	0	0
469 B, 433, 471	1	0
Research and Development Facility	1	1
Total	**77**	**23**

Table 8. Solvent Management Plans E&EC Permitted Facilities in E&EC Study Permit Database

Point Source Category and Subcategory	Number of Facilities Submitting Solvent Management Plans	Number of Solvent Management Plans Covering all Toxic Organics
Direct Dischargers		
469 A	1	0
469 B	0	0
469 A, 433	0	0
Total	**1**	**0**

40 CFR 469 A – E&EC Semiconductor Subcategory

40 CFR 469 B – E&EC Electronic Crystals Subcategory

40 CFR 469 D – E&EC Luminescent Materials Subcategory

40 CFR 433 – Metal Finishing Point Source Category

40 CFR 471 – Nonferrous Metals Forming and Metal Powders Point Source Category

2.3.4 Data Quality and Limitations

All data sources used to develop the E&EC permit database were provided by control authorities (states, EPA regions, and pretreatment control authorities), E&EC facilities and EPA websites, which are assumed to be accurate, reliable, and fit for use. After confirming a data source met these data acceptance criteria, EPA imported the permit information directly into the database or did manual data entry depending on the source's formatting. Once a data source was entered into the database, a second person confirmed the data acceptance criteria and checked the entries for accuracy and completeness.

EPA encountered several limitations when assessing permitting information for this study. EPA was not able to identify or review any permitting information from facilities permitted under 40 CFR 469 Subcategory C and only reviewed permitting data from one facility permitted under Subcategory D.

2.4 References

1. U.S. EPA. 2004. Local Limits Development Guidance. (July). EPA-HQ-OW-2021-0547. DCN EEC0600.

3. Wastewater Characterization

EPA collected wastewater discharge characterization data from 98 indirect and four direct discharging facilities permitted under 40 CFR 469, resulting in a dataset of approximately 84,000 records for 291 analytes. EPA obtained discharge data for most of these E&EC facilities by reaching out to their permitting authorities. EPA gathered additional data from state permitting databases, EPA's Enforcement and Compliance History Online (ECHO) website, and by directly contacting E&EC dischargers. EPA requested a minimum of one year's sampling data from permitting authorities and dischargers. While the database is not a census of all indirect discharging E&EC facilities in the U.S., it is a robust representation of the E&EC industry. EPA is not aware of any additional direct discharging E&EC facilities.

EPA stored the wastewater characterization data in an Access database, implementing the quality control procedures described in Section 2.3.4 to ensure data were transcribed accurately and that sources were representative of the E&EC industry. All original sampling documents as well as the final access database are available in the supporting docket.[7]

This section describes EPA's analysis and discussion of the E&EC wastewater discharge characterization data.

3.1 E&EC Wastewater Discharge Characterization and Identification of Parameters of Interest

This section provides summary statistics for EPA's wastewater characterization database and describes the Agency's analysis to identify E&EC industry "parameters of interest" that warrant additional analysis in Section 4 of this report.

3.1.1 E&EC Wastewater Discharge Characterization Data

EPA compiled a series of summary statistics tables (Table 9 through Table 11) to describe the E&EC wastewater discharge characterization database. Table 9 provides the distribution of wastewater characterization data by discharge status and by point source category and subcategory. This distribution is comprised of 102 facilities, predominantly indirect dischargers (96%) and a few direct dischargers (4 percent). Facilities identified by permitting authorities as semiconductor manufacturers comprise the majority of E&EC facilities (67%), followed by electronic crystal manufacturers (9%), and several integrated plants manufacturing both electronic crystals and semiconductors or performing both E&EC and metal finishing operations (22%). EPA did not collect wastewater characterization data from any cathode ray tube manufacturing facilities and collected data from only two luminescent materials manufacturing facilities; this is consistent with the decline in the cathode ray tube and fluorescent lamps industries since the early 1980s when the E&EC regulations were promulgated. Table 9 also shows that most records are non-detected results (approximately 77 percent).

[7] https://www.regulations.gov/docket/EPA-HQ-OW-2021-0547

Table 9. Data Collection by Point Source Category and E&EC Subcategory

Point Source Category and Subcategory	Number of Facilities	Number of Records (Total)	Number of Records (Detected)
Indirect Dischargers			
469 A	67	41,556	11,464
469 A, 433	15	20,380	2,954
469 A, 469 B	3	361	146
469 A, 469 B, 433	1	196	37
469 B	8	1,550	522
469 B, 433	2	14,526	1,173
469 D	2	1,931	825
Total	**98**	**80,500**	**17,121**
Direct Dischargers			
469 A	1	182	182
469 A, 433	2	2,711	1,634
469 B	1	529	523
Total	**4**	**3,422**	**2,339**

40 CFR 469 A – E&EC Semiconductor Subcategory

40 CFR 469 B – E&EC Electronic Crystals Subcategory

40 CFR 469 D – E&EC Luminescent Materials Subcategory

40 CFR 433 – Metal Finishing Point Source Category

EPA focused on identifying and acquiring data from facilities located in regions with high concentrations of E&EC dischargers (e.g., California, Pacific Northwest, Texas) (Table 10). EPA also collected data from other regions of the U.S. and believes the current data set is representative of the national industry. EPA is not aware of any additional 40 CFR 469 direct discharging facilities beyond the four already identified.

Table 10. Data Collection by State

State	Number of Facilities	Number of Records (Total)
Indirect Dischargers		
CA	61	15,835
IL	1	39
MI	1	250
MN	1	275
MO	1	242
NC	4	380
NY	2	1,304
OR	8	2,418
PA	2	47
TX	10	54,488
VA	2	3,575
WA	5	1,647
Total	**98**	**80,500**
Direct Dischargers		
NY	1	1,651

Table 10. Data Collection by State

State	Number of Facilities	Number of Records (Total)
OR	1	529
TX	1	182
VT	1	1,060
Total	**4**	**3,422**

EPA received data for 122 unique analytes detected in E&EC wastewater (Table 11). Approximately 170 additional analytes, consisting of organic compounds and a few metals, were never detected in routine pollutant scans conducted at E&EC facilities.

Table 11. Analytes by Pollutant Category

Pollutant Category	Number of Analytes with at Least One Detected Result	Number of Analytes with no Detected Results
Indirect Dischargers		
Anions	8	0
Classical Wet Chemistry	22	0
Metals	32	5
Organic Compounds	53	163
Direct Dischargers		
Anions	2	0
Classical Wet Chemistry	10	0
Metals	14	8
Organic Compounds	8	8

3.1.2 Parameters of Interest

This section describes the approach EPA used to identify parameters of interest for the E&EC Study. In this analysis, "parameters of interest" refer to analytes that warrant additional analysis in Section 4 of this report. In the first step of this analysis, EPA identified pollutants detected in E&EC wastewater discharges. Table B-1 and Table B-2 of Attachment B present summary statistics for analytes detected at least once in wastewater discharges from indirect and direct discharging E&EC facilities, respectively. In the second step, EPA applied the following criteria to identify the subset of parameters of interest:

1. Pollutants currently regulated under 40 CFR 469.
   - Indirect dischargers: total toxic organics, arsenic, cadmium, antimony, zinc, fluoride, chromium, lead (40 CFR 469 A, B, C, and D).
   - Direct dischargers: total toxic organics, arsenic, pH, fluoride, total suspended solids (40 CFR 469 A and B).

2. Parameters that are frequently detected and that are either (1) nutrients or (2) have a relatively high toxic weighting factor[8].
   - Frequency of detection:
     - Parameters detected in at least 25 percent of facilities measuring for the pollutant, AND
     - Parameters detected in at least 25 percent of results.
   - Potential environmental concern:
     - Parameters with a toxic weighting factor of at least 0.001, OR
     - Parameters that are nutrients (phosphates, ammonia, phosphorus, nitrates, nitrites, nitrogen, total Kjeldahl nitrogen).

Table B-3 and Table B-4 in Attachment B list the detected parameters and the results of the selection criteria for indirect and direct dischargers, respectively. Table 12 and Table 13 lists the parameters of interest for indirect and direct dischargers.

In addition to the parameters of interest listed in Table 12 and Table 13, EPA identified per- and polyfluoroalkyl substances (PFAS) for review. PFAS in E&EC discharges were identified in EPA's PFAS Strategic Roadmap, which summarizes its review of and plan to address potential industrial sources. See Section 4.2.1 for more information.

[8] Toxic weighting factors are derived from chronic aquatic life criteria and human health criteria established for the consumption of fish; they are used to compare the toxicity of one pollutant relative to another and are normalized based on the toxicity of copper (ERG, 2007).

Table 12. E&EC Industry Parameters of Interest – Indirect Dischargers

Pollutant	Units	Number of Facilities Measuring	Number of Facilities with Detects	Number of Results	Number of Detects	Toxic Weighting Factor [a]	Minimum Detected Concentration	Maximum Detected Concentration	Mean Detected Concentration	Median Detected Concentration
Total Toxic Organics										
Total Toxic Organics	mg/L	57	27	836	182	N/A	0.00092	0.957	0.0752	0.01675
Classical Wet Chemistry										
Ammonia	mg/L	30	30	618	607	0.00111	0.05	1,300	87.9	36.1
Nitrogen, Total	mg/L	3	3	12	12	N/A	9.14	25.3	16.6	17.4
Phosphorus, Total	mg/L	18	17	142	139	N/A	0.102	202	6.35	1.72
Total Kjeldahl Nitrogen	mg/L	8	8	133	131	N/A	0.28	274	76.8	58.5
Anions										
Fluoride, Total	mg/L	36	27	907	783	0.03	0.00054	114	9.02	6.8
Nitrates	mg/L	6	6	40	40	0.000747	0.16	12.3	4.56	4.28
Nitrates/Nitrites	mg/L	9	9	52	51	N/A	0.5	12.44	4.38	4.37
Nitrites	mg/L	6	6	40	38	0.0032	0.026	4.19	0.455	0.265
Metals										
Aluminum, Total	mg/L	10	9	26	20	0.06	0.0215	0.434	0.119	0.0755
Antimony, Total	mg/L	18	7	161	17	0.01	0.0000951	0.129	0.0186	0.009
Arsenic, Total	mg/L	53	35	1,159	482	3.47	0.000063	6.16	0.192	0.062
Barium, Total	mg/L	11	10	26	25	0.00199	0.000723	0.039	0.0131	0.0127
Boron, Total	mg/L	8	7	228	218	0.00834	0.047	5	0.311	0.27
Cadmium, Total	mg/L	64	17	1,072	157	22.8	0.0000116	0.1928	0.00522	0.002
Chromium, Total	mg/L	68	42	1,211	280	0.07	0.0000133	0.82	0.0192	0.005

Table 12. E&EC Industry Parameters of Interest – Indirect Dischargers

Pollutant	Units	Number of Facilities Measuring	Number of Facilities with Detects	Number of Results	Number of Detects	Toxic Weighting Factor [a]	Minimum Detected Concentration	Maximum Detected Concentration	Mean Detected Concentration	Median Detected Concentration
Copper, Total	mg/L	67	57	1,309	996	0.623	0.00015	5.64	0.213	0.05
Gallium, Total	mg/L	1	1	3	2	0.13	0.025	0.269	0.147	0.147
Iron, Total	mg/L	7	7	33	16	0.0056	0.00684	1.91	0.208	0.0671
Lead, Total	mg/L	66	33	1,062	199	2.24	0.00002	0.44	0.0200	0.005
Manganese, Total	mg/L	9	8	22	21	0.103	0.000599	0.0337	0.0103	0.00431
Molybdenum, Total	mg/L	36	25	169	76	0.2	0.00014	3.74	0.0921	0.00793
Nickel, Total	mg/L	69	48	1,170	753	0.1	0.000154	2.99	0.118	0.01
Potassium, Total	mg/L	4	4	401	401	0.00105	0.754	181	36.7	35.6
Selenium, Total	mg/L	42	19	441	116	1.12	0.00008	0.6	0.0181	0.006
Tellurium, Total	mg/L	1	1	14	14	0.04	0.053	0.624	0.234	0.157
Titanium, Total	mg/L	3	3	3	3	0.02	0.001	0.00504	0.0025	0.00146
Zinc, Total	mg/L	67	60	1,284	1,009	0.04	0.000751	22	0.112	0.03

[a] Toxic weighting factors are derived from chronic aquatic life criteria and human health criteria established for the consumption of fish; they are used to compare the toxicity of one pollutant relative to another and are normalized based on the toxicity of copper (ERG, 2007).

N/A – Not Available

Table 13. E&EC Industry Parameters of Interest – Direct Discharges

Pollutant	Units	Number of Facilities Measuring	Number of Facilities with Detects	Number Results	Number Detects	Toxic Weighting Factor [a]	Minimum Detected Concentration	Maximum Detected Concentration	Mean Detected Concentration	Median Detected Concentration
Total Toxic Organics										
Total Toxic Organics	mg/L	2	2	60	54	N/A	0.00013	0.02	0.00657	0.00378
Classical Wet Chemistry										
Ammonia	mg/L	2	2	180	105	0.00111	0.01	13	4.784	5.3
Cyanide, Total	mg/L	2	2	73	29	1.11	0.004	0.16	0.0190	0.01
Phosphorus, Total	mg/L	1	1	45	45	N/A	0.077	0.248	0.148	0.141
Total suspended solids	mg/L	3	3	224	224	N/A	1.08	61	7.29	5.15
Anions										
Fluoride, Total	mg/L	4	4	227	227	0.03	0.17	19	9.74	10
Phosphates	mg/L	1	1	30	30	N/A	0.01	0.12	0.0488	0.04
Metals										
Aluminum, Total	mg/L	1	1	45	39	0.06	0.1	0.9	0.179	0.1
Cadmium, Total	mg/L	1	1	28	28	22.8	0.0002	0.056	0.00521	0.002
Chromium, Total	mg/L	3	2	165	120	0.07	0.00011	0.56	0.0126	0.00107
Copper, Total	mg/L	2	2	105	102	0.623	0.013	0.092	0.0284	0.0255
Iron, Total	mg/L	2	2	105	94	0.0056	0.044	0.345	0.114	0.104
Lead, Total	mg/L	2	2	135	91	2.24	0.001	0.05	0.00155	0.001
Nickel, Total	mg/L	2	1	105	90	0.1	0.008	0.186	0.0274	0.0215
Silver, Total	mg/L	2	1	45	30	16.5	0.01	0.02	0.0147	0.01
Tungsten, Total	mg/L	1	1	45	26	0.00525	0.11	0.21	0.145	0.135
Zinc, Total	mg/L	2	2	150	106	0.04	0.008	0.05	0.0181	0.02

Table 13. E&EC Industry Parameters of Interest – Direct Discharges

Pollutant	Units	Number of Facilities Measuring	Number of Facilities with Detects	Number Results	Number Detects	Toxic Weighting Factor [a]	Minimum Detected Concentration	Maximum Detected Concentration	Mean Detected Concentration	Median Detected Concentration
Organic Compounds										
Bromodichloromethane	mg/L	1	1	15	10	0.03	0.001	0.003	0.00163	0.00165
Bromoform	mg/L	1	1	15	15	0.00457	0.005	0.022	0.0119	0.01
Chloroform	mg/L	1	1	15	10	0.00208	0.001	0.002	0.00141	0.00105
pH										
pH	SU	4	4	364	364	N/A	3.37	10.91	7.22	7.2

[a] Toxic weighting factors are derived from chronic aquatic life criteria and human health criteria established for the consumption of fish; they are used to compare the toxicity of one pollutant relative to another and are normalized based on the toxicity of copper (ERG, 2007).

N/A – Not Available

3.2 Wastewater Characterization Data Discussion

Section 3.2 discusses E&EC industry wastewaters (wastestream generation, composition, exceedances) and the data quality and limitations of the E&EC wastewater characterization database.

3.2.1 E&EC Wastestreams

EPA compared wastewater discharge characteristics from indirect and direct dischargers and found that direct dischargers generally had lower effluent concentrations of pollutants than indirect dischargers (e.g., total toxic organics, fluoride, cadmium, zinc; see Table 13 and Table 14). Direct dischargers have additional wastewater treatments in place which would result in lower discharge concentrations (SIA, 2016).

EPA collected wastewater discharge characterization data from 40 CFR 469 B (electronic crystals) and 469 D (luminescent materials) facilities but was unable to contact manufacturers or industry trade associations to discuss modern wastestreams generated by these facilities. According to EPA's 1983 Development Document for Effluent Limitations Guidelines and Standards for the E&EC Point Source Category (Phase One) the major source of wastewater from electronic crystal manufacturing is from rinses associated with crystal fabrication. Fabrication steps generating wastewater include slicing, lapping, grinding, polishing, etching, and cleaning. Wastewater may also be generated from crystal growth operations. The major pollutants of concern in the 1983 development document were total toxic organics, fluoride, arsenic, total suspended solids, and pH (U.S. EPA, 1983).

EPA's 1984 Development Document for the E&EC Point Source Category (Phase Two) states that most luminescent material wastewater is from various crystallization, washing, and filtration steps associated with production of intermediate and final product powders. The major pollutants of concern for luminescent materials manufacturers were pH, total suspended solids, antimony, cadmium, and zinc. EPA did not obtain wastewater discharge characterization data for cathode ray tube manufacturers; the 1984 development document discusses that most cathode ray tube manufacturing wastewater is from wash and rinse operations. Hydrofluoric acid was commonly cited in both the 1983 and 1984 development documents as a fluoride source for cathode ray tube and luminescent materials subcategories (U.S. EPA, 1984).

Figure B-1 and Figure B-2 in Attachment B provide box and whisker plots for indirect and direct discharge parameters of interest, respectively, to better visualize the distribution of detected concentrations. For pollutants regulated under 40 CFR 469, EPA found that the upper quartile values for detected concentrations were consistently below the most stringent daily maximum effluent limitations for both indirect and direct dischargers. While there are a few instances of detected concentrations that exceed the daily maximum effluent limitations (arsenic, antimony, chromium, fluoride, and zinc for indirect dischargers, and pH for direct dischargers), these are infrequent, site-specific instances of treated effluent excursions and exceedances.

3.2.2 Data Quality and Limitations

EPA required wastewater characterization presented in Section 3 to meet three criteria for inclusion in the database:

1. Wastewater (outfall) represents E&EC process wastewater discharge
2. Analytes identified and units included in the data source
3. Wastewater characterization data provided by control authorities, E&EC facilities, and EPA websites are assumed to be accurate and reliable, all other sources should be investigated

After confirming a data source met these data acceptance criteria, EPA imported the wastewater discharge results directly into the database or did manual data entry depending on the source's formatting. Once a data source was entered into the database, a second person confirmed the data acceptance criteria and checked the entries for accuracy and completeness. After quality control, EPA moved mass-based sampling data along with temperature and flow data into an “excluded from analysis” table as such results, while acceptable, were not used for analysis. EPA consolidated similar pollutant names (e.g., nickel vs. nickel, total), units (e.g., ng/l to mg/l), and populated supplemental fields (used for analysis queries) such as “pollutant category” and “toxic weighting factor” before finalizing the database.

EPA encountered several limitations when assessing wastewater characterization data for this study. EPA was not able to collect any wastewater characterization data from facilities permitted under 40 CFR 469 Subcategory C and collected data from only two facilities permitted under Subcategory D. EPA is also interested in PFAS wastewater characteristics for the E&EC industry but was able to collect data from only one facility (see Table B-1). EPA inquired on PFAS discharges when possible but was unable to secure a larger PFAS monitoring data set.

3.3 Additional E&EC Wastewater Characterization Review

To further understand current E&EC wastewater characteristics, EPA conducted a literature review, attended industry conferences, and contacted several facilities, trade associations, and NACWA members.

SIA has indicated that as the industry has evolved it has adapted new tools, chemicals, materials, and operations. Since the 1980s, the semiconductor industry has incorporated up to 49 additional chemical elements into semiconductor manufacturing operations (ERG, 2016). EPA’s research confirmed that new manufacturing processes, operation practices, and chemicals adopted by the E&EC industry that may result in discharges of some of the pollutants listed in Table 7 For instance, some semiconductor manufacturing facilities use copper metallization, which was introduced in the 1990s and is an alternative to aluminum interconnects (ERG, 2016). Similarly, a presentation at the ASMC SEMI Conference discussed a semiconductor manufacturing facility, which uses copper metallization for their Through-Silicon Via (TSV) process (Gopalakrishnan, 2016). Therefore, semiconductor facilities, which have incorporated copper metallization into manufacturing processes since the 1983 E&EC ELGs, may discharge copper in their wastewater because of this operational change (see Table 7). In addition, SIA provided information on the abatement of fluorinated greenhouse gases (used in chamber cleaning) resulting in fluoride in semiconductor wastewaters via wet scrubbers (ERG, 2016).

EPA’s research also identified that the semiconductor industry has developed several new process chemistries for photolithography over the past 30 years. Photolithography patterns a wafer using the steps illustrated in Figure 3. For example, industry uses new solvent systems, such as ethyl lactate and propylene glycol monomethyl ether acetate (PGMEA). Also, semiconductor manufacturing facilities commonly use aqueous developers for photoresists, which contain tetramethyl ammonium hydroxide (TMAH). CMP slurries, used to chemically and physically polish the wafer surface, typically contain low concentrations of engineered nanomaterials.

In addition, some chemically amplified photoresists and antireflective coatings can contain perfluoroalkyl substances (e.g., PFAS). A study on treatment of PFAS in semiconductor wastewater points out that PFAS is primarily used in photolithography because of its unique properties, including optical characteristics and acid-generating efficiency (Tang, 2006). A study in the European Union indicated that for photolithography the semiconductor industry uses PFAS in photoresist (0.02 percent to 0.1 percent PFAS concentration), antireflective coating (0.1 percent PFAS concentration), and developer solutions (0.01 percent to 1.0 percent PFAS concentration) (Brooke, 2004). While most photolithography waste is handled as solvent and incinerated, Brooke indicates that some facilities send approximately 40 percent of waste antireflective coating (containing PFAS) to wastewater treatment.

Despite rapid advances within the industry and changing operations and process chemistries, SIA indicated that semiconductor manufacturing requires specialized chemicals that operate precisely with advanced equipment and materials, and that offer distinctive functionality to accomplish high yield, high volume manufacturing. SIA asserted that chemical alternatives may not be available (or known) for use within the industry for certain operations. SIA indicated that researching chemical alternatives and incorporating them into a semiconductor manufacturing process might take 10 to 15 years.

Through facilities contacted as part of the 2016 Annual Review EPA learned that some of the chemicals previously used in semiconductor manufacturing operations have been replaced. For instance, one facility noted that trichloroethylene had been phased out of operations 20 years ago (Wasielewski, 2016). Although some hazardous chemicals, PFAS for example, are difficult to replace in certain semiconductor manufacturing process steps. SIA stated that organic chemicals currently identified as TTO have been eliminated from lithography and the industry has tried to eliminate or minimize other constituents of concern in specific process steps (e.g., organic solvents, ozone depleting substances, lead from assembly or packaging) (ERG, 2016).

NACWA members stated that pollutants such as ammonia, nitrogen, sulfate, fluoride, and copper are becoming more prevalent in discharges from E&EC facilities. Additionally, due to water conservation programs, E&EC facilities are using less water; therefore, increasing the relative concentration of pollutants in the water discharged to POTWs (U.S. EPA, 2016).

In summary, through various data sources described previously, EPA determined that E&EC wastewater characteristics have changed since 1983. Research indicates that the industry may be discharging several new pollutants not considered at the time of the 1983 rulemaking, and that are not reported to DMR or TRI, including some toxic pollutants (e.g., TMAH, PFAS) that are used in various semiconductor manufacturing processes. In addition, industry may be discharging more substantial quantities of certain previously considered and/or regulated pollutants including copper and fluoride due to manufacturing process changes. Additionally, as indicated by SIA, some facilities may have phased out the use of other pollutants regulated as part of the 1983 ELGs, such as organic chemicals currently identified as TTO.

3.4 E&EC Wastewater Treatment Technologies

The E&EC ELGs established limitations for the E&EC Category generally based on solvent management to control TTO, neutralization, chemical precipitation (hydroxide) with clarification, in-process control for specific pollutants, and filtration. See Section 1.1.3 for further details on the wastewater treatment technologies used to establish the E&EC ELGs.

To understand current wastewater treatment technologies and practices, EPA contacted several facilities and trade associations, conducted a literature review, and reviewed information available in EPA's Industrial Wastewater Treatment Technologies (IWTT) database. For the facility contacts, EPA compiled a summary of the facility type, wastewater generation processes, and wastewater treatment technologies employed. Most of the facilities contacted use the wastewater treatment technologies established in the E&EC ELGs; however, some facilities employ, or plan to employ, more advanced wastewater treatment. Biological treatment, ion exchange, electrowinning, and zeolite resin systems are examples of such advanced wastewater treatments. Table 6 provides a summary of the wastewater treatment information obtained from the facility contacts. While some of the facilities contacted are direct dischargers, SIA indicated that the vast majority of semiconductor manufacturing facilities pretreat semiconductor wastewater, through processes such as pH adjustment or neutralization, prior to discharging to a POTW, and use dedicated solvent waste drains and collection systems (ERG, 2016). Most E&EC facilities also implement a solvent management plan which is designed to prevent most organic contaminants from entering the wastewater prior to discharge to the POTW. Some facilities will recover organic solvents for reuse or resale (e.g., isopropyl alcohol, n-methyl pyrrolidone) (ERG, 2016). SIA explained that some semiconductor manufacturing plants have implemented water reuse practices, such as using RO reject water in other process operations (e.g., scrubbers, cooling towers); however, no zero discharge semiconductor facilities exist in the U.S. to their knowledge (ERG, 2016). Similarly, NACWA stated that they were not aware of any E&EC zero discharge facilities (U.S. EPA, 2016).

EPA also performed a targeted literature search and identified several wastewater treatment studies specific to the E&EC industry.

One semiconductor manufacturing facility, the East Fishkill Facility in Hopewell Junction, New York, provided specific details on a heavy metal wastewater treatment plant it employs on site (Marone, 2016). The heavy metal wastewater treatment plant consists of calcium hydroxide precipitation (to remove fluoride and other metals), microfiltration, polymer flocculation, an acid/base slurry treatment step, and clarification. In addition, the facility operates an ammonia treatment plant for segregated industrial wastewater streams, where ammonia is removed, distilled, and marketed to another party (Marone, 2016).

To identify additional emerging technologies that are being evaluated and/or implemented by the E&EC industry, EPA reviewed recent literature compiled in the IWTT database.[9] EPA queried the IWTT database for treatment of E&EC wastewater, which produced five articles with pollutant removal data (Mehta, 2014; Kim, 2012; Kim, 2011; Huang, 2011; Ryu, 2008). Table 14 presents the parameter effluent concentration and percent removal data for all five articles. All but one of the studies were pilot scale (Ryu, 2008). However, EPA identified two studies that evaluated the performance of traditional chemical precipitation systems used by the industry, and three studies focused on more advanced technologies for the industry, including biological treatment or filtration technologies. In addition, most of the studies evaluated removal efficiency of pollutants that do not currently have E&EC ELGs, including ammonium-nitrogen, TOC, COD, and TMAH (Mehta, 2014; Kim, 2012; Kim, 2011; Huang, 2011; Ryu, 2008).

[9] For more information on the IWTT database, go to https://www.epa.gov/eg/industrial-wastewater-treatment-technology-database-iwtt.

Table 14. Summary of Wastewater Treatment Technologies for Electrical and Electronic Components Wastewater

Wastewater Treatment Technology (Order of Unit Processes)	Treatment Scale	Parameter	Effluent Concentration	Percent Removal	Reference
Anaerobic Suspended Growth, Aerobic Suspended Growth, Clarification, Advanced Oxidation Processes (NEC), Anaerobic Suspended Growth, and Clarification	Pilot	Ammonium-nitrogen (NH_4-N)	3	78.57%	Mehta, 2014
		Chemical oxygen demand	NR	98.00%	
		Nitrogen, Kjeldahl total (TKN)	27	83.64%	
		Tetramethyl ammonium hydroxide (TMAH)	NR	80.00%	
		Total organic carbon (TOC)	NR	98.00%	
Aerobic Suspended Growth, Clarification, Advanced Oxidation Processes (NEC), Anaerobic Suspended Growth, and Clarification	Pilot	Ammonium-nitrogen (NH_4-N)	6.4	8.57%	
		Nitrogen, Kjeldahl total (TKN)	26	96.53%	
		Tetramethyl ammonium hydroxide (TMAH)	NR	99.00%	
		Total organic carbon (TOC)	NR	98.00%	
Electrocoagulation	Pilot	Copper	NR	95.00%	Kim, 2012
Chemical Precipitation, Controlled Hydrodynamic Cavitation, and Clarification	Pilot	Calcium	23.4	90.71%	Kim, 2011
Granular-Media Filtration, Membrane Filtration, and Reverse Osmosis	Pilot	Alkalinity (as $CaCO_3$)	< 1.5	> 97.69%	Huang, 2011
		Ammonium-nitrogen (NH_4-N)	1.62	84.57%	
		Chemical oxygen demand	4.9	93.57%	
		Chloride	21.1	92.19%	
		Conductivity	69.2	97.35%	
		Hardness (as $CaCO_3$)	< 1.5	> 99.12%	
		Nitrate (as N)	0.73	51.33%	
			0.06	71.43%	
		Silicate (SiO_4-2 as SiO_2)	0.98	88.28%	
		Sulfate (as SO_4)	0.34	99.87%	
		Suspended solids	1	97.50%	
		Total dissolved solids (TDS)	53.5	95.18%	
		Total organic carbon (TOC)	1.3	76.79%	
		Turbidity	0.06	99.80%	
Chemical Precipitation and Clarification	Full	Ammonium-nitrogen (NH_4-N)	17	88.96%	Ryu, 2008

NR – Not Reported

3.5 References

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4. Potential Impacts from E&EC Wastewater Discharges

As discussed in Section 3, E&EC process wastewater contains a variety of pollutants including nutrients, fluorine, and metals. E&EC manufacturing processes continue to evolve, impacting their waste management practices and discharge concerns. Permit writers monitoring changes within the industry have identified a few industry-wide potential emerging parameters of interest, but largely have determined that the environmental impacts are limited to site-specific concerns with a particular publicly owned treatment works (POTWs) or receiving water. The following sections present a summary of the wastewater management practices used at E&EC facilities prior to discharge, an overview of potential emerging pollutants within the industry, and a discussion of the potential concerns associated with E&EC indirect discharges to POTWs and direct discharges to receiving waters.

4.1 Waste Management and Wastewater Treatment Prior to Discharge

E&EC facilities use a number of management practices to control their toxic wastes. These management practices include solvent management plans, segregation of wastes, and waste disposal alternatives.

E&EC facilities may choose to develop a solvent management plan in lieu of monitoring for TTO if allowed by the permitting or control authority. These plans must meet the requirements in 40 CFR 469.13. The plan must specify "the toxic organic compounds used; the method of disposal used instead of dumping, such as reclamation, contract hauling, or incineration; and procedures for assuring that toxic organics do not routinely spill or leak into the wastewater." [40 CFR 469.13(b and d)]. Based on conversations with permitting agencies, EPA noted that E&EC facilities may no longer use the listed toxic organic compounds in their production process. For example, representatives from the City of Dallas noted that E&EC facilities that discharge to the City of Dallas do not use organics included on the list of TTOs in 40 CFR 469. Therefore, the city allows these facilities to develop solvent management plans and submit certification statements in lieu of monitoring for TTO. (ERG, 2020b).

E&EC facilities may also choose to segregate their wastes. Segregation of waste allows facilities to treat, dispose, or reclaim wastes in more cost-effective manners. Examples of waste segregation commonly seen at E&EC facilities include keeping wastewaters with different wastes separate prior to treatment (e.g., segregated treatment of acid and fluoride-containing wastes) and segregating solvents-containing wastes for disposal.

E&EC facilities typically manage their wastewater by either discharging to a POTW or direct discharging to a receiving stream. However, E&EC facilities may choose alternative disposal methods for some wastestreams. Materials that are classified as a hazardous waste may be hauled off-site for disposal in a hazardous waste landfill or treated by incineration. Solvents and acids may be segregated for reclamation as an alternative to discharge.

EPA found that many E&EC facilities have worked to reduce, remove, or replace chemicals in their process. This has resulted in fewer toxic organic compounds in their wastewater. The replacement of chemicals at these facilities may be due to either production requirements or to comply with discharge permit requirements. One example of the facility changing chemicals used in their processes is Micron Technology, Inc. (Micron) in Manassas, VA. According to Virginia Department of Environmental Quality representatives, Micron was issued a sodium effluent discharge limit based on water quality limits needed to protect the drinking water use of the receiving stream. Micron switched from using sodium hydroxide to potassium hydroxide to meet a sodium discharge limit (ERG, 2020d).

4.2 Potential Emerging Parameters of Interest

As the semiconductor industry continues to rapidly change, permitting and control authorities express concern that they are often reacting to control new pollutant discharges rather than proactively regulating new pollutants (ERG, 2020a). A few emerging pollutants, however, are beginning to gain the attention of permitting and control authorities as potential parameters of interest across the industry. Per- and polyfluoroalkyl substances (PFAS) and elements, such as germanium and gallium, with emerging increased usage within the industry represent examples of parameters that may merit further investigation in the future.

4.2.1 PFAS

Interest in PFAS, driven largely by EPA's review of potential industrial sources for PFAS, is one example of an emerging pollutant within the semiconductor industry. PFAS are a family of thousands of synthetic organic chemicals that contain a chain of carbon-fluorine bonds, one of the strongest chemical bonds. Many PFAS are highly stable, water- and oil-resistant, and exhibit other properties that make them useful in a variety of consumer products and industrial processes. Due to these properties, PFAS do not easily degrade by natural processes and thus accumulate over time. According to the U.S. Department of Health and Human Services, Agency for Toxic Substances and Disease Registry (ATSDR), the environmental persistence and mobility of some PFAS, combined with decades of widespread use, have resulted in their global presence in surface water, groundwater, drinking water, rainwater, soil, sediment, ice caps, outdoor and indoor air, plants, animal tissue, and human blood serum (ATSDR, 2021). Certain PFAS can accumulate in the environment and human body over time and can lead to adverse human health impacts.

The regulatory community has historically been interested in two groups of PFAS: (1) long-chain perfluoroalkane sulfonic acids (PFSAs), including perfluorooctane sulfonic acid (PFOS); and (2) long-chain perfluoroalkyl carboxylic acids (PFCAs), including perfluorooctanoic acid (PFOA). Long-chain PFAS, including PFOA and PFOS, were manufactured and used in the U.S. for many decades. Due to evidence of long-term persistence and adverse health outcomes with long-chain PFAS, EPA implemented restrictions on the manufacture, use, and import of certain long-chain PFAS in the U.S. and some manufacturers have voluntarily phased out these chemicals.[10] More recently, manufacturers have developed, and industries have adopted alternative short-chain PFAS chemistries to replace long-chain PFAS. Many short-chain PFAS are structurally similar to their long-chain predecessors and manufactured by the same companies. Publicly available health, toxicity, and hazard assessments are limited to only a small fraction of alternate short-chain PFAS chemistries.

Historically, photolithography processes in semiconductor manufacturing generated wastewater that could potentially contain elevated levels of PFOS (Tang, 2006). Due to its stability, integration with manufacturing tools, and unique functionality, PFOS was considered a critical ingredient in leading edge photoresists and antireflective coatings used in the photolithographic process for imprinting circuitry on silicon wafers (ERG, 2019). In May of 2017, the World Semiconductor Council (WSC) provided a joint statement detailing the elimination of the remaining uses of PFOS in the semiconductor manufacturing processes by its member companies. The WSC acknowledged that non-member companies may still be using PFOS (World Semiconductor Council Joint Statement, 2017). Then in February 2018 WSC released a statement to the United Nations Stockholm Convention on Persistent Organic Pollutants Review Committee, announcing that the phase-out of the use of PFOS had been completed and the industry no longer required the exemptions that had been granted for their use (World Semiconductor Council, 2018). Although the industry has largely, if not completely, eliminated the use of PFOS, it continues to use long chain fluorinated carbon (FC) compounds, including PFOA, while some member companies within the WSC and Semiconductor Industry Association (SIA) are transitioning to short chain FC compounds. The member companies that comprise the WSC have committed to phasing out the use of PFOA by 2025 (World Semiconductor Council and Semiconductor Industry Associations, 2019). The toxicity of these

[10] See: https://www.epa.gov/assessing-and-managing-chemicals-under-tsca/fact-sheet-20102015-pfoa-stewardship-program for more information.

short chain replacement PFAS compounds are not well understood, and ongoing studies continue to investigate the potential environmental and health effects they may pose.

Data on specific PFAS chemicals used, concentrations in discharges, and if PFAS discharges are controlled by solvent management plans is limited. Some permitting and control authorities are beginning to include PFAS monitoring requirements in permits; however, monitoring efforts have been limited by the lack of analytical methods for monitoring PFAS in wastewater discharges (ERG, 2020e). North Carolina is one region were PFAS monitoring requirements are beginning to become more prevalent. POTWs in North Carolina are required to monitor their influent for PFAS. To further understand the potential sources for PFAS in their influent, Durham County, NC surveyed their industrial dischargers on PFAS use and disposal practices. Survey results among E&EC dischargers in Durham County determined that two out of the three E&EC facilities had PFAS chemicals onsite and chose to manage their PFAS waste by hauling it offsite for disposal (ERG, 2020c and Cree, 2019). Another control authority, Clean Water Services in Hillsboro, OR, established quarterly sampling for PFAS by their industrial dischargers. Initial sampling results demonstrated a correlation between the PFAS in the influent at the POTW and the PFAS being discharged by one of their E&EC facilities. Subsequent sampling at the E&EC facility confirmed that that the PFAS source was process wastewater and not source water contamination (ERG, 2020a). EPA identified one direct discharge E&EC permit with PFAS monitoring requirements. GLOBALFOUNDRIES Essex Junction NPDES permit, issued on July 1, 2021, includes quarterly monitoring requirements for PFAS for the first year of the permit and annual monitoring beginning in 2022 (Vermont Department of Environmental Conservation, 2021a). Currently, EPA has not established ELG requirements on PFAS discharges and there are multiple ongoing studies regarding PFAS wastewater discharges from specific industrial categories. EPA is working across the Agency to better understand the potential impacts of these compounds.

4.2.2 Gallium and Germanium

The use of new elements in the semiconductor manufacturing process continues to expand as the industry develops new technologies. Over the years, the semiconductor industry has grown from using approximately 11 elements in the 1980s, when the ELG was first developed, to currently using over 60 different elements during the semiconductor production process across the industry (Semiconductor Industry Association, 2016). No single facility uses anywhere near this many elements within a given process. Permitting and control authorities have expressed concern that as the industry continues to add novel constituents to production processes, they are required to make permitting decisions with limited guidance and information on how to determine appropriate levels of control prior to discharge (ERG, 2020a and Rydberg, 2021). As an example, gallium and germanium were mentioned as potential emerging elements of interest during EPA discussions with the state of New York. Gallium is used in photovoltaic applications, as integrated circuits, and in newer (3G, 4G, and 5G) cell phone technologies in greater quantities than previous generations (Foley et. al, 2017). Gallium is set to surpass the use of silicon as the primary element used in power switching technologies as greater demands are placed on the need for higher power density and efficiency requirements (Rydberg, 2021). Germanium was used in some of the first transistors within the semiconductor industry. Today, germanium is primarily used during production of semiconductors for power transfer and power systems. Both gallium and germanium are considered technology critical elements which are defined as elements critical to emerging technologies (e.g., information and telecommunications technology, semiconductors, electronic displays, optic/photonic or energy-related technologies) whose use is rapidly increasing (Cobelo-García, 2015).

Minimal guidance is readily available to permitting and control authorities trying to evaluate the potential impacts these increased discharges of gallium and germanium may cause to POTWs or surfaces waters. There are no federal pretreatment standards, national recommended water quality criteria, or state water quality standards to follow for establishing gallium and germanium limits.

Gallium ecological effects studies are limited; however, one acute toxicity study determined a mean LC_{50} value (the concentration value when 50 percent of specimens die) of 95.6 ± 14.3 mg/L after 96 hours of exposure for carp (*Cyprinus Carpio Linnaeus*) (Betoulle et al., 2002). Chronic mean LC_{50} values for developing rainbow trout (*Oncorhynchus mykiss*) were 3.5 mg/L after 28 days of exposure (Birge et al., 1980). Human health studies on gallium exposure have largely focused on inhalation of synthetic gallium arsenide (GaAs) by workers in the semiconductor industry. Human health concerns from long-term gallium exposure in drinking water or soils are largely unknown; however, gallium health effects and ecological effects are likely similar to those observed from aluminum given their similar chemical characteristics (Foley et al., 2017).

There are limited ecological and human health effects studies on germanium. Mean LC_{50} values for chronic toxicity from germanium on developing rainbow trout (*Oncorhynchus mykiss*) are reported at 0.05 mg/L after 28 days of exposure (Birge et al., 1980). Germanium is considered nonessential as it has no known physiological role in human biochemical functions. Germanium does not appear to be carcinogenic and presents a low toxicity risk (Shanks et al., 2017).

Although the increased use of gallium and germanium within the industry is known, there is minimal data available on process wastewater effluent concentrations. In wastewater characterization data compiled in support of this study, EPA identified only two facilities that were monitoring their discharges for gallium or germanium. GLOBALFOUNDRIES in Malta, NY detected gallium in two out of three indirect discharge samples and reported gallium concentrations ranging from 0.025 to 0.269 mg/L. GLOBALFOUNDRIES Hopewell Junction monitoring data did not detect germanium in any of the 15 samples reported between 2016 and 2019. Although monitoring data is limited, the use of gallium and germanium is likely to continue to increase and may merit further assessment in the future as potential emerging parameters of interest within the E&EC industry.

4.3 Potential Impacts from Indirect Discharges of E&EC Wastewater

As discussed in Section 2, a limited number of pollutants are regulated under 40 CFR 469 for indirect dischargers. Regulated pollutants differ among the different subparts and include TTO, total fluoride, total antimony, total arsenic, total cadmium, total chromium, total lead, and total zinc. TTO, the only pollutant regulated in three out of four subparts within the E&EC ELG, is largely no longer a concern within the industry as the use and management of these chemicals and solvents have changed over time (ERG, 2020a). Across the industry, E&EC facilities have either phased out the use of TTO chemicals or manage TTO concerns through the use of solvent management plans which typically involve the transport of toxic organic wastes offsite for disposal (ERG, 2020b and ERG, 2020d). TTO concentrations reported in indirect discharges are well below ELG limits with 100 percent of detected concentrations below the 1.37 mg/L daily maximum ELG limit and 78 percent (142 out of 182) of detected concentrations at least two orders of magnitude lower.

In addition to ELG limits, E&EC indirect permits also include local limits based on site-specific restrictions for the POTW or its receiving water (see Section 2). Common local limits in E&EC indirect permits include pH, oil and grease, total arsenic, total cadmium, total chromium, total copper, total cyanide, total lead, total mercury, total nickel, total silver, and total zinc. As part of this study, EPA reviewed 13 annual pretreatment reports from 2018 and 2019 and contacted multiple control authorities, E&EC facilities, and local and state regulatory entities to identify potential industry-wide concerns. During this review, EPA did not find any evidence that E&EC facilities have caused or contributed to consistent performance issues at POTWs that received E&EC wastewater. Pollutants highlighted by control authorities as potential parameters of interest included: ammonia, total copper, chloride, and sulfate. Pollutant-specific concerns were site-specific in nature and addressed by more restrictive local limits or site-specific treatment options.

Table C-1 presents the potential parameters of interest identified in indirect E&EC discharges and summarizes the concerns associated with their discharge to POTWs. Table C-1 also highlights the range of local limits values included in the indirect discharge permits and summarizes the permit violations documented in EPA's review of the 2018 and 2019 pretreatment annual reports. EPA focused their review on local limits to highlight where control authorities felt additional or more stringent limits than those at 40 CFR 469 were needed to address site-specific concerns at the POTW. The range of local limits reported in indirect discharge permits provides an assessment of the level of control determined among control authorities necessary to mitigate any concerns that may lead to interference, upset or pass through at the POTW. Pollutants were selected for Table C-1 based on the parameters of interest analysis described in Section 3, documented permit violations, or a specific interest in the pollutant identified during discussions with control authorities.

4.4 Potential Impacts from Direct Discharges of E&EC Wastewater

Regulated pollutants for direct dischargers vary among the different subparts of 40 CFR 469 and include TTO, total fluoride, pH, TSS, total antimony, total arsenic, total cadmium, total chromium, total lead, and total zinc. Direct dischargers identified in the detailed study were regulated under either Subparts A or B which include limits for TTO, total fluoride, and pH. Similar to indirect dischargers, TTO is no longer a concern among direct dischargers with only three out of the four E&EC NPDES permits including a TTO limit and the maximum concentration detected among direct dischargers reported at 0.02 mg/L, well below the ELG daily maximum limit of 1.37 mg/L. Additional pollutants limits identified in the direct discharge permits were technology-based limits for 40 CFR 433 or site-specific receiving water quality concerns.

Table C-2 presents the parameters of interest identified in direct E&EC discharges, the range of effluent limits reported in E&EC NPDES permits, and summarizes the potential environmental concerns associated with their discharge to surface waters. EPA focused their review on facility effluent limits beyond pollutants and concentrations regulated by the existing 40 CFR 469 ELG to highlight where permitting authorities felt additional and or stricter limits than those required under 40 CFR 469 were needed to address site-specific concerns in the receiving water. The range of effluent limits reported in direct discharge permits provides an assessment of the level of control determined among regulatory authorities necessary to mitigate any environmental concerns within receiving waters. Parameters were selected for Table C-2 based on the parameters of interest analysis described in Section 3.

4.5 Summary of Findings from EPA's Review of the E&EC Category

As part of the 2016 Annual Review, EPA expanded the scope of its review beyond sapphire crystal manufacturing, considered in the 2015 Annual Review, to include the entire E&EC Category. Furthermore, EPA studied the E&EC industry to understand how the industry profile, wastewater discharges, and wastewater treatment have changed since promulgation of the ELGs in 1983. EPA analyzed all four subparts of the 1983 E&EC ELGs, with a specific emphasis on Subpart A, semiconductor manufacturing. EPA evaluated several publicly available data sources including DMR and TRI data, IBISWorld industry market reports, economic census data, and peer-reviewed journal articles (from the literature review and IWTT database). In addition, EPA contacted facilities, met with SIA, and attended industry conferences (e.g., 2016 ASMC SEMI conference, 2016 SEMICON West).

From these data collection efforts, EPA determined that the majority of E&EC facilities are indirect dischargers (discharge to POTWs). They have implemented several new process operations using new chemicals and the resulting wastewater characteristics have likely changed over time. Further, the industry may also be phasing out the use of some currently regulated pollutants, including TTO.

Specifically, relating to all four of the existing E&EC subcategories, from the 2016 Annual Review EPA determined:

- Subpart A – Semiconductor Manufacturing.
    - Over the past 30 years, discharge practices have not changed dramatically. Most semiconductor manufacturing facilities continue to discharge to POTWs. SIA and NACWA members stated they were not aware of any zero-discharge semiconductor manufacturing facilities (ERG, 2016, U.S. EPA, 2016).

    - EPA did not identify significant changes in the overall semiconductor manufacturing process operation sequence, though semiconductor manufacturers have added updated processes (e.g., plating, CVS, copper metallization, CMP, C4 bump) and increased repetition of the sequence (from up to 20 times in 1983 to 90 times in 2016).
    - EPA confirmed that updated manufacturing processes introduce new pollutants in the wastewater, due to new materials, lithography process chemistries, and advancement of tools required to keep up with rapidly changing technology demands. Most noteworthy of the new pollutants are PFAS and TMAH, which are toxic, persistent, and bioaccumulative (Tang, 2006; ERG, 2016). NACWA members also expressed concerns with higher concentrations of ammonia, nitrogen, sulfate, fluoride, and copper discharged from E&EC facilities (U.S. EPA, 2016).
    - EPA's review of wastewater treatment technologies shows that the industry continues to rely on the traditional technologies identified at the time of the 1983 ELG rulemaking. However, the industry is actively evaluating new technologies (e.g., biological, ion exchange, reverse osmosis, electrowinning) and wastewater management practices (e.g., rinse recycle, RO reject recycle) aimed at treating some of the newer pollutants and conserving water.
- Subpart B – Electronic Crystal Manufacturing.
    - During the 2015 Annual Review, EPA determined that sapphire crystal manufacturing is a growing sector of the electronic crystal manufacturing industry and that the E&EC ELGs apply to this sector. Though EPA did not specifically focus on electronic crystals manufacturing during the 2016 Annual Review, EPA found at least one source that suggests that GaAs and sapphire crystal manufacturing process steps are similar in nature, and that the manufacturing process operation sequence has not changed substantially since 1983.
    - EPA has not thoroughly investigated the processes, wastewater characteristics, discharges, or treatment associated with existing electronic crystal manufacturing.
- Subpart C – CRT Manufacturing.
    - EPA's research indicates that CRTs have mostly been replaced by newer technologies (e.g., LCD, OLED, plasma display) for TV applications (Robertson, 2018). The market for electron tube manufacturing has decreased significantly since 1983. In addition, several regulations and other efforts have been established for recycling CRTs, suggesting their accelerated phase out.
    - While EPA has identified replacement technologies for CRTs, EPA has not evaluated current processes, wastewater generation, or treatment technologies.
- Subpart D – Luminescent Materials Manufacturing.
    - Luminescent materials consisted of fluorescent lamp phosphors in 1983 (applied, e.g., in TVs, video game displays, and lamps); however, most of these applications have been replaced with newer technologies, such as LEDs.
    - While EPA has identified replacement technologies for luminescent materials, EPA has not evaluated current processes, wastewater generation, or treatment technologies.

As part of its additional review of the E&EC Category, EPA did not identify any industry-wide concerns regarding accepting E&EC discharges at POTWs or in discharging E&EC process wastewater to surface waters. Pollutant issues identified by permit writers were site-specific in nature and did not appear to be representative of broader issues within the industry. E&EC facilities are known for their willingness to explore alternative "greener" chemicals when a potential issue is identified. Most pollutants detected in screening data used for permit development were observed at concentrations that did not pose a threat to cause interference or upset at the POTW or were at concentrations lower than local water quality standards. Permit violations documented among indirect and direct E&EC dischargers were rare, isolated exceedances that did not represent consistent issues at the facility or across the industry. The industry continues to rapidly change as new technologies are developed and new chemicals used in E&EC process. A few facilities are beginning to track and monitor potential emerging pollutants (e.g., PFAS and gallium), to the extent that they are able, but to date have not identified any new industry-wide potential parameters of concern for E&EC dischargers.

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Attachment A: Summary of E&EC Permitting Information

Table A-1 and Table A-2 summarize permit information for E&EC indirect discharge facilities that are permitted either solely under the ELGs at 40 CFR 469 and under 40 CFR 469 and a combination of 40 CFR 433 and 40 CFR 471, respectively. For each parameter, the tables provide counts of facilities whose permits list each parameter (either for limitations or for monitoring only) as well as the basis of any limitations. For permits that include local limits, the tables list the minimum, maximum, and mean concentrations of those local limits. Note that the local limits include a variety of durations and frequencies including but not limited to daily maximum, monthly average, and instantaneous maximum limits. Parameters highlighted in yellow are pollutants regulated at 40 CFR 469; for Table A-1 these include pollutants regulated at Subparts A, B, and D, and for Table A-2 these include pollutants regulated at Subparts A and B. Parameters highlighted in orange in Table A-2 are pollutants regulated at 40 CFR 433.

Table A-1. Permit Information for E&EC Indirect Discharge Facilities Permitted Solely Under 40 CFR 469

Parameter	Count of Facilities with Parameter (N 92 permits)	Count of Facilities with Permit Limits			Local Limits			
		40 CFR 469 ELG Limits	Local Limits	Local Limits More Stringent than ELG Limits	Minimum	Maximum	Mean	Units
1,2-Dichloroethane	2	N/A	2	N/A	0.5	0.5	0.5	mg/l
1,4-Dioxane	5	N/A	5	N/A	1	1	1	mg/l
2,4-Dinitrotoluene	2	N/A	2	N/A	0.13	0.13	0.13	mg/l
Acrylonitrile	2	N/A	2	N/A	1	1	1	mg/l
Aldrin	7	N/A	7	N/A	0.01	0.01	0.01	mg/l
Alkalinity	1	N/A	0	N/A	N/A	N/A	N/A	N/A
Aluminum	1	N/A	1	N/A	9.4	9.4	9.4	mg/l
Ammonia	19	N/A	16	N/A	40	662	348	mg/l
Antimony, Total	17	2	15	0	5	5	5	mg/l
Arsenic, Total	74	7	71	6	0.047	15	1.21	mg/l
Barium, Total	2	N/A	2	N/A	5	5	5	mg/l
Beryllium	18	N/A	18	N/A	0.01	1	0.737	mg/l
BOD5	13	N/A	10	N/A	240	1,880	1,144	mg/l
Boron, Total	5	N/A	5	N/A	1	20	5.6	mg/l
Bromide	1	N/A	1	N/A	0.1	0.1	0.1	mg/l
BTEX	1	N/A	1	N/A	2.6	2.6	2.6	mg/l
Cadmium, Total	71	2	71	1	0.01	15	1.8	mg/l

Table A-1. Permit Information for E&EC Indirect Discharge Facilities Permitted Solely Under 40 CFR 469

Parameter	Count of Facilities with Parameter (N 92 permits)	Count of Facilities with Permit Limits			Local Limits			
		40 CFR 469 ELG Limits	Local Limits	Local Limits More Stringent than ELG Limits	Minimum	Maximum	Mean	Units
Chlordane	9	N/A	9	N/A	0.01	0.03	0.0144	mg/l
Chloride	12	N/A	6	N/A	175	880	404	mg/l
Chlorinated Phenolics	1	N/A	1	N/A	0.189	0.189	0.189	mg/L
Chlorine Demand	2	N/A	2	N/A	50	50	50	mg/l
Chlorobenzene	2	N/A	2	N/A	0.2	0.2	0.2	mg/l
Chloroform	2	N/A	2	N/A	0.2	0.2	0.2	mg/l
Chromium, Hexavalent	1	N/A	1	N/A	10	10	10	mg/l
Chromium, Total	71	N/A	71	N/A	0.5	25	5.77	mg/l
Chronic pH Excursions	2	N/A	2	N/A	0	60	30	minutes
COD	11	N/A	3	N/A	420	3,000	1,604	mg/l
Copper, Total	73	N/A	73	N/A	0.13	17	3.59	mg/l
Cyanide, Total	71	N/A	71	N/A	0.01	10	2.37	mg/l
Dieldrin	7	N/A	7	N/A	0.01	0.01	0.01	mg/l
Electrical Conductivity	1	N/A	1	N/A	712	712	712	umhos/cm
Endosulfan	1	N/A	1	N/A	0.0013	0.0013	0.0013	mg/l
Endrin	8	N/A	8	N/A	0.0006	0.01	0.00883	mg/l
Fixed Dissolved Solids	1	N/A	1	N/A	4,270	4,270	4,270	mg/l

Table A-1. Permit Information for E&EC Indirect Discharge Facilities Permitted Solely Under 40 CFR 469

Parameter	Count of Facilities with Parameter (N 92 permits)	Count of Facilities with Permit Limits			Local Limits			
		40 CFR 469 ELG Limits	Local Limits	Local Limits More Stringent than ELG Limits	Minimum	Maximum	Mean	Units
Flash Cup	2	N/A	2	N/A	60	60	60	°C
Flash Point	7	N/A	7	N/A	60	60	60	°C
Flow	32	N/A	24	N/A	0.329	4,824,000	403,236	GPD
Fluoride, Total	26	2	23	0	3	180	39.2	mg/l
Formaldehyde	7	N/A	7	N/A	50	50	50	mg/l
Hexachlorocyclohexane	8	N/A	8	N/A	0.0007	0.01	0.00884	mg/l
Iron, Total	4	N/A	4	N/A	5	250	69.5	mg/l
Lead, Total	70	N/A	70	N/A	0.04	40	4.6	mg/l
Manganese, Total	8	N/A	8	N/A	0.5	6.1	4.08	mg/l
Mercury, Total	75	N/A	75	N/A	0.000142	142	1.88	mg/l
Molybdenum, Total	23	N/A	17	N/A	0.15	2.3	1.54	mg/l
Nickel, Total	72	N/A	72	N/A	0.31	22	4.04	mg/l
Nitrate	1	N/A	1	N/A	No concentration-based limits			
Nitrobenzene	2	N/A	2	N/A	2	2	2	mg/l
Oil and Grease	64	N/A	64	N/A	50	600	160	mg/l
Organophosphate	2	N/A	2	N/A	1	1	1	mg/l
PCBs	14	N/A	14	N/A	0.01	0.222	0.0212	mg/l

Table A-1. Permit Information for E&EC Indirect Discharge Facilities Permitted Solely Under 40 CFR 469

Parameter	Count of Facilities with Parameter (N 92 permits)	Count of Facilities with Permit Limits			Local Limits			
		40 CFR 469 ELG Limits	Local Limits	Local Limits More Stringent than ELG Limits	Minimum	Maximum	Mean	Units
Pentachlorophenol	2	N/A	2	N/A	0.04	0.04	0.04	mg/l
Pesticides	6	N/A	6	N/A	0.01	0.01	0.01	mg/l
pH	90	N/A	90	N/A	5	12.5	NC	SU
Phenolics	8	N/A	8	N/A	5	30	8.13	mg/l
Phenols	19	N/A	19	N/A	1	500	50.8	mg/l
Phosphorus, Total	2	N/A	2	N/A	9	9	9	mg/l
Priority Pollutants	1	N/A	0	N/A	N/A	N/A	N/A	N/A
Selenium, Total	44	N/A	43	N/A	0.006	9.37	1.68	mg/l
Silver, Total	64	N/A	64	N/A	0.04	15	3.22	mg/l
Sodium	1	N/A	1	N/A	140	140	140	mg/l
Sulfate	6	N/A	6	N/A	400	3,660	1,365	mg/l
Sulfides	18	N/A	17	N/A	0.1	10	2.38	mg/l
TDS	14	N/A	6	N/A	1,000	4,270	1,809	mg/l
Temperature	20	N/A	20	N/A	40	66	61.1	°C
Total Detectable DDT	7	N/A	7	N/A	0.01	0.01	0.01	mg/l
Total Kjeldahl Nitrogen	2	N/A	2	N/A	75	75	75	mg/l

Table A-1. Permit Information for E&EC Indirect Discharge Facilities Permitted Solely Under 40 CFR 469

Parameter	Count of Facilities with Parameter (N 92 permits)	Count of Facilities with Permit Limits			Local Limits			
		40 CFR 469 ELG Limits	Local Limits	Local Limits More Stringent than ELG Limits	Minimum	Maximum	Mean	Units
Total Petroleum Hydrocarbon	1	N/A	1	N/A	100	100	100	mg/l
Toxaphene	7	N/A	7	N/A	0.01	0.01	0.01	mg/l
Trichloroethylene	2	N/A	2	N/A	0.2	0.2	0.2	mg/l
TSS	23	N/A	13	N/A	175	2,031	959	mg/l
TTO	90	88	23	5	0.5	2.13	1.65	mg/l
Zinc, Total	73	2	72	0	0.16	25	6.23	mg/l

N/A - Not Applicable

NC - Not Calculated

Table A-2. Permit Information for E&EC Indirect Discharge Facilities Permitted Under Both 40 CFR 469 and 40 CFR 433

Parameter	Count of Facilities with Parameter (N 19 permits)	Count of Facilities with Permit Limits			Local Limits			
		40 CFR 469 ELG Limits	Local Limits	Local Limits More Stringent than ELG Limits	Minimum	Maximum	Mean	Units
1,2,4-Triazole	1	N/A	0	N/A	N/A	N/A	N/A	N/A
Aldrin	2	N/A	2	N/A	0	0.01	0.005	mg/l
Ammonia	5	N/A	4	N/A	25	150	66.3	mg/l
Antimony, Total	3	N/A	3	N/A	5	5	5	mg/l
Arsenic, Total	13	2	13	3	0.06	3	1.01	mg/l
Benzene	1	N/A	0	N/A	N/A	N/A	N/A	N/A
Beryllium	3	N/A	3	N/A	0.75	0.75	0.75	mg/l
BOD5	3	N/A	2	N/A	230	240	235	mg/l
Bromine, Iodine, Chlorine	1	N/A	1	N/A	100	100	100	mg/l
Cadmium, Total	19	N/A	13	N/A	0.14	15	2.7	mg/l
Cerium, Total	1	N/A	0	N/A	N/A	N/A	N/A	N/A
Chlordane	2	N/A	2	N/A	0	0.01	0.005	mg/l
Chloride	2	N/A	0	N/A	N/A	N/A	N/A	N/A
Choline Hydroxide	1	N/A	0	N/A	N/A	N/A	N/A	N/A
Chromium, Total	19	N/A	12	N/A	0.62	10	3.12	mg/l
Cobalt, Total	1	N/A	1	N/A	0.012	0.02	0.016	mg/l
COD	3	N/A	0	N/A	N/A	N/A	N/A	N/A
Copper, Total	19	N/A	12	N/A	0.208	15	4.09	mg/l
Cyanate	1	N/A	1	N/A	10	10	10	mg/l
Cyanide, Total	19	N/A	12	N/A	0.04	10	2.09	mg/l
Dieldrin	2	N/A	2	N/A	0	0.01	0.005	mg/l
Endrin	2	N/A	2	N/A	0	0.01	0.005	mg/l
Ethylenediaminetetraacetic acid	1	N/A	0	N/A	N/A	N/A	N/A	N/A

Table A-2. Permit Information for E&EC Indirect Discharge Facilities Permitted Under Both 40 CFR 469 and 40 CFR 433

Parameter	Count of Facilities with Parameter (N 19 permits)	Count of Facilities with Permit Limits			Local Limits			
		40 CFR 469 ELG Limits	Local Limits	Local Limits More Stringent than ELG Limits	Minimum	Maximum	Mean	Units
Flash Point	3	N/A	3	N/A	60	60	60	°C
Flow	6	N/A	4	N/A	2,230	8,100,000	2,945,664	GPD
Fluoride, Total	5	N/A	4	N/A	10	48	29	mg/l
Formaldehyde	1	N/A	1	N/A	50	50	50	mg/l
Gallium	1	N/A	0	N/A	N/A	N/A	N/A	N/A
Hafnium	1	N/A	0	N/A	N/A	N/A	N/A	N/A
Hexachlorocyclohexane	2	N/A	2	N/A	0	0.01	0.005	mg/l
Hydrogen Peroxide	1	N/A	0	N/A	N/A	N/A	N/A	N/A
Langelier Saturation Index	1	N/A	0	N/A	N/A	N/A	N/A	N/A
Lead, Total	19	N/A	14	N/A	0.039	40	6.2	mg/l
Mercuric Chloride	1	N/A	1	N/A	1	1	1	mg/l
Mercury, Total	13	N/A	13	N/A	0.0002	2	0.328	mg/l
Molybdenum, Total	3	N/A	3	N/A	3.7	6.58	5.62	mg/l
Nickel, Total	18	N/A	12	N/A	0.2	12	3.25	mg/l
Oil and Grease	10	N/A	10	N/A	100	300	154	mg/l
PCBs	2	N/A	2	N/A	0	0.01	0.005	mg/l
pH	15	N/A	15	N/A	5	12.5	NC	SU
Phenolics	2	N/A	2	N/A	5	30	17.5	mg/l
Phenols	2	N/A	2	N/A	30	30	30	mg/l
Phosphorus, Total	2	N/A	1	N/A	4.9	4.9	4.9	mg/l
Ruthenium, Total	1	N/A	0	N/A	N/A	N/A	N/A	N/A
Selenium, Total	9	N/A	9	N/A	0.2	4.48	1.54	mg/l
Silver, Total	19	N/A	12	N/A	0.05	5	1.18	mg/l
Sulfides	3	N/A	3	N/A	0.1	10	3.4	mg/l

Table A-2. Permit Information for E&EC Indirect Discharge Facilities Permitted Under Both 40 CFR 469 and 40 CFR 433

Parameter	Count of Facilities with Parameter (N 19 permits)	Count of Facilities with Permit Limits			Local Limits			
		40 CFR 469 ELG Limits	Local Limits	Local Limits More Stringent than ELG Limits	Minimum	Maximum	Mean	Units
TDS	3	N/A	0	N/A	N/A	N/A	N/A	N/A
Temperature	4	N/A	4	N/A	40	65.6	56.4	°C
Tetrachloroethylene	1	N/A	1	N/A	0.031	0.031	0.031	mg/l
Tin, Total	1	N/A	0	N/A	N/A	N/A	N/A	N/A
Total Detectable DDT	2	N/A	2	N/A	0	0.01	0.005	mg/l
Total Kjeldahl Nitrogen	1	N/A	0	N/A	N/A	N/A	N/A	N/A
Toxaphene	2	N/A	2	N/A	0	0.01	0.005	mg/l
Trichloroethylene	1	N/A	1	N/A	0.026	0.026	0.026	mg/l
Tritium	1	N/A	0	N/A	N/A	N/A	N/A	N/A
TSS	5	N/A	2	N/A	150	300	225	mg/l
TTO	18	18	2	1	1	2.13	1.57	mg/l
Zinc, Total	19	N/A	12	N/A	2.55	25	6.57	mg/l
Zirconium, Total	1	N/A	1	N/A	10	10	10	mg/l

N/A - Not Applicable
NC - Not Calculated

Table A-3 and Table A-4 summarize permit information for E&EC direct discharge facilities that are permitted either solely under the ELGs at 40 CFR 469 and under both 40 CFR 469 and 40 CFR 433, respectively. For each parameter, the tables provide counts of facilities whose permits list each parameter (either for limitations or for monitoring only) as well as the basis of any limitations. For permits that include local limits, the tables list the minimum, maximum, and mean concentrations of those local limits. Note that the local limits include a variety of durations and frequencies including but not limited to daily maximum, monthly average, and instantaneous maximum limits. Parameters highlighted in yellow are pollutants regulated at 40 CFR 469; for Table A-3 these include pollutants regulated at Subparts A and B and for Table A-4 these include pollutants regulated at Subpart A. Parameters highlighted in orange in Table A-4 are pollutants regulated at 40 CFR 433.

Table A-3. Permit Information for E&EC Direct Discharge Facilities Permitted Solely Under 40 CFR 469

Parameter	Count of Facilities with Parameter (N 3 permits)	Count of Facilities with Permit Limits			Local Limits			
		40 CFR 469 ELG Limits	Local Limits	Local Limits More Stringent than ELG Limits	Minimum	Maximum	Mean	Units
Acetone	1	N/A	0	N/A	N/A	N/A	N/A	N/A
Aluminum	1	N/A	1	N/A	1	1	1	mg/l
Ammonia	1	N/A	1	N/A	1.3	2.7	2	mg/l
Arsenic, Total	1	0	1	0	0.1	0.1	0.1	mg/l
BOD5	1	N/A	1	N/A	15	30	22.5	mg/l
Bromine, Total	1	N/A	1	N/A	0.2	0.5	0.35	mg/l
Bromobenzene	1	N/A	0	N/A	N/A	N/A	N/A	N/A
Bromoform	1	N/A	0	N/A	N/A	N/A	N/A	N/A
CBOD	1	N/A	1	N/A	8	8	8	mg/l
Chlorine, Total Residual	1	N/A	1	N/A	0.1	0.5	0.3	mg/l
Chloroform	1	N/A	0	N/A	N/A	N/A	N/A	N/A
Chromium, Hexavalent	1	N/A	1	N/A	0.013	0.013	0.013	mg/l
Chromium, Total	2	N/A	2	N/A	0.02	0.5	0.19	mg/l
cis-1,2 Dichloroethylene	1	N/A	1	N/A	0.01	0.01	0.01	mg/l
Cobalt, Total	1	N/A	1	N/A	0.006	0.006	0.006	mg/l
Copper, Total	1	N/A	1	N/A	No concentration-based limits			
Cyanide, Total	1	N/A	1	N/A	0.06	0.06	0.06	mg/l
Dichlorobromomethane	1	N/A	0	N/A	N/A	N/A	N/A	N/A
Dichlorodifluoromethane	1	N/A	1	N/A	0.01	0.01	0.01	mg/l
Dissolved Oxygen	1	N/A	0	N/A	N/A	N/A	N/A	N/A
Ethylbenzene	1	N/A	0	N/A	N/A	N/A	N/A	N/A
Fecal Coliform	1	N/A	1	N/A	200	400	300	MPN/100 ml
Flow	2	N/A	2	N/A	520,000	6,000,000	2,406,667	GPD
Fluoride, Total	3	2	2	1	7.3	7.3	7.3	mg/l
Free Available Chlorine	1	N/A	1	N/A	0.2	0.5	0.35	mg/l

Table A-3. Permit Information for E&EC Direct Discharge Facilities Permitted Solely Under 40 CFR 469

Parameter	Count of Facilities with Parameter (N 3 permits)	Count of Facilities with Permit Limits			Local Limits			
		40 CFR 469 ELG Limits	Local Limits	Local Limits More Stringent than ELG Limits	Minimum	Maximum	Mean	Units
Germanium, Total	1	N/A	0	N/A	N/A	N/A	N/A	N/A
Hafnium	1	N/A	0	N/A	N/A	N/A	N/A	N/A
Iron, Total	1	N/A	0	N/A	N/A	N/A	N/A	N/A
Lead, Total	1	N/A	1	N/A	0.08	0.08	0.08	mg/l
Methyl Tert Butyl Ether	1	N/A	1	N/A	0.01	0.01	0.01	mg/l
Molybdenum, Total	1	N/A	1	N/A	3.75	3.75	3.75	mg/l
Nickel, Total	1	N/A	0	N/A	N/A	N/A	N/A	N/A
N-Methyl-2-Pyrrolidone	1	N/A	1	N/A	0.02	0.02	0.02	mg/l
Palladium, Total	1	N/A	1	N/A	0.1	0.1	0.1	mg/l
pH	3	2	1	1	6.5	8.5	NC	SU
Phosphate, Total	1	N/A	1	N/A	10	15	12.5	mg/l
Rhenium, Total	1	N/A	0	N/A	N/A	N/A	N/A	N/A
Ruthenium, Total	1	N/A	0	N/A	N/A	N/A	N/A	N/A
Silver, Total	1	N/A	0	N/A	N/A	N/A	N/A	N/A
Solids, Settleable	1	N/A	1	N/A	0.1	0.1	0.1	mg/l
Tantalum, Total	1	N/A	0	N/A	N/A	N/A	N/A	N/A
TDS	1	N/A	1	N/A	1,628	4,884	3,318	mg/l
Tetrachloroethylene	1	N/A	1	N/A	0.0012	0.0012	0.0012	mg/l
Tin, Total	1	N/A	1	N/A	2	2	2	mg/l
Titanium, Total	1	N/A	1	N/A	0.53	0.53	0.53	mg/l
Toluene	1	N/A	0	N/A	N/A	N/A	N/A	N/A
Trichloroethylene	1	N/A	0	N/A	N/A	N/A	N/A	N/A
TSS	2	1	2	0	25	40	32.5	mg/l
TTO	2	2	1	0	2.74	2.74	2.74	mg/l
Tungsten, Total	1	N/A	1	N/A	3.75	3.75	3.75	mg/l

Table A-3. Permit Information for E&EC Direct Discharge Facilities Permitted Solely Under 40 CFR 469

Parameter	Count of Facilities with Parameter (N 3 permits)	Count of Facilities with Permit Limits			Local Limits			
		40 CFR 469 ELG Limits	Local Limits	Local Limits More Stringent than ELG Limits	Minimum	Maximum	Mean	Units
Vinyl chloride	1	N/A	0	N/A	N/A	N/A	N/A	N/A
Xylene	1	N/A	0	N/A	N/A	N/A	N/A	N/A
Zinc, Total	1	N/A	1	N/A	0.36	0.36	0.36	mg/l

N/A - Not Applicable

NC - Not Calculated

Table A-4. Permit Information for E&EC Direct Discharge Facilities Permitted Under Both 40 CFR 469 and 40 CFR 433

Parameter	Count of Facilities with Parameter (N 1 permit)	Count of Facilities with Permit Limits			Local Limits			
		40 CFR 469 ELG Limits	Local Limits	Local Limits More Stringent than ELG Limits	Minimum	Maximum	Mean	Units
Ammonia	1	N/A	0	N/A	N/A	N/A	N/A	N/A
BOD5	1	N/A	0	N/A	N/A	N/A	N/A	N/A
Cadmium, Total	1	N/A	1	N/A	No concentration-based limits			
Chromium, Trivalent	1	N/A	1	N/A	No concentration-based limits			
Copper, Total	1	N/A	1	N/A	No concentration-based limits			
Cyanide, Free	1	N/A	1	N/A	0.65	1.2	0.925	mg/l
Dichloroethene	1	N/A	0	N/A	N/A	N/A	N/A	N/A
E. Coli	1	N/A	1	N/A	77	77	77	#/100 ml
Ethyl Benzene	1	N/A	0	N/A	N/A	N/A	N/A	N/A
Flow	1	N/A	1	N/A	8,000,000	8,000,000	8,000,000	GPD
Fluoride, Total	1	1	1	1	28	28	28	mg/l
Hydrogen Peroxide	1	N/A	1	N/A	10	15	12.5	mg/l
Iron, Total	1	N/A	0	N/A	N/A	N/A	N/A	N/A
Lead, Total	1	N/A	1	N/A	No concentration-based limits			
Nickel, Total	1	N/A	1	N/A	No concentration-based limits			
Nitrite plus Nitrate	1	N/A	0	N/A	N/A	N/A	N/A	N/A
Nitrogen, Total	1	N/A	0	N/A	N/A	N/A	N/A	N/A
Oil and Grease	1	N/A	1	N/A	No concentration-based limits			
PFHpA	1	N/A	0	N/A	N/A	N/A	N/A	N/A
PFHxS	1	N/A	0	N/A	N/A	N/A	N/A	N/A
PFNA	1	N/A	0	N/A	N/A	N/A	N/A	N/A
PFOA	1	N/A	0	N/A	N/A	N/A	N/A	N/A
PFOS	1	N/A	0	N/A	N/A	N/A	N/A	N/A
pH	1	0	1	1	6.5	8.5	NC	SU
Phosphorus, Total	1	N/A	1	N/A	0.8	0.8	0.8	mg/l

Table A-4. Permit Information for E&EC Direct Discharge Facilities Permitted Under Both 40 CFR 469 and 40 CFR 433

Parameter	Count of Facilities with Parameter (N 1 permit)	Count of Facilities with Permit Limits			Local Limits			
		40 CFR 469 ELG Limits	Local Limits	Local Limits More Stringent than ELG Limits	Minimum	Maximum	Mean	Units
Silver, Total	1	N/A	1	N/A	No concentration-based limits			
Tetrachloroethylene	1	N/A	0	N/A	N/A	N/A	N/A	N/A
Total Kjeldahl Nitrogen	1	N/A	0	N/A	N/A	N/A	N/A	N/A
Trichloroethylene	1	N/A	0	N/A	N/A	N/A	N/A	N/A
TSS	1	N/A	1	N/A	10.5	10.5	10.5	mg/l
TTO	1	1	0	0	N/A	N/A	N/A	N/A
Ultimate Oxygen Demand	1	N/A	1	N/A	No concentration-based limits			
Vinyl Chloride	1	N/A	0	N/A	N/A	N/A	N/A	N/A
Whole Effluent Toxicity	1	N/A	1	N/A	7	7	7	%
Xylene	1	N/A	0	N/A	N/A	N/A	N/A	N/A
Zinc, Total	1	N/A	1	N/A	No concentration-based limits			

N/A - Not Applicable

NC - Not Calculated

Attachment B: Summary of E&EC Wastewater Discharge Characterization

Table B-1 and Table B-2 provide summary statistics for all pollutants detected in wastewater discharges from E&EC indirect and direct discharge facilities. The tables include counts of facilities, counts of results, and statistics for detected concentrations (minimum, maximum, mean, and median concentrations). Detected concentrations are rounded to no more than 3 significant digits. The tables also present toxic weighting factors for pollutants where available. Toxic weighting factors are derived from chronic aquatic life criteria and human health criteria established for the consumption of fish; they are used to compare the toxicity of one pollutant relative to another and are normalized based on the toxicity of copper (ERG, 2007). All columns are queried from the E&EC wastewater characterization Access database except for median concentration which was calculated in Excel.

Table B-1. Summary Statistics for Pollutants Detected in Wastewater Discharges from E&EC Indirect Discharge Facilities

Pollutant	Units	Number of Facilities Measuring	Number of Facilities with Detects	Number of Results	Number of Detects	Toxic Weighting Factor [a]	Minimum Detected Concentration	Maximum Detected Concentration	Mean Detected Concentration	Median Detected Concentration
Total Toxic Organics	mg/L	57	27	836	182	N/A	0.00092	0.957	0.0752	0.01675
Classical Wet Chemistry										
Acidity, Total	mg/L	1	1	40	36	N/A	16	56	35.4	38
Alkalinity	mg/L	2	2	93	93	N/A	56	240	134	130
Ammonia	mg/L	30	30	618	607	0.00111	0.05	1,300	87.9	36.1
BOD5	mg/L	28	25	750	690	N/A	0.3	4,178	86.6	46.85
Calcium hardness	mg/L	1	1	5	5	N/A	696	828	768	784
Carbon dioxide, free	mg/L	1	1	40	39	N/A	0.6	2.78	1.20	1.1
CBOD	mg/L	1	1	4	3	N/A	14	18	16.3	17
COD	mg/L	16	16	191	178	N/A	7	923	158	144.5
Conductivity	umhos/cm	6	6	694	694	N/A	9.05	5,850	2,731	3,264.5
Cyanide, Total	mg/L	51	22	933	111	1.11	0.0014	4.2	0.0756	0.025
Dissolved oxygen	mg/L	1	1	40	40	N/A	12.21	39.4	23.4	24.49
Fixed dissolved solids	mg/L	1	1	9	9	N/A	230	3,540	2,060	2,064
Hydrogen peroxide	mg/L	1	1	79	79	N/A	3.8	780	488	500
Nitrogen, Total	mg/L	3	3	12	12	N/A	9.14	25.3	16.6	17.4
Oil & Grease	mg/L	24	12	291	161	N/A	0.2	2,701.7	29.7	4.8
Oil & Grease, non-polar	mg/L	1	1	9	3	N/A	1.05	7.4	4.15	4
Oil & Grease, polar	mg/L	1	1	9	5	N/A	1.2	10.6	3.53	2.1
Phosphorus, Total	mg/L	18	17	142	139	N/A	0.102	202	6.35	1.72

Table B-1. Summary Statistics for Pollutants Detected in Wastewater Discharges from E&EC Indirect Discharge Facilities

Pollutant	Units	Number of Facilities Measuring	Number of Facilities with Detects	Number of Results	Number of Detects	Toxic Weighting Factor [a]	Minimum Detected Concentration	Maximum Detected Concentration	Mean Detected Concentration	Median Detected Concentration
Total dissolved solids	mg/L	28	27	393	392	N/A	58	13,800	872	566
Total Kjeldahl Nitrogen	mg/L	8	8	133	131	N/A	0.28	274	76.8	58.5
Total petroleum hydrocarbons	mg/L	3	2	20	4	0.1	1.8	3.6	2.92	3.145
Total suspended solids	mg/L	46	42	936	808	N/A	0.4	7,760	71.2	23
Anions										
Bromide	mg/L	2	2	430	428	N/A	0.01	24	0.107	0.05
Chloride	mg/L	28	27	419	418	0.0000243	1	7,090	222	138
Fluoride, Total (excluding Skorpios continuous monitoring data)	mg/L	36	27	907	783	0.03	0.00054	114	9.02	6.8
Fluoride, Total (Skorpios continuous monitoring data)	mg/L	1	1	96,160	96,160	0.03	0.92	100	14.4	17.92
Nitrates	mg/L	6	6	40	40	0.000747	0.16	12.3	4.56	4.28
Nitrates/Nitrites	mg/L	9	9	52	51	N/A	0.5	12.44	4.38	4.37
Nitrites	mg/L	6	6	40	38	0.0032	0.026	4.19	0.455	0.265
Sulfates	mg/L	11	11	169	169	0.0000056	5.9	3,470	698	599
Sulfides	mg/L	11	4	144	21	N/A	0.027	0.92	0.237	0.19
Metals										
Aluminum, Total	mg/L	10	9	26	20	0.06	0.0215	0.434	0.119	0.0755
Antimony, Total	mg/L	18	7	161	17	0.01	0.0000951	0.129	0.0186	0.009
Arsenic, Total	mg/L	53	35	1,159	482	3.47	0.000063	6.16	0.192	0.062

Table B-1. Summary Statistics for Pollutants Detected in Wastewater Discharges from E&EC Indirect Discharge Facilities

Pollutant	Units	Number of Facilities Measuring	Number of Facilities with Detects	Number of Results	Number of Detects	Toxic Weighting Factor [a]	Minimum Detected Concentration	Maximum Detected Concentration	Mean Detected Concentration	Median Detected Concentration
Barium, Total	mg/L	11	10	26	25	0.00199	0.000723	0.039	0.0131	0.0127
Beryllium, Total	mg/L	14	3	35	3	1.05	0.000000025	0.00072	0.000297	0.00017
Bismuth, Total	mg/L	1	1	14	13	N/A	0.03	0.308	0.0967	0.066
Boron, Total	mg/L	8	7	228	218	0.00834	0.047	5	0.311	0.27
Cadmium, Total	mg/L	64	17	1,072	157	22.8	0.0000116	0.1928	0.00522	0.002
Calcium, Total	mg/L	3	3	42	42	0.000028	1.49	481	274	279
Cerium, Total	mg/L	1	1	40	38	N/A	0.051	0.846	0.232	0.1465
Chromium, Total	mg/L	68	42	1,211	280	0.07	0.0000133	0.82	0.0192	0.005
Cobalt, Total	mg/L	10	6	62	9	0.11	0.0000218	0.0139	0.00253	0.000625
Copper, Total	mg/L	67	57	1,309	996	0.623	0.00015	5.64	0.213	0.05
Gallium, Total	mg/L	1	1	3	2	0.13	0.025	0.269	0.147	0.147
Iron, Total	mg/L	7	7	33	16	0.0056	0.00684	1.91	0.208	0.0671
Lead, Total	mg/L	66	33	1,062	199	2.24	0.00002	0.44	0.0200	0.005
Magnesium, Total	mg/L	2	2	2	2	0.000866	0.895	1.16	1.03	1.0275
Manganese, Total	mg/L	9	8	22	21	0.103	0.000599	0.0337	0.0103	0.00431
Mercury, Total	mg/L	45	24	592	111	110	0.000001	0.02	0.000953	0.00007
Molybdenum, Total	mg/L	36	25	169	76	0.2	0.00014	3.74	0.0921	0.00793
Nickel, Total	mg/L	69	48	1,170	753	0.1	0.000154	2.99	0.118	0.01
Potassium, Total	mg/L	4	4	401	401	0.00105	0.754	181	36.7	35.6
Selenium, Total	mg/L	42	19	441	116	1.12	0.00008	0.6	0.0181	0.006
Silver, Total	mg/L	64	24	1,028	211	16.5	0.000026	0.4	0.00771	0.002

Table B-1. Summary Statistics for Pollutants Detected in Wastewater Discharges from E&EC Indirect Discharge Facilities

Pollutant	Units	Number of Facilities Measuring	Number of Facilities with Detects	Number of Results	Number of Detects	Toxic Weighting Factor [a]	Minimum Detected Concentration	Maximum Detected Concentration	Mean Detected Concentration	Median Detected Concentration
Sodium, Total	mg/L	4	4	401	401	0.00000549	26.2	207	118	119
Tellurium, Total	mg/L	1	1	14	14	0.04	0.053	0.624	0.234	0.157
Tin, Total	mg/L	9	4	22	4	0.3	0.000187	0.00565	0.00315	0.003385
Titanium, Total	mg/L	3	3	3	3	0.02	0.001	0.00504	0.0025	0.00146
Total metals	mg/L	3	2	22	5	N/A	0.00109	0.03813	0.00911	0.00212
Vanadium, Total	mg/L	4	2	10	2	0.28	0.00337	0.00514	0.00426	0.004255
Zinc, Total	mg/L	67	60	1,284	1,009	0.04	0.000751	22	0.112	0.03
Zirconium, Total	mg/L	2	1	41	2	0.54	0.005	0.006	0.0055	0.0055
Organic Compounds										
1,1,2-Trichloroethane	mg/L	33	1	647	1	0.03	0.00274	0.00274	0.00274	0.00274
1,1-Dichloroethane	mg/L	24	2	590	3	0.000514	0.00038	0.0006	0.000457	0.00039
1,1-Dichloroethene	mg/L	32	1	646	2	0.47	0.0004	0.00115	0.000775	0.000775
1,2,4-Triazole	mg/L	1	1	2	2	N/A	1	1.2	1.1	1.1
1,2-Dichlorobenzene	mg/L	35	2	683	3	0.01	0.00104	0.0065	0.00457	0.00618
1,2-Dichloroethane	mg/L	33	2	647	2	0.01	0.00082	0.00199	0.00141	0.001405
1,3-Dichlorobenzene	mg/L	34	2	696	2	0.01	0.00559	0.00582	0.00571	0.005705
1,4-Dichlorobenzene	mg/L	34	1	696	1	0.07	0.00602	0.00602	0.00602	0.00602
2,4-Dimethylphenol	mg/L	21	1	545	2	0.00941	0.044	0.044	0.044	0.044
2-Hexanone	mg/L	12	1	43	1	0.000375	0.00137	0.00137	0.00137	0.00137
2-Nitrophenol	mg/L	31	1	594	1	0.00162	0.00041	0.00041	0.00041	0.00041

Table B-1. Summary Statistics for Pollutants Detected in Wastewater Discharges from E&EC Indirect Discharge Facilities

Pollutant	Units	Number of Facilities Measuring	Number of Facilities with Detects	Number of Results	Number of Detects	Toxic Weighting Factor [a]	Minimum Detected Concentration	Maximum Detected Concentration	Mean Detected Concentration	Median Detected Concentration
4-Bromophenyl phenyl ether	mg/L	21	1	542	1	0.13	0.0013	0.0013	0.0013	0.0013
624 Volatiles	mg/L	30	5	101	12	N/A	0.0025	12.1	1.12	0.02045
625 Semi Volatiles	mg/L	26	1	83	1	N/A	0.0325	0.0325	0.0325	0.0325
Acetone	mg/L	22	18	101	45	0.00000846	0.0091	37.7	2.71	0.182
Acrolein	mg/L	26	1	582	3	0.98	0.00213	0.0305	0.0133	0.0074
Benzene	mg/L	27	3	717	8	0.03	0.00107	0.00232	0.00149	0.00114
Benzidine	mg/L	22	1	546	1	2818	0.0073	0.0073	0.0073	0.0073
Benzyl butyl phthalate	mg/L	31	3	595	3	0.02	0.0013	0.009204	0.00410	0.0018
Bis(2-chloroisopropyl) ether	mg/L	21	1	544	1	0.02	0.02797	0.02797	0.0280	0.02797
Bis(2-ethylhexyl) phthalate	mg/L	34	18	605	86	0.25	0.000543	0.201	0.0375	0.0093
Bromodichloromethane	mg/L	35	15	651	59	0.03	0.00016	0.0107	0.00233	0.002
Bromoform	mg/L	25	7	590	32	0.00457	0.0004	0.00825	0.00168	0.00145
Bromomethane	mg/L	25	2	591	3	0.05	0.00057	0.00103	0.000737	0.00061
Butanone	mg/L	16	1	83	1	0.0000263	0.00485	0.00485	0.00485	0.00485
Carbon disulfide	mg/L	12	3	39	6	2.8	0.000863	0.00487	0.00313	0.003635
Chlorobenzene	mg/L	26	1	593	1	0.00293	0.00269	0.00269	0.00269	0.00269
Chloroform	mg/L	37	24	658	93	0.00208	0.000207	0.75	0.0116	0.00238
Chloromethane	mg/L	25	3	588	6	0.00536	0.00052	0.00439	0.00225	0.00217
Choline hydroxide	mg/L	1	1	2	1	N/A	0.9	0.9	0.9	0.9
Dibromochloromethane	mg/L	26	7	591	34	0.04	0.00062	0.0184	0.00200	0.00135

Table B-1. Summary Statistics for Pollutants Detected in Wastewater Discharges from E&EC Indirect Discharge Facilities

Pollutant	Units	Number of Facilities Measuring	Number of Facilities with Detects	Number of Results	Number of Detects	Toxic Weighting Factor [a]	Minimum Detected Concentration	Maximum Detected Concentration	Mean Detected Concentration	Median Detected Concentration
Dibutyl phthalate	mg/L	32	6	595	12	0.01	0.000371	0.00797	0.00237	0.0015
Dichloromethane	mg/L	36	8	775	15	0.00101	0.0004	0.176	0.0225	0.00225
Diethyl phthalate	mg/L	24	8	552	17	0.000688	0.000342	0.0132	0.00315	0.0017
Dimethyl phthalate	mg/L	21	2	545	2	0.00329	0.005051	0.0083	0.00668	0.0066755
Dioctyl phthalate	mg/L	22	2	562	2	0.46	0.0019	0.002	0.00195	0.00195
Ethylbenzene	mg/L	33	3	767	4	0.00141	0.00111	0.003	0.00192	0.00179
Isopropyl alcohol	mg/L	3	1	39	3	N/A	2.6	12.1	7.12	6.66
Naphthalene	mg/L	34	2	628	4	0.01	0.0013	0.008606	0.00418	0.0034
N-Methyl-2-pyrrolidone	mg/L	2	1	106	87	N/A	0.32	5,000	103	9.4
N-Nitrosodipropylamine	mg/L	19	1	542	1	1.1	0.0086	0.0086	0.0086	0.0086
Pentachlorophenol	mg/L	31	1	593	1	0.55	0.005439	0.005439	0.00544	0.005439
PFOA	mg/L	1	1	1	1	N/A	0.0000229	0.0000229	0.0000229	0.0000229
PFOS	mg/L	1	1	1	1	N/A	0.00001	0.00001	0.00001	0.00001
Phenol	mg/L	41	15	736	53	0.02	0.0000045	2.4	0.128	0.0027
Pyridine	mg/L	4	1	9	1	0.00302	0.00357	0.00357	0.00357	0.00357
Tetrachloroethylene	mg/L	34	2	651	7	0.23	0.00102	0.02376	0.00665	0.00196
Toluene	mg/L	36	5	772	9	0.00563	0.00065	0.01023	0.00358	0.00208
Toxaphene	mg/L	12	1	101	1	30017	0.000002	0.000002	0.000002	0.000002
Trichloroethylene	mg/L	34	4	633	14	0.01	0.00044	0.21	0.0174	0.0017
Vinyl chloride	mg/L	25	1	591	2	0.22	0.00076	0.00289	0.00183	0.001825
Xylenes, Total	mg/L	18	1	194	1	0.00432	0.02	0.02	0.02	0.02

Table B-1. Summary Statistics for Pollutants Detected in Wastewater Discharges from E&EC Indirect Discharge Facilities

Pollutant	Units	Number of Facilities Measuring	Number of Facilities with Detects	Number of Results	Number of Detects	Toxic Weighting Factor [a]	Minimum Detected Concentration	Maximum Detected Concentration	Mean Detected Concentration	Median Detected Concentration
pH										
pH	SU	86	86	4,449	4,449	N/A	2	13	7.65	7.46

[a] Toxic weighting factors are derived from chronic aquatic life criteria and human health criteria established for the consumption of fish; they are used to compare the toxicity of one pollutant relative to another and are normalized based on the the toxicity of copper (ERG, 2007).
N/A – Not Available

Table B-2. Summary Statistics for Pollutants Detected in Wastewater Discharges from E&EC Direct Discharge Facilities

Pollutant	Units	Number of Facilities Measuring	Number of Facilities with Detects	Number of Results	Number of Detects	Toxic Weighting Factor [a]	Minimum Detected Concentration	Maximum Detected Concentration	Mean Detected Concentration	Median Detected Concentration
Total Toxic Organics	mg/L	2	2	60	54	N/A	0.00013	0.02	0.00657	0.00378
Classical Wet Chemistry										
Ammonia	mg/L	2	2	180	105	0.00111	0.01	13	4.78	5.3
BOD5	mg/L	2	2	135	132	N/A	2	8.9	5.18	5.3
Cyanide, Total	mg/L	2	2	73	29	1.11	0.004	0.16	0.0190	0.01
Dissolved oxygen	mg/L	1	1	135	135	N/A	6	8.9	7.11	7.1
Hydrogen peroxide	mg/L	1	1	90	90	N/A	0.15	3.41	0.677	0.5
Oil & Grease	mg/L	1	1	30	30	N/A	2	3	2.09	2
Phosphorus, Total	mg/L	1	1	45	45	N/A	0.077	0.248	0.148	0.141
Total dissolved solids	mg/L	1	1	90	90	N/A	833	1,430	1,116	1,108
Total residual chlorine	mg/L	1	1	45	1	0.5	0.1	0.1	0.1	0.1
Total suspended solids	mg/L	3	3	224	224	N/A	1.08	61	7.29	5.15
Anions										
Fluoride, Total	mg/L	4	4	227	227	0.03	0.17	19	9.74	10
Phosphates	mg/L	1	1	30	30	N/A	0.01	0.12	0.0488	0.04
Metals										
Aluminum, Total	mg/L	1	1	45	39	0.06	0.1	0.9	0.179	0.1
Cadmium, Total	mg/L	1	1	28	28	22.8	0.0002	0.056	0.00521	0.002

Table B-2. Summary Statistics for Pollutants Detected in Wastewater Discharges from E&EC Direct Discharge Facilities

Pollutant	Units	Number of Facilities Measuring	Number of Facilities with Detects	Number of Results	Number of Detects	Toxic Weighting Factor [a]	Minimum Detected Concentration	Maximum Detected Concentration	Mean Detected Concentration	Median Detected Concentration
Chromium, Hexavalent, Total	mg/L	1	1	46	3	0.51	0.011	0.014	0.013	0.014
Chromium, Total	mg/L	3	2	165	120	0.07	0.00011	0.56	0.0126	0.00107
Cobalt, Total	mg/L	1	1	45	1	0.11	0.006	0.006	0.006	0.006
Copper, Total	mg/L	2	2	105	102	0.623	0.013	0.092	0.0284	0.0255
Iron, Total	mg/L	2	2	105	94	0.0056	0.044	0.345	0.114	0.104
Lead, Total	mg/L	2	2	135	91	2.24	0.001	0.05	0.00155	0.001
Molybdenum, Total	mg/L	1	1	45	10	0.2	0.03	0.07	0.039	0.03
Nickel, Total	mg/L	2	1	105	90	0.1	0.008	0.186	0.0274	0.0215
Ruthenium, Total	mg/L	1	1	15	1	N/A	0.1	0.1	0.1	0.1
Silver, Total	mg/L	2	1	45	30	16.5	0.01	0.02	0.0147	0.01
Tungsten, Total	mg/L	1	1	45	26	0.00525	0.11	0.21	0.145	0.135
Zinc, Total	mg/L	2	2	150	106	0.04	0.008	0.05	0.0181	0.02
Organic Compounds										
Acetone	mg/L	1	1	15	2	0.00000846	0.006	0.007	0.0065	0.0065
Bromodichloromethane	mg/L	1	1	15	10	0.03	0.001	0.003	0.00163	0.00165
Bromoform	mg/L	1	1	15	15	0.00457	0.005	0.022	0.0119	0.01
Chloroform	mg/L	1	1	15	10	0.00208	0.001	0.002	0.00141	0.00105
Dichlorodifluoromethane	mg/L	1	1	45	1	0.000593	0.001	0.001	0.001	0.001

Table B-2. Summary Statistics for Pollutants Detected in Wastewater Discharges from E&EC Direct Discharge Facilities

Pollutant	Units	Number of Facilities Measuring	Number of Facilities with Detects	Number of Results	Number of Detects	Toxic Weighting Factor [a]	Minimum Detected Concentration	Maximum Detected Concentration	Mean Detected Concentration	Median Detected Concentration
N-Methyl-2-pyrrolidone	mg/L	1	1	45	2	N/A	0.02	0.07	0.045	0.045
Toluene	mg/L	1	1	15	2	0.00563	0.003	0.003	0.003	0.003
pH										
pH	SU	4	4	364	364	N/A	3.37	10.91	7.22	7.2

[a] Toxic weighting factors are derived from chronic aquatic life criteria and human health criteria established for the consumption of fish; they are used to compare the toxicity of one pollutant relative to another and are normalized based on the toxicity of copper (ERG, 2007).

N/A – Not Available

Table B-3 and Table B-4 provide the results of the E&EC "parameters of interest" selection criteria for indirect and direct dischargers, respectively. To be selected as a "parameter of interest," a detected analyte must meet either Criteria 1 or Criteria 2.1/2.2.

Table B-3. "Parameters of Interest" Selection Criteria Results for E&EC Indirect Discharge Facilities

Parameter	Criteria 1 40 CFR 469 Regulated Pollutant (Y/N)	Criteria 2				Pollutant of Interest? (Y/N)
		Criteria 2.1 Frequency of Detection		Criteria 2.2 Potential Environmental Concern		
		≥ 25% of Facilities (Y/N)	≥ 25% of Results (Y/N)	Toxic Weighting Factor ≥ 0.001 (Y/N)	Nutrient (Y/N)	
Total Toxic Organics						
Total Toxic Organics	Y	Y	N	N	N	Y
Classical Wet Chemistry						
Acidity, Total	N	Y	Y	N	N	N
Alkalinity	N	Y	Y	N	N	N
Ammonia	N	Y	Y	Y	Y	Y
BOD5	N	Y	Y	N	N	N
Calcium hardness	N	Y	Y	N	N	N
Carbon dioxide, free	N	Y	Y	N	N	N
CBOD	N	Y	Y	N	N	N
COD	N	Y	Y	N	N	N
Conductivity	N	Y	Y	N	N	N
Cyanide, Total	N	Y	N	Y	N	N
Dissolved oxygen	N	Y	Y	N	N	N
Fixed dissolved solids	N	Y	Y	N	N	N
Hydrogen peroxide	N	Y	Y	N	N	N
Nitrogen, Total	N	Y	Y	N	Y	Y
Oil & Grease	N	Y	Y	N	N	N
Oil & Grease, non-polar	N	Y	Y	N	N	N
Oil & Grease, polar	N	Y	Y	N	N	N
Phosphorus, Total	N	Y	Y	N	Y	Y
Total dissolved solids	N	Y	Y	N	N	N

Table B-3. "Parameters of Interest" Selection Criteria Results for E&EC Indirect Discharge Facilities

Parameter	Criteria 1 40 CFR 469 Regulated Pollutant (Y/N)	Criteria 2				Pollutant of Interest? (Y/N)
		Criteria 2.1 Frequency of Detection		Criteria 2.2 Potential Environmental Concern		
		≥ 25% of Facilities (Y/N)	≥ 25% of Results (Y/N)	Toxic Weighting Factor ≥ 0.001 (Y/N)	Nutrient (Y/N)	
Total Kjeldahl Nitrogen	N	Y	Y	N	Y	Y
Total petroleum hydrocarbons	N	Y	N	Y	N	N
Total suspended solids	N	Y	Y	N	N	N
Anions						
Bromide	N	Y	Y	N	N	N
Chloride	N	Y	Y	N	N	N
Fluoride, Total	Y	Y	Y	Y	N	Y
Nitrates	N	Y	Y	N	Y	Y
Nitrates/Nitrites	N	Y	Y	N	Y	Y
Nitrites	N	Y	Y	Y	Y	Y
Sulfates	N	Y	Y	N	N	N
Sulfides	N	Y	N	N	N	N
Metals						
Aluminum, Total	N	Y	Y	Y	N	Y
Antimony, Total	Y	Y	N	Y	N	Y
Arsenic, Total	Y	Y	Y	Y	N	Y
Barium, Total	N	Y	Y	Y	N	Y
Beryllium, Total	N	N	N	Y	N	N
Bismuth, Total	N	Y	Y	N	N	N
Boron, Total	N	Y	Y	Y	N	Y
Cadmium, Total	Y	Y	N	Y	N	Y

Table B-3. "Parameters of Interest" Selection Criteria Results for E&EC Indirect Discharge Facilities

Parameter	Criteria 1 40 CFR 469 Regulated Pollutant (Y/N)	Criteria 2				Pollutant of Interest? (Y/N)
		Criteria 2.1 Frequency of Detection		Criteria 2.2 Potential Environmental Concern		
		≥ 25% of Facilities (Y/N)	≥ 25% of Results (Y/N)	Toxic Weighting Factor ≥ 0.001 (Y/N)	Nutrient (Y/N)	
Calcium, Total	N	Y	Y	N	N	N
Cerium, Total	N	Y	Y	N	N	N
Chromium, Total	Y	Y	N	Y	N	Y
Cobalt, Total	N	Y	N	Y	N	N
Copper, Total	N	Y	Y	Y	N	Y
Gallium, Total	N	Y	Y	Y	N	Y
Iron, Total	N	Y	Y	Y	N	Y
Lead, Total	Y	Y	N	Y	N	Y
Magnesium, Total	N	Y	Y	N	N	N
Manganese, Total	N	Y	Y	Y	N	Y
Mercury, Total	N	Y	N	Y	N	N
Molybdenum, Total	N	Y	Y	Y	N	Y
Nickel, Total	N	Y	Y	Y	N	Y
Potassium, Total	N	Y	Y	Y	N	Y
Selenium, Total	N	Y	Y	Y	N	Y
Silver, Total	N	Y	N	Y	N	N
Sodium, Total	N	Y	Y	N	N	N
Tellurium, Total	N	Y	Y	Y	N	Y
Tin, Total	N	Y	N	Y	N	N
Titanium, Total	N	Y	Y	Y	N	Y
Total metals	N	Y	N	N	N	N
Vanadium, Total	N	Y	N	Y	N	N

Table B-3. "Parameters of Interest" Selection Criteria Results for E&EC Indirect Discharge Facilities

Parameter	Criteria 1 40 CFR 469 Regulated Pollutant (Y/N)	Criteria 2				Pollutant of Interest? (Y/N)
		Criteria 2.1 Frequency of Detection		Criteria 2.2 Potential Environmental Concern		
		≥ 25% of Facilities (Y/N)	≥ 25% of Results (Y/N)	Toxic Weighting Factor ≥ 0.001 (Y/N)	Nutrient (Y/N)	
Zinc, Total	Y	Y	Y	Y	N	Y
Zirconium, Total	N	Y	N	Y	N	N
Organic Compounds						
1,1,2-Trichloroethane	N	N	N	Y	N	N
1,1-Dichloroethane	N	N	N	N	N	N
1,1-Dichloroethene	N	N	N	Y	N	N
1,2,4-Triazole	N	Y	Y	N	N	N
1,2-Dichlorobenzene	N	N	N	Y	N	N
1,2-Dichloroethane	N	N	N	Y	N	N
1,3-Dichlorobenzene	N	N	N	Y	N	N
1,4-Dichlorobenzene	N	N	N	Y	N	N
2,4-Dimethylphenol	N	N	N	Y	N	N
2-Hexanone	N	N	N	N	N	N
2-Nitrophenol	N	N	N	Y	N	N
4-Bromophenyl phenyl ether	N	N	N	Y	N	N
624 Volatiles	N	N	N	N	N	N
625 Semi Volatiles	N	N	N	N	N	N
Acetone	N	Y	Y	N	N	N
Acrolein	N	N	N	Y	N	N
Benzene	N	N	N	Y	N	N
Benzidine	N	N	N	Y	N	N
Benzyl butyl phthalate	N	N	N	Y	N	N

Table B-3. "Parameters of Interest" Selection Criteria Results for E&EC Indirect Discharge Facilities

Parameter	Criteria 1 40 CFR 469 Regulated Pollutant (Y/N)	Criteria 2				Pollutant of Interest? (Y/N)
		Criteria 2.1 Frequency of Detection		Criteria 2.2 Potential Environmental Concern		
		≥ 25% of Facilities (Y/N)	≥ 25% of Results (Y/N)	Toxic Weighting Factor ≥ 0.001 (Y/N)	Nutrient (Y/N)	
Bis(2-chloroisopropyl) ether	N	N	N	Y	N	N
Bis(2-ethylhexyl) phthalate	N	Y	N	Y	N	N
Bromodichloromethane	N	Y	N	Y	N	N
Bromoform	N	Y	N	Y	N	N
Bromomethane	N	N	N	Y	N	N
Butanone	N	N	N	N	N	N
Carbon disulfide	N	Y	N	Y	N	N
Chlorobenzene	N	N	N	Y	N	N
Chloroform	N	Y	N	Y	N	N
Chloromethane	N	N	N	Y	N	N
Choline hydroxide	N	Y	Y	N	N	N
Dibromochloromethane	N	Y	N	Y	N	N
Dibutyl phthalate	N	N	N	Y	N	N
Dichloromethane	N	N	N	Y	N	N
Diethyl phthalate	N	Y	N	N	N	N
Dimethyl phthalate	N	N	N	Y	N	N
Dioctyl phthalate	N	N	N	Y	N	N
Ethylbenzene	N	N	N	Y	N	N
Isopropyl alcohol	N	Y	N	N	N	N
Naphthalene	N	N	N	Y	N	N
N-Methyl-2-pyrrolidone	N	Y	Y	N	N	N
N-Nitrosodipropylamine	N	N	N	Y	N	N

Table B-3. "Parameters of Interest" Selection Criteria Results for E&EC Indirect Discharge Facilities

Parameter	Criteria 1 40 CFR 469 Regulated Pollutant (Y/N)	Criteria 2				Pollutant of Interest? (Y/N)
		Criteria 2.1 Frequency of Detection		Criteria 2.2 Potential Environmental Concern		
		≥ 25% of Facilities (Y/N)	≥ 25% of Results (Y/N)	Toxic Weighting Factor ≥ 0.001 (Y/N)	Nutrient (Y/N)	
Pentachlorophenol	N	N	N	Y	N	N
PFOA	N	Y	Y	N	N	N
PFOS	N	Y	Y	N	N	N
Phenol	N	Y	N	Y	N	N
Pyridine	N	Y	N	Y	N	N
Tetrachloroethylene	N	N	N	Y	N	N
Toluene	N	N	N	Y	N	N
Toxaphene	N	N	N	Y	N	N
Trichloroethylene	N	N	N	Y	N	N
Vinyl chloride	N	N	N	Y	N	N
Xylenes, Total	N	N	N	Y	N	N
pH						
pH	N	Y	Y	N	N	N

Table B-4. "Parameters of Interest" Selection Criteria Results for E&EC Direct Discharge Facilities

Parameter	Criteria 1 40 CFR 469 Regulated Pollutant (Y/N)	Criteria 2				Pollutant of Interest? (Y/N)
		Criteria 2.1 Frequency of Detection		Criteria 2.2 Potential Environmental Concern		
		≥ 25% of Facilities (Y/N)	≥ 25% of Results (Y/N)	Toxic Weighting Factor ≥ 0.001 (Y/N)	Nutrient (Y/N)	
Total Toxic Organics						
Total Toxic Organics	Y	Y	Y	N	N	Y
Classical Wet Chemistry						
Ammonia	N	Y	Y	Y	Y	Y
BOD5	N	Y	Y	N	N	N
Cyanide, Total	N	Y	Y	Y	N	Y
Dissolved oxygen	N	Y	Y	N	N	N
Hydrogen peroxide	N	Y	Y	N	N	N
Oil & Grease	N	Y	Y	N	N	N
Phosphorus, Total	N	Y	Y	N	Y	Y
Total dissolved solids	N	Y	Y	N	N	N
Total residual chlorine	N	Y	N	Y	N	N
Total suspended solids	Y	Y	Y	N	N	Y
Anions						
Fluoride, Total	Y	Y	Y	Y	N	Y
Phosphates	N	Y	Y	N	Y	Y

Table B-4. "Parameters of Interest" Selection Criteria Results for E&EC Direct Discharge Facilities

Parameter	Criteria 1 40 CFR 469 Regulated Pollutant (Y/N)	Criteria 2				Pollutant of Interest? (Y/N)
		Criteria 2.1 Frequency of Detection		Criteria 2.2 Potential Environmental Concern		
		≥ 25% of Facilities (Y/N)	≥ 25% of Results (Y/N)	Toxic Weighting Factor ≥ 0.001 (Y/N)	Nutrient (Y/N)	
Metals						
Aluminum, Total	N	Y	Y	Y	N	Y
Cadmium, Total	N	Y	Y	Y	N	Y
Chromium, Hexavalent, Total	N	Y	N	Y	N	N
Chromium, Total	N	Y	Y	Y	N	Y
Cobalt, Total	N	Y	N	Y	N	N
Copper, Total	N	Y	Y	Y	N	Y
Iron, Total	N	Y	Y	Y	N	Y
Lead, Total	N	Y	Y	Y	N	Y
Molybdenum, Total	N	Y	N	Y	N	N
Nickel, Total	N	Y	Y	Y	N	Y
Ruthenium, Total	N	Y	N	N	N	N
Silver, Total	N	Y	Y	Y	N	Y
Tungsten, Total	N	Y	Y	Y	N	Y
Zinc, Total	N	Y	Y	Y	N	Y

Table B-4. "Parameters of Interest" Selection Criteria Results for E&EC Direct Discharge Facilities

Parameter	Criteria 1 40 CFR 469 Regulated Pollutant (Y/N)	Criteria 2				Pollutant of Interest? (Y/N)
		Criteria 2.1 Frequency of Detection		Criteria 2.2 Potential Environmental Concern		
		≥ 25% of Facilities (Y/N)	≥ 25% of Results (Y/N)	Toxic Weighting Factor ≥ 0.001 (Y/N)	Nutrient (Y/N)	
Organic Compounds						
Acetone	N	Y	N	N	N	N
Bromodichloromethane	N	Y	Y	Y	N	Y
Bromoform	N	Y	Y	Y	N	Y
Chloroform	N	Y	Y	Y	N	Y
Dichlorodifluoromethane	N	Y	N	N	N	N
N-Methyl-2-pyrrolidone	N	Y	N	N	N	N
Toluene	N	Y	N	Y	N	N
pH						
pH	Y	Y	Y	N	N	Y

Table B-1 and Table B-2 are box and whisker plots for detected concentrations for indirect and direct discharger parameters of interest, respectively. All plots were done in Excel and are grouped based on maximum concentration to ensure that box and whisker plots with larger maximum concentrations do not make plots with lower maximum concentrations unreadable. For box plots, the bottom and top of the box displays the 25th and 75th percentile concentrations defined as the interquartile range (IQR). The median is displayed as the horizontal line within the box. The whiskers show the relative distribution of data points outside of the IQR and represent 1.5 times the IQR. All points outside the whisker range are plotted individually. Red lines indicate the most stringent daily maximum limitations for 40 CFR 469 regulated pollutants.

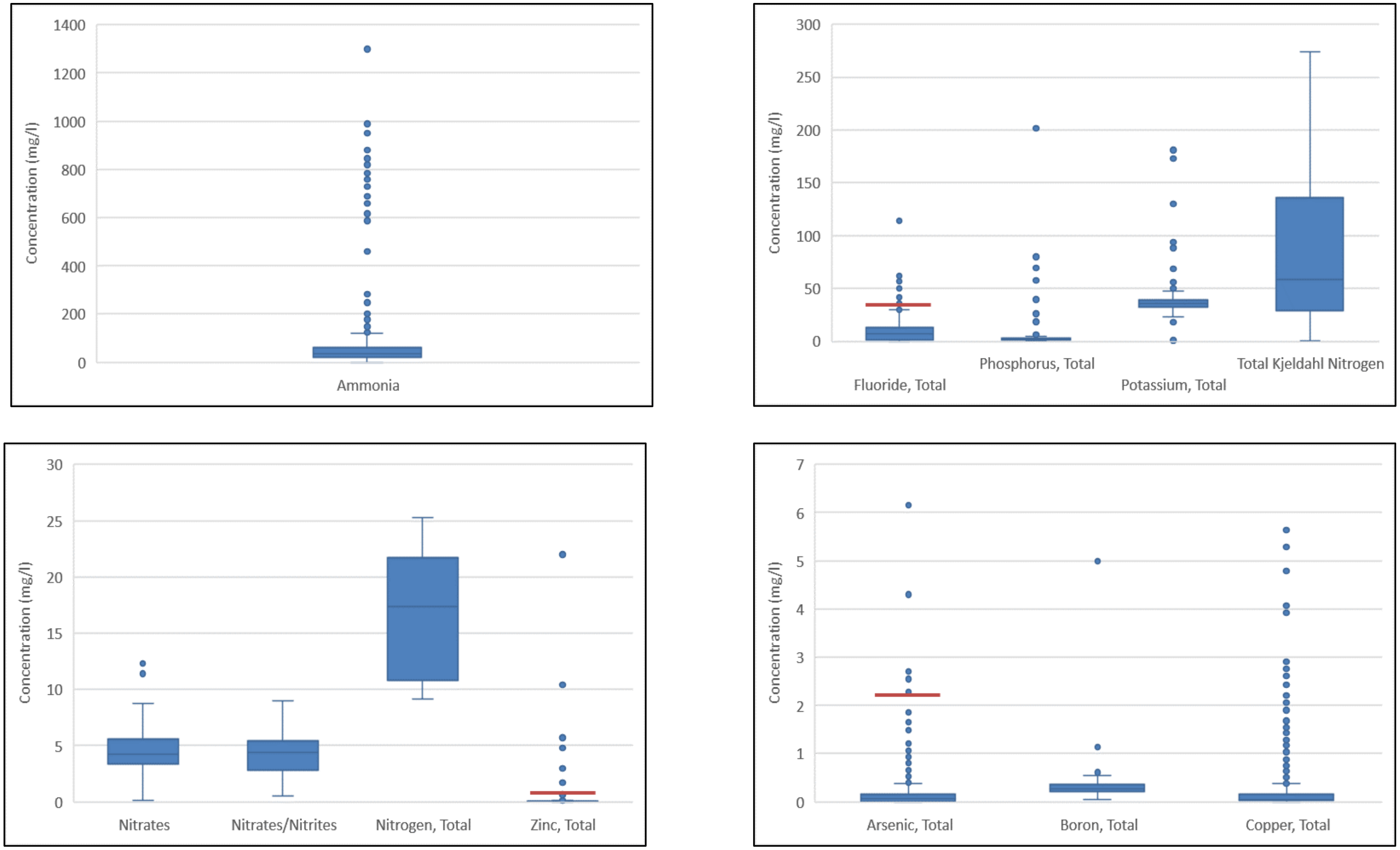

Figure B-1. Indirect Discharger “Parameters of Interest” Box and Whisker Plot

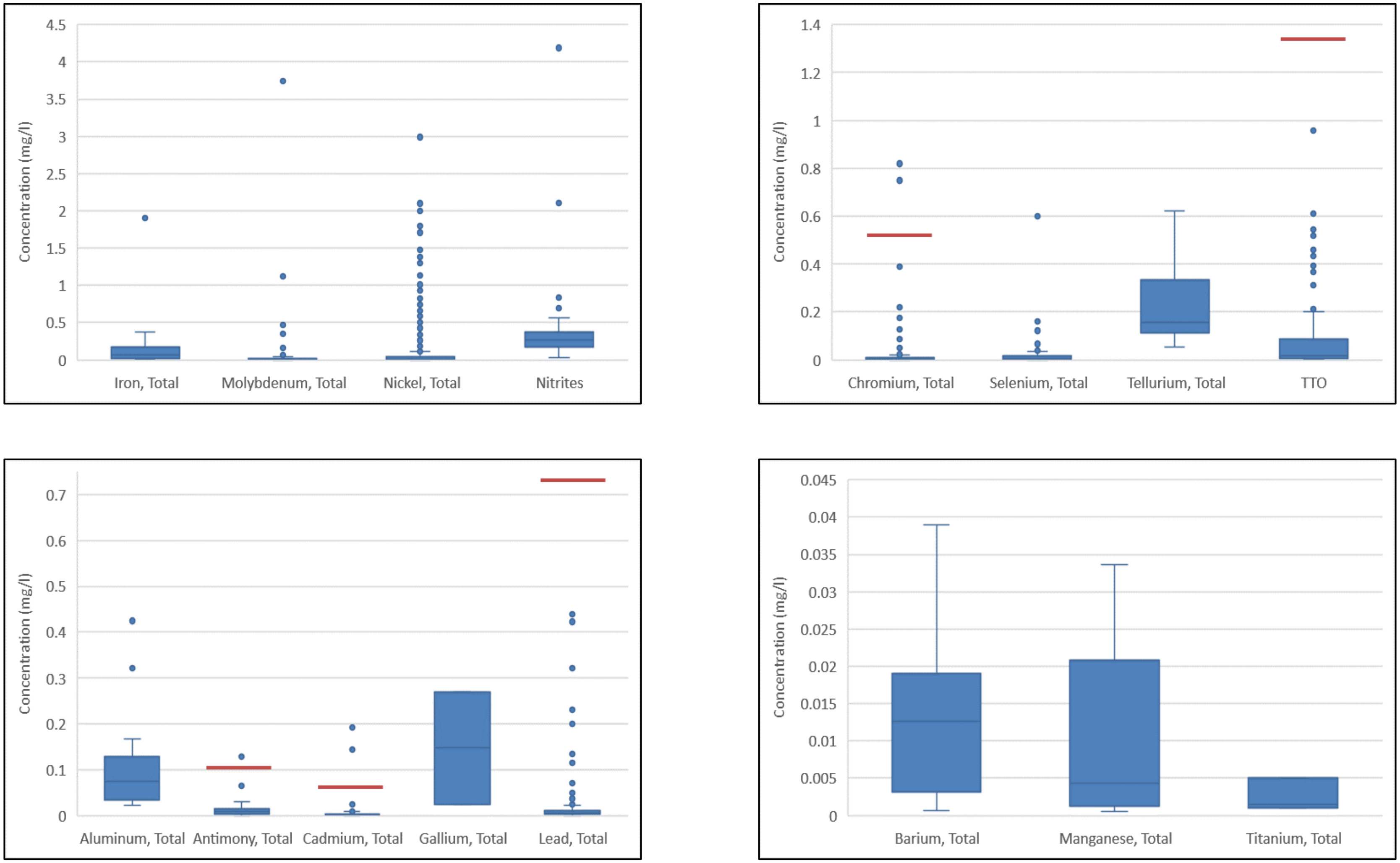

Figure B-1. (continued).

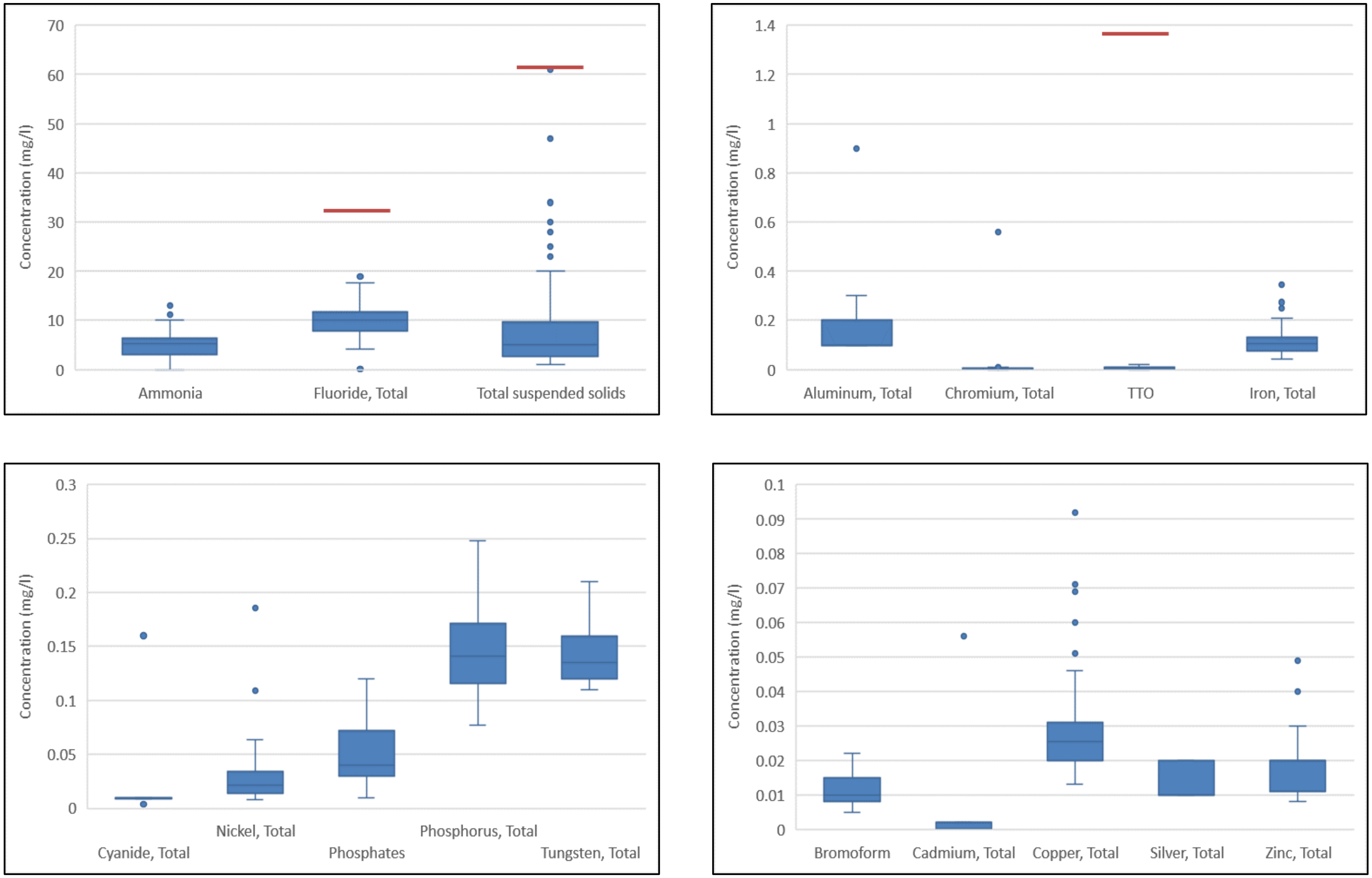

Figure B-2. Direct Discharger "Parameters of Interest" Box and Whisker Plots

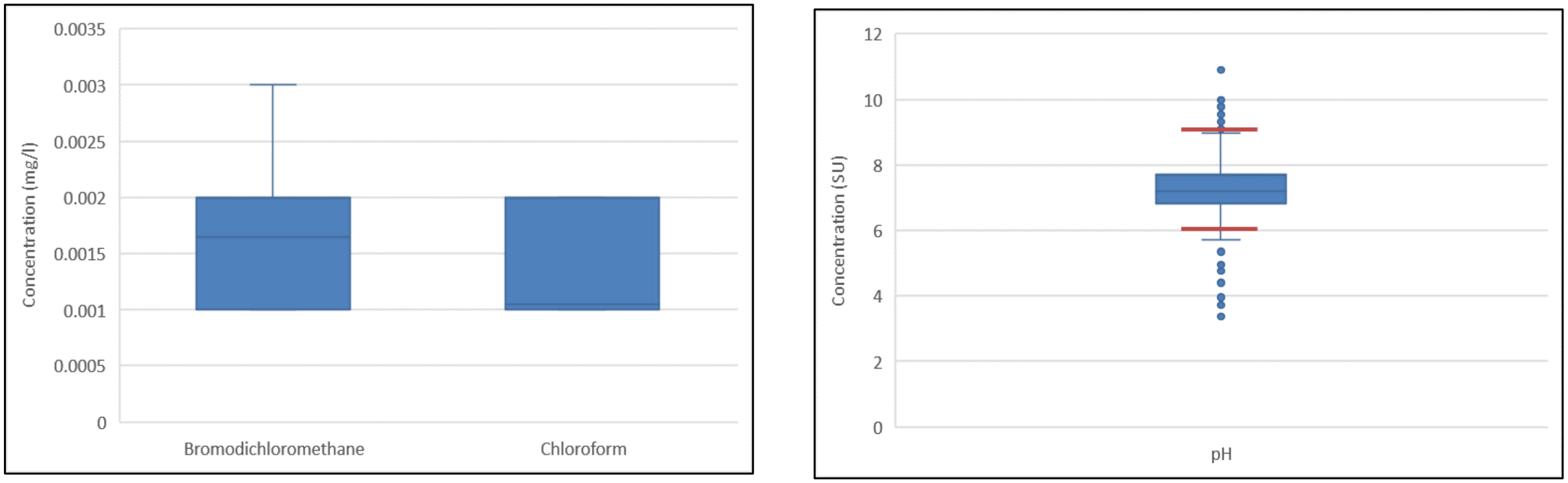

Figure B-2. (Continued)

Attachment C: Review of Potential Impacts from Indirect and Direct Discharges of E&EC Wastewaters

Table C-1. Parameters of Interest for E&EC Indirect Dischargers

Parameter	Indirect Discharge Parameter of Interest	Identified by Control Authority	Local Limit Permit Range[a] (mg/L)	Number of Permit Violations[b]	Potential Concern
Fluoride, Total	X		3 to 180	2	• Total Fluoride is regulated under 40 CFR 469 Subparts C and D for indirect dischargers. • Total Fluoride present in E&EC wastewater is from the use of hydrofluoric acid or ammonium bifluoride as an etchant or cleaning agent or as an intermediate powder in lamp phosphor production during the manufacturing process (U.S. EPA, 1983 and U.S. EPA, 1984). • There is no significant removal of fluoride by typical POTW treatment systems; therefore, pass-through of fluoride does occur (U.S. EPA, 1984). For Subparts A and B, in spite of pass-through, EPA determined that there is little likelihood of health or environmental effects from the introduction of fluoride into a POTW at the flows and concentrations observed from these industries (U.S. EPA, 1983). • Fluoride can be toxic to livestock and plants and can cause tooth mottling in humans (U.S. EPA, 1984). • Total fluoride concentrations in treated process water are typically below the daily maximum ELG limit of 35 mg/L. In EPA's wastewater characterization database, 97 percent (757/783 detected values) of total fluoride detected concentrations were less than 35 mg/L. • Both permit violations identified in the pretreatment annual reports were for one-time exceedances of the daily maximum value and were the result of equipment malfunctions and/or human error (Union Sanitary District, 2017 and City of Sunnyvale Environmental Services Department, 2019). • Control authorities did not identify total fluoride as a pollutant for further control or study.
Ammonia	X	X	25 to 662	0	• Ammonia is a "conditional" pollutant of concern for POTW pretreatment evaluations due to the potential to cause toxicity issues in POTW effluent (U.S. EPA, 2004). • Uncontrolled loadings of ammonia can cause pass-through and interference problems at the POTW (U.S. EPA, 2004).

Table C-1. Parameters of Interest for E&EC Indirect Dischargers

Parameter	Indirect Discharge Parameter of Interest	Identified by Control Authority	Local Limit Permit Range[a] (mg/L)	Number of Permit Violations[b]	Potential Concern
					• Elevated ammonia concentrations in POTW influent can increase the amount of alkalinity consumed during nitrification processes within the POTW (U.S. EPA, 2004). • Detected ammonia concentrations in indirect E&EC discharges are generally within or less than the range of typical untreated domestic wastewater (i.e., 85 percent of detected ammonia concentrations are less than 50 mg/L)c. • Site-specific concerns for ammonia may be identified due to elevated ammonia concentrations (i.e., greater than 50 mg/L) in E&EC discharges or nutrient issues within the receiving water for the POTW effluent. Site-specific ammonia concerns are addressed through local limits and ammonia surcharges. For example, Micron, a semiconductor manufacturing facility who discharges to the Upper Occoquan Service Authority (UOSA), has a local limit for ammonia but, pays an ammonia surcharge to address excess ammonia loads (ERG, 2020e). • 20 indirect discharge permits included a local limit for ammonia. • No control authorities reported issues of interference or pass-through associated with ammonia.
Nitrates	X		NLL	0	• Nutrients other than Ammonia • Nutrient loads in POTW influent can place a burden on POTWs to meet their nutrient discharge limits. Biological treatment processes designed to meet secondary treatment effluent standards • frequently do not remove total nitrogen or total phosphorus to levels low enough to protect certain receiving waters. Enhanced treatment may be required through either retrofitting the POTW to improve the biological treatment processes or to include additional chemical treatments to further precipitate phosphorus prior to discharge to surface waters (U.S. EPA, 2008).
Nitrates/Nitrites	X		NLL	0	
Nitrites	X		NLL	0	
Nitrogen, Total	X		NLL	0	
Phosphorus, Total	X		4.9 to 9	0	
Total Kjeldahl Nitrogen	X		75	0	

Table C-1. Parameters of Interest for E&EC Indirect Dischargers

Parameter	Indirect Discharge Parameter of Interest	Identified by Control Authority	Local Limit Permit Range[a] (mg/L)	Number of Permit Violations[b]	Potential Concern
					• Nutrient concerns from E&EC effluent are site-specific and are addressed through local limits at POTWs. • 3 indirect permits included local limits for nutrients other than ammonia.
Aluminum, Total	X		9.4	0	• Metals • Several metals are regulated for indirect dischargers under 40 CFR 469 Subpart C including total cadmium, total chromium, total lead, and total zinc. • Total cadmium and total zinc are also regulated under 40 CFR 469 Subpart D for indirect dischargers as well as total antimony. • Local limits for metals are often based on water quality concerns within the POTWs' receiving water. Local limits for metals are site-specific as several water quality standards and criteria for metals depend on the hardness, pH, and temperature of the receiving water (U.S. EPA, 2004). • Metals assigned local limits at greater than 90 indirect facilities include total arsenic, total cadmium, total chromium, total copper, total lead, total nickel, and total zinc. • Copper was the only metal specifically identified in EPA's discussions with control authorities as a potential industry-wide pollutant of interest (ERG, 2019b). • Total arsenic and total copper permit violations identified in the 2018 and 2019 pretreatment annual reports were isolated exceedances of the maximum allowable limits that were then resolved at the facilities (San Jose-Santa Clara Regional Wastewater Facility, 2019 and City of Sunnyvale, 2019). • The facility with the total zinc permit limit violation was unable to identify the source; this facility closed in 2018 (City of Sunnyvale, 2019).
Antimony, Total	X		0.04 to 5	0	
Arsenic, Total	X		0.047 to 15	1	
Barium, Total	X		5	0	
Boron, Total	X		1 to 20	0	
Cadmium, Total	X		0.01 to 15	0	
Chromium, Total	X		0.26 to 25	0	
Copper, Total	X	X	0.13 to 17	1	
Gallium, Total	X		NLL	0	
Iron, Total	X		5 to 250	0	
Lead, Total	X		0.039 to 40	0	
Manganese, Total	X		0.5 to 6.1	0	
Molybdenum, Total	X		0.15 to 6.58	0	
Nickel, Total	X		0.2 to 22	0	
Potassium, Total	X		NLL	0	
Selenium, Total	X		0.006 to 9.37	0	
Tellurium, Total	X		NLL	0	
Titanium, Total	X		NLL	0	

Table C-1. Parameters of Interest for E&EC Indirect Dischargers

Parameter	Indirect Discharge Parameter of Interest	Identified by Control Authority	Local Limit Permit Range[a] (mg/L)	Number of Permit Violations[b]	Potential Concern
Zinc, Total	X		0.16 to 25	1	
Total Toxic Organics	X		0.5 to 2.13	0	• TTO is regulated under 40 CFR 469 Subparts A, B, and C for indirect dischargers. • Meeting TTO permit limits are not a concern as TTO chemicals are no longer in use or many facilities manage toxic organics through solvent management plans. • 77 out of 112 indirect permits reported having solvent management plans. • TTO was only detected in 22 percent of indirect samples (182/836 detected values). When TTO was detected, it was at least 1 order of magnitude lower than the 1.37 mg/L daily maximum limit listed in 40 CFR 469 Subparts A and B.
Chloride		X	175 to 880	1	• Chloride in POTW influent can decay or prevent the formation of inorganic films and precipitates that protect sewer walls from chemical corrosion (U.S. EPA, 2004). • Chloride ions are used in copper electroplating baths to inhibit plating on areas where a reduced plating rate is desired (Dupont, 2016). Chloride ions may also be present from purchased or potable water used during manufacturing. • The Thousand Oaks City wastewater control authority, which permits discharges from two Skyworks semiconductor manufacturing facilities, stated that E&EC facilities have not had compliance issues except for slight chloride hits during droughts when water is imported (ERG, 2019b). • The City of Lompoc Regional Wastewater Reclamation Plant reported a permit violation for chloride from Raytheon in their 2018 Annual Pretreatment Report, but found no significant findings during inspection. Raytheon is reported as consistently achieving compliance (City of Lompoc, 2019). • Local limits are used to address site-specific concerns with chloride. For example, UOSA is concerned with the addition of salts, such as chloride, to

Table C-1. Parameters of Interest for E&EC Indirect Dischargers

Parameter	Indirect Discharge Parameter of Interest	Identified by Control Authority	Local Limit Permit Range[a] (mg/L)	Number of Permit Violations[b]	Potential Concern
					its receiving water which is used as a drinking water source for Fairfax County. UOSA implemented local limits to manage salt loading into the reservoir (ERG, 2020e). • 6 indirect E&EC permits have local limits for chloride.
Sulfate		X	400 to 3,660	0	• Sulfate concentrations in POTW influent can form hydrogen sulfide within collection systems through anaerobic degradation when wastewater is allowed to stagnate. The formation of hydrogen sulfide can corrode metals (e.g., iron, copper, lead, and zinc) within the treatment system. Sulfate can also corrode and crack concrete through the formation of calcium sulfate (U.S. EPA, 2004). • Sulfate in E&EC wastewater is often from copper sulfate used in copper electroplating baths (Dupont, 2016). • Austin Water noted in their discussions with EPA that they are continuing to the watch sulfate concentrations from the five E&EC facilities within their system due to potential aquatic wildlife health concerns in their receiving waters. A sulfate limit has been discussed, but not implemented as a study is currently underway to reevaluate the issue (U.S. EPA, 2019). • 5 indirect permits have local limits for sulfate.

Table C-1. Parameters of Interest for E&EC Indirect Dischargers

Parameter	Indirect Discharge Parameter of Interest	Identified by Control Authority	Local Limit Permit Range[a] (mg/L)	Number of Permit Violations[b]	Potential Concern
pH			5 to 12.5 S.U.	6	• Discharges with a pH lower than 5.0 are prohibited under the General Pretreatment Regulations unless the POTW is specifically designed to accommodate such discharges. Upper pH limits are established by the POTW at a level that is both protective of the facility and avoids characterization of the discharge as hazardous waste (i.e., pH > 12.5) (U.S. EPA, 2004). • POTWs that accept Industrial wastewater with high pH values may observe a reduction in odor emissions, aid in nitrification, improved precipitation in clarifiers, and reduction in chloride and sulfate ions in influent to the POTWs system (U.S. EPA, 2004). • pH was the most frequent parameter reported for permit limit violations in EPA's review of the 2018 and 2019 pretreatment annual reports. Durations of pH permit limit violations from E&EC facilities were often brief (e.g., 2 minutes to less than 5 hours) and then brought back within compliance.

NLL- No local limit. No indirect permits were identified with a local limit expressed as a concentration value. Some permits may contain a limit expressed as a load.

a. Permit limits presented only include parameter concentration limits based on local limits. Local limits presented include a variety of durations and frequencies including but not limited to daily maximum, monthly average, and instantaneous maximum limits. Limits reported as loads, based on other regulations (i.e., 40 CFR 433), or listed as specific prohibitions are not presented.

b. EPA identified permit limit violations for indirect E&EC dischargers by reviewing annual pretreatment reports from 2018 and 2019 from 13 wastewater control authorities.

c. Ammonia concentrations in untreated domestic wastewater typically range from 10 to 50 mg/L (U.S. EPA, 2004).

Table C-2. Parameters of Interest for E&EC Direct Discharges

Parameter	NPDES Permit Limit Range[a] (mg/L)	Number of Permit Violations[b]	Potential Concerns

Fluoride, Total	7.3 to 28	0	• Total fluoride is regulated under 40 CFR 469 Subparts A, B, C, and D for direct dischargers.
			• There are no national recommended water quality criteria (NRWQC) for total fluoride; however, EPA has established a drinking water maximum contaminant level (MCL) of 4 mg/L to be protective against bone disease and a secondary non-enforceable level of 2 mg/L for tooth mottling in children.
			• Fluoride can be toxic to livestock in drinking water at levels greater than 2 mg/L and toxic to plants in irrigation water at concentrations greater than 1 mg/L (U.S. EPA, 1984).
			• Texas and New York both have water quality standards for total fluoride.
			  ○ Texas state water quality standard for human health for the consumption of water and organisms for total fluoride is 4 mg/L. The maximum concentration of total fluoride detected in NXP Ed Bluestein was 0.24 mg/L.
			  ○ New York state water quality guidance limit for human health in freshwater for total fluoride is 1.5 mg/L with aquatic life guidance concentrations based on site-specific determinations using hardness values in receiving waters.
			  ○ The permit for GLOBALFOUNDRIES Hopewell Junction included a site-specific daily maximum limit for total fluoride of 7.3 mg/L. The maximum concentration observed in effluent from GLOBALFOUNDRIES Hopewell Junction was 7 mg/L.
			• Total fluoride concentrations in direct discharges ranged from 0.17 mg/L to 19 mg/L, well below the daily maximum concentration of 32 mg/L required under 40 CRF 469 Subparts A and B.

Ammonia	1.3 to 2.7	2	• Ammonia in surface waters can be toxic to aquatic organisms due to the potential for toxic buildup of ammonia in internal tissues and blood which can lead to death (U.S. EPA, 2013). Environmental factors such as pH and temperature can affect ammonia toxicity by altering the ability of aquatic organisms to excrete ammonia from their systems (U.S. EPA, 2013). • Ammonia concentrations in surface water also contribute to total nitrogen loads within a waterbody which can lead to problems with nutrient over-enrichment and cause indirect effects on aquatic life (U.S. EPA, 2013).

Table C-2. Parameters of Interest for E&EC Direct Discharges

Parameter	NPDES Permit Limit Range[a] (mg/L)	Number of Permit Violations[b]	Potential Concerns
			• Ammonia NRWQC are site-specific based on pH, temperature, and dependent on the life-stages of aquatic life present in the receiving water. • GLOBALFOUNDRIES Hopewell Junction's permit included water quality-based limits for seasonal monthly average ammonia concentrations of 1.3 mg/L (April to October) and 2.7 mg/L (November to March). • Ammonia was detected in 15 out of 90 samples from GLOBALFOUNDRIES Hopewell Junction. Where 80 percent of detected values were less than 0.5 mg/L. • GLOBALFOUNDRIES Hopewell Junction reported two permit violations that exceeded the seasonal average monthly limit of 2.7 and 1.3 mg/L in March and April of 2021. • Ammonia monitoring is required in GLOBALFOUNDRIES Essex Junction' permit to support nutrients monitoring for the Lake Champaign Phosphorus TMDL.
Phosphorus, Total	0.8	0	<u>Total Phosphorus and Phosphates</u>
Phosphates	10 to 15	0	• Total phosphorus is an essential nutrient for plants and organisms; however, over-enrichment of phosphorus loads in surface waters can cause adverse effects such as algae blooms, accelerated plant growth, and problems with low dissolved oxygen concentrations in surface waters. • There are no NRWQC for total phosphorus or phosphates; however, EPA has developed multiple ecoregional criteria for total phosphorus based on site-specific criteria. • GLOBALFOUNDRIES Essex Junction has a site-specific limit for total phosphorus based on the WLA set for the wastewater treatment facility onsite in support of the Lake Chaplain Phosphorus TMDL. • Siltronic Corporation has daily and monthly limits for total phosphates; however effluent concentrations are historically well below the permit limit. In the permit renewal data for the past five years, the long term daily maximum concentration of total phosphate was less than 1.1 mg/L. (Oregon Department of Environmental Quality, 2009b).

Table C-2. Parameters of Interest for E&EC Direct Discharges

Parameter	NPDES Permit Limit Range[a] (mg/L)	Number of Permit Violations[b]	Potential Concerns
TSS	10.5 to 40	2	• TSS is regulated under 40 CFR 469 Subparts B, C, and D for direct dischargers. • NRWQC for total suspended solids is expressed as a narrative criterion that states TSS should not lower the compensation point for photosynthetic activity by more than 10 percent in surface waters (U.S. EPA, 1986). • Site-specific limits for TSS were set for 2 of 4 the direct discharge facilities.
Cyanide, Total	0.06	0	• Total cyanide is regulated under 40 CFR 433 for metal finishing processing facilities. • EPA has issued NRWQC for cyanide for both aquatic life and human health. Aquatic life NRWQC for freshwater are expressed as free cyanide with acute criteria set at 0.022 mg/L and chronic criteria at 0.0052 mg/L. The NRWQC for total cyanide for human health for the consumption of water and organisms is 0.004 mg/L and water only is 0.4 mg/L. • 1 direct discharge facility has a water quality-based permit limit for total cyanide. • 1 direct discharge facility has water quality-based permit limits for free cyanide ranging from 0.65 mg/L to 1.2 mg/L. • Total cyanide was detected in 29 out of 73 samples with 28 detects coming from GLOBALFOUNDRIES Essex Junction who is regulated under both 40 CFR 433 and 40 CFR 469 Subpart B. • Detected values ranged from 0.004 mg/L to 0.16 mg/L with 27 out of 29 detected values reported at concentrations equal to or lower than 0.01 mg/L.
Arsenic, Total	0.1	0	<u>Metals</u> • No metals are regulated under 40 CFR 469 Subpart A • Total arsenic is regulated under 40 CFR 469 Subpart B for discharges from gallium or indium arsenide crystal manufacturing facilities. • Total cadmium and total zinc are both regulated under 40 CFR 469 Subparts C and D for direct dischargers. • Total chromium and total lead are both regulated under 40 CFR 469 Subparts C for direct dischargers. • Multiple metals in E&EC direct discharges have NRWQC for aquatic life and human health. NRWQC for metals are often presented as the dissolved concentration and are
Aluminum, Total	1	0	
Cadmium, Total	NL	0	
Chromium, Total	0.02 to 0.5	0	
Copper, Total	NL	0	
Iron, Total	NL	0	
Lead, Total	0.08	0	
Nickel, Total	NL	0	
Silver, Total	NL	0	
Tungsten, Total	3.75	0	
Zinc, Total	0.36	0	

Table C-2. Parameters of Interest for E&EC Direct Discharges

Parameter	NPDES Permit Limit Range[a] (mg/L)	Number of Permit Violations[b]	Potential Concerns
			calculated based on site-specific environmental parameters such as the pH and or hardness of the surface water. • 3 out of the 4 direct dischargers included at least 1 or more water quality-based limits for a metal. • Detected concentrations for metals were below water quality-based limits identified in the permits with the following maximum concentrations detected for total metals: aluminum (0.9 mg/L), cadmium (0.056 mg/L), chromium (0.56 mg/L), lead (0.05mg/L), and zinc (0.05 mg/L). • Total arsenic was not detected in any of the 45 direct discharge samples in the wastewater characterization database.
Total Toxic Organics	2.74	0	• TTO is regulated under 40 CFR 469 Subparts A, B, and C for direct dischargers. • There are no NRWQC for TTO. • 1 facility included a limit for TTO of 2.74 mg/L for a single grab sample. • 1 direct discharge E&EC facility has a solvent management plan to manage TTO discharges. • The maximum detected concentration of TTO in direct discharges was 0.02 mg/L.
Bromodichloromethane	NL	0	Disinfection byproducts: bromodichloromethane, bromoform, and chloroform • GLOBALFOUNDRIES Hopewell Junction's NPDES permit included monitoring action levels limits which require additional monitoring if the limits are exceeded within specified consecutive sampling events. • E&EC process wastewater at GLOBALFOUNDRIES Hopewell Junction is comingled with treated sanitary and groundwater. Due to the comingling of wastewaters, the exact source of chloroform is unknown.
Bromoform	NL	0	
Chloroform	NL	0	

Table C-2. Parameters of Interest for E&EC Direct Discharges

Parameter	NPDES Permit Limit Range[a] (mg/L)	Number of Permit Violations[b]	Potential Concerns
pH	6.5 to 8.5 S.U.	1	• In surface waters, pH plays a critical role in many chemical and biological processes. For example, the dissolved concentration of metals, and the resulting level of toxicity, are often controlled by the pH in surface waters (U.S. EPA, 1986). • The NRWQC for freshwater aquatic life is 6.5 to 9 S.U. • 2 facilities included site-specific limits for pH that were more restrictive than the limits required under 40 CFR 469. • GLOBALFOUNDRIES Essex Junction reported 1 exceedance of the daily pH maximum value of 8.5 in May 2021 with a daily pH value of 8.8.

NL- No site-specific limit. No direct permits were identified with a site-specific limit expressed as a concentration value. Some permits may contain a limit expressed as a load.

NPDES permit limit ranges presented exclude limits from 40 CFR 469.

Permit limit violations were identified by reviewing discharge monitoring data available in ECHO from 1/1/2018 to 5/31/2021.