

# **Evaluation of Emerging Contaminant Data at Solid Waste Facilities**

Prepared for

Minnesota Pollution Control Agency – Closed Landfill Program

May 2020



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## Abbreviations

|              |                                                                                                                                                                                            |
|--------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| AHC          | Agglomerative Hierarchical Cluster analysis                                                                                                                                                |
| CLP          | Closed Landfill Program                                                                                                                                                                    |
| EC           | Emerging Contaminants                                                                                                                                                                      |
| HBV          | Minnesota Health-Based Value                                                                                                                                                               |
| HRL          | Minnesota Health Risk Limit                                                                                                                                                                |
| µg/L         | microgram per liter, typical reporting units for various analytes in water, equivalent to ppb for water samples with a density of 1 gram per centiliter (i.e., low total dissolved solids) |
| MPCA         | Minnesota Pollution Control Agency                                                                                                                                                         |
| PFAS         | Per- and polyfluoroalkyl substances                                                                                                                                                        |
| PFBS         | Perfluorobutanesulfonic acid                                                                                                                                                               |
| PFDA         | Perfluorodecanoic acid                                                                                                                                                                     |
| PFDoA/PFDoDA | Perfluorododecanoic acid                                                                                                                                                                   |
| PFDS         | Perfluorodecane sulfonate                                                                                                                                                                  |
| PFHpA        | Perfluoroheptanoic acid                                                                                                                                                                    |
| PFHxA        | Perfluorohexanoic acid                                                                                                                                                                     |
| PFHpA        | Perfluoroheptanoic acid                                                                                                                                                                    |
| PFHxS        | Perfluorohexanesulfonic acid                                                                                                                                                               |
| PFNA         | Perfluorononanoic acid                                                                                                                                                                     |
| PFOA         | Perfluorooctanoic acid                                                                                                                                                                     |
| PFOS         | Perfluorooctanesulfonic acid                                                                                                                                                               |
| PFOSA/FOSA   | Perfluorooctane-sulfonamide                                                                                                                                                                |
| PFPeA        | Perfluoropentanoic acid                                                                                                                                                                    |
| PFUnA/PFUnDA | Perfluoroundecanoic acid                                                                                                                                                                   |

## Disclaimers

The purpose of this study was to assess the distribution and range of available emerging contaminant data for waste disposal sites in Minnesota. Data provided by MPCA were assumed to be accurate and minimal QA/QC of the raw data was conducted. Where referenced, regulatory guidance/values were used to provide a point of reference and are not intended to indicate the need for specific additional actions at specific facilities, which is beyond the scope of this study and should involve a wider consideration of each facility's unique conditions and setting. No attempt was made to evaluate sample locations in relation to groundwater flow at a site or potential neighboring sources of groundwater contamination. It is assumed that concentrations in groundwater are associated with the waste disposal site. However, it is possible that concentrations observed in groundwater at some locations may also be affected by other nearby release sites and/or represent background conditions for a larger area.

## Certifications

I hereby certify that this plan, document, or report was prepared by me or under my direct supervision and that I am a duly Licensed Professional Geologist under the laws of the state of Minnesota.



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Evan G. Christianson  
PG #: 51379

6/2/2020

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Date

# Evaluation of Emerging Contaminant Data at Solid Waste Facilities

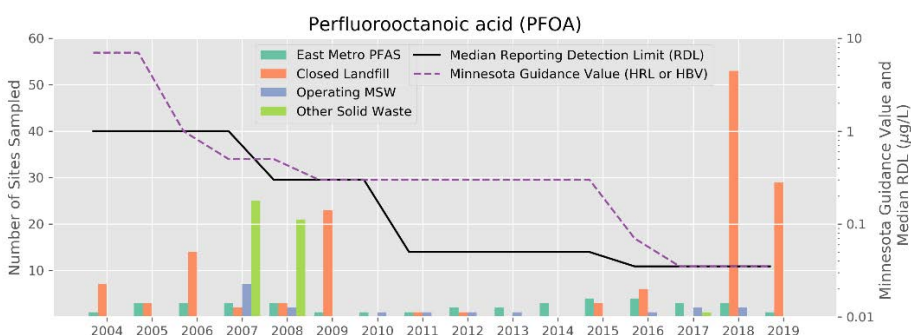
## Executive Summary

### SUMMARY

Emerging contaminants (ECs) are those contaminants for which there is new awareness regarding how they move in the environment or affect public health. The emerging contaminants Per- and polyfluoroalkyl substances (PFAS) and 1,4-dioxane may be associated with many landfills and other solid waste facilities. This study compiles available data from the MPCA for these ECs in the closed landfill program (CLP), other operating solid waste facilities across Minnesota, and similar sites known to be sources of PFAS in the eastern Twin Cities Metropolitan Area. These data were then summarized and analyzed to evaluate trends, correlations, and summary statistics to better understand the potential distribution of these ECs present at CLP sites and similar facilities.

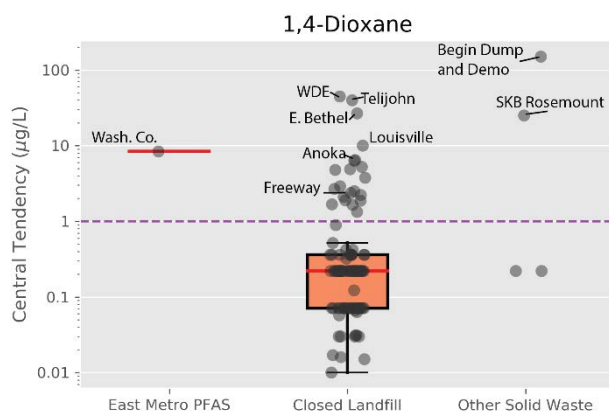
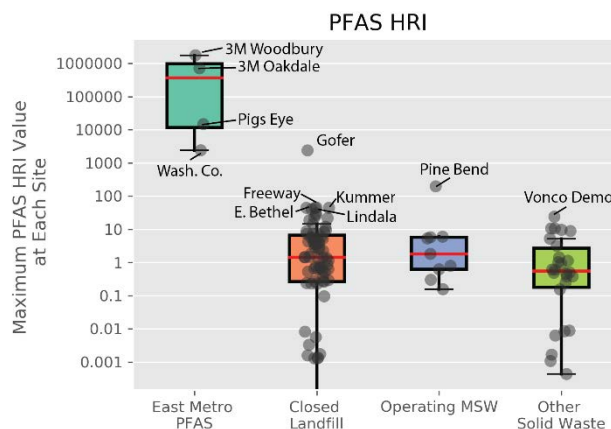
### DATA AVAILABILITY

Over the past fifteen years, both the laboratory detection limits and the regulatory standards for PFAS have decreased significantly. Much of the available PFAS data was collected in the past two years at CLP sites, or is from 2006-2009 when regulatory guidance values and laboratory reporting limits were up to an order of magnitude greater than today. With the exception of closed landfills, there are very little data available for 1,4-dioxane at solid waste facilities.



### PFAS

The distribution of PFAS in groundwater near the known sources in the east metro (including the Washington County Landfill) are distinct and typically much higher than most other solid waste facilities. However, near many facilities the composite Health Risk Index (HRI) values for PFAS are greater than 1.0 indicating possible exceedance of regulatory guidance. For sites within the CLP, 56 percent of sites had a maximum HRI for PFAS greater than 1.0. PFOA, PFOS and PFHxS are the most common PFAS detected at solid waste facilities above drinking water guidance values. PFBS and PFBA are typically not detected above the drinking water guidance values.



### 1,4-Dioxane

With the exception of the CLP sites, very little data are available for 1,4-dioxane in groundwater near solid waste facilities. Within the CLP sites, 25 percent of the facilities with data for 1,4-dioxane had an average concentration greater than the Minnesota drinking water guidance value of 1 µg/L. 1,4-dioxane was found to be correlated with many volatile organic compounds, indicating facilities with historically high groundwater concentrations for some VOCs may have concentrations of 1,4-dioxane at levels of concern.

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# 1 Introduction

A study was conducted of available public data provided by the Minnesota Pollution Control Agency (MPCA) to better understand the range of emerging contaminants (ECs) at waste disposal sites in Minnesota. In recent years, MPCA has increased sampling for ECs at waste disposal sites, particularly in water samples related to groundwater monitoring, waste leachate, or related groundwater remediation systems.

Emerging contaminants are those contaminants for which there is new awareness regarding how they move in the environment or affect public health. Often these contaminants have been in the environment for some time but have typically not been tested for, either because laboratory techniques did not exist to test at low concentrations or there was lack of awareness that they may be present and of concern for public health or the environment.

Per- and polyfluoroalkyl substances (PFAS) and 1,4-dioxane are emerging contaminants of concern that may be associated with many landfills and other solid waste facilities. While in some contexts these contaminants are no longer emerging, as awareness of their presence has been growing for over a decade, the regulatory standards for these contaminants have been lowered over the last several years as new research is conducted and new analytical methods have reduced laboratory detection limits. Today's regulatory standards for PFAS are well below what were the laboratory detection limits less than 10 years ago.

It was only recently that these contaminants have been tested for at and near closed landfills within the Closed Landfill Program (CLP). This study compiles all available data for these emerging contaminants at facilities within the CLP and other solid waste facilities outside of the CLP across Minnesota. Data were also compiled for similar sites that the MPCA determined to be sources of PFAS in the eastern Twin Cities Metropolitan Area. These data were then summarized and analyzed to evaluate trends, correlations, and summary statistics to better understand the potential prevalence and risk of these emerging contaminants at closed landfill and similar facilities.

## 1.1 PFAS

PFAS were used in the manufacture of a wide range of products, including Teflon™, breathable water-proof fabrics, carpet and textile coatings, treated food wrappers, wire coatings, non-stick cookware, aqueous fire-fighting foam (AFFF), concrete and rock sealants, electrical capacitors, dyes, paints and coatings, batteries, photographic films, printing inks, herbicide and pesticide formulations, car wash surfactants, and as a vapor suppressor in metal plating processes (Kissa, 2001; 3M, 1999; Knepper and Langue, 2012). They are a ubiquitous presence in most households and consequently are found in municipal waste streams and in most landfills (Busch et al., 2009; MPCA, 2009).

The fluorine-carbon bond is one of the strongest chemical bonds and gives products made with PFAS the highly desirable properties of chemical, heat, and oil resistance; physical durability; and low electrical conductivity. Most PFAS are highly soluble in water and are resistant to degradation. They adsorb poorly

to material with low organic material content, and when they bond, it is typically to surfaces of organic material. In saturated, unconsolidated deposits and fractured rock media, they are mobile and migrate similar to an unattenuated solute in flowing groundwater.

The most commonly studied PFAS are perfluorooctanoic acid (PFOA) and perfluorooctane sulfonate (PFOS). These are the eight-carbon chained molecules that were historically used in the majority of PFAS containing products. PFOA (perfluorooctanoic acid) is one of a class of fluorinated hydrocarbon compounds associated with fluoropolymers – most commonly recognized as Teflon®. PFOA and PFOS are no longer produced in North America.

Minnesota has established drinking water guidance values for five different PFAS (Table 1). The guidance values for these PFAS compounds have changed relatively frequently over the last decade as more studies and additional information have become available. These five PFAS are also the most common PFAS that are sampled for at solid waste facilities in Minnesota.

**Table 1 Minnesota Guidance Values for PFAS in Drinking Water**

| PFAS                                           | Minnesota Drinking Water Guidance Value (micrograms per liter (µg/L)) |
|------------------------------------------------|-----------------------------------------------------------------------|
| Perfluorobutane Sulfonate (PFBS) <sup>2</sup>  | 2                                                                     |
| Perfluorohexane Sulfonate (PFHxS) <sup>2</sup> | 0.047                                                                 |
| Perfluorooctane Sulfonate (PFOS) <sup>2</sup>  | 0.015                                                                 |
| Perfluorobutanoic Acid (PFBA) <sup>1</sup>     | 7                                                                     |
| Perfluorooctanoic Acid (PFOA) <sup>1</sup>     | 0.035                                                                 |

(1) Values are Minnesota Health Risk Limit (HRL)

(2) Values are Minnesota Health-Based Value (HBV)

According to the Minnesota Department of Health (MDH), an HBV or HRL is the level of a contaminant that can be present in water and pose little or no health risk to a person drinking that water. HBVs and HRLs were developed to protect sensitive or highly exposed populations (MDH, 2020).

## 1.2 1,4-Dioxane

1,4-dioxane is most often associated with chlorinated solvents as it was commonly used as a stabilizer/preservative for solvent products. As a result, 1,4-dioxane can be present at chlorinated solvent release sites. 1,4-dioxane is very miscible in water, does not volatilize easily, adsorbs poorly to soil, and is resistant to degradation. Therefore, 1,4-dioxane is highly mobile in groundwater. Additionally, water impacted with 1,4-dioxane presents additional challenges as it cannot be treated with carbon-based

treatment technologies that are often used for the remediation of chlorinated solvents sites. The current Minnesota HRL for 1,4-Dioxane is 1 µg/L.

## 2 Data Availability

Analytical data were provided from the MPCA's EQuIS™ database, including data from 109 CLP sites, 124 permitted solid waste facilities, and three former disposal areas within the eastern Twin Cities metropolitan area that are known sources of PFAS and have been part of the MPCA superfund program (east metro PFAS sites). These include Pigs Eye Dump, 3M Oakdale Disposal Site, and 3M Woodbury Disposal Site. The data provided included all analytical results in the database, including both emerging contaminants and data for analytes and parameters that have traditionally been monitored at waste facilities for decades such as: volatile organic compounds (VOCs), metals, and polychlorinated biphenyls (PCBs). For the east metro sites, data were available from the MPCA's EQuIS™ database for the 3M Woodbury Disposal Site and the Pigs Eye Dump. PFAS data for the 3M Oakdale Disposal Site were obtained from the 2018 annual PFAS monitoring report (Weston, 2019), provided by MPCA. In total, 5,956,217 records from 236 waste disposal sites were included in the dataset used for this study.

Data provided by MPCA were assumed to be accurate and minimal QA/QC of the raw data was conducted. Much of the data was processed to allow for consistent units and was converted to units of µg/L when possible. During the process of unit conversion some samples were noted to have units that were not consistent with the media being evaluated (e.g. units of µg/kg for a water concentration). These data were excluded and not considered for further analysis. Also, data from laboratory blanks, duplicates, gas extraction, soil gas, finished water, and storm water were not included in the analysis.

Many samples from closed landfills include locations within the footprint of the waste. When comparing to groundwater from other facilities these samples were excluded as they often represent results from targeted investigations and are not applicable when comparing to compliance monitoring from other facilities.

### 2.1 Grouping of Facility Types

For comparative purposes, four groups were established based on the type of site: closed landfills, sites in the east metro that are known sources of PFAS, operating solid waste facilities that accept mixed municipal solid waste (MSW), and all other permitted solid waste facilities. The Washington County landfill, which is part of the closed landfill program, has also been identified by MPCA as a source of PFAS in the east metro, in part due to the former legal disposal by 3M of industrial wastes from the manufacture of PFAS-containing materials. Waste from the Washington County Landfill was excavated and placed on a liner system in 2011. Due to the unique history of Washington County Landfill, it is more similar to other east metro PFAS sites than typical closed landfills. For the purpose of this study, Washington County Landfill is typically grouped with the east metro PFAS sites rather than the closed landfill sites. Additional discussion of the unique characteristics of Washington County Landfill compared to other closed landfills is presented throughout this report.

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The Pigs Eye dump is located in the east metro and is a known source of PFAS in groundwater and surface water. This site is administered under the superfund program and for the purpose of the study is grouped with the east metro PFAS sites. Sites that do not fit the categories of CLP, East Metro PFAS sites, or operating MSW sites are grouped together as “other solid waste” facilities. This group primarily consists of demolition landfills but also includes specialty facilities that accept industrial waste.

The geographic extent and number of monitoring locations for data associated with the 3M Woodbury Disposal Site and the Washington County Landfill is much more expansive than all other locations evaluated as part of this study. These sites are known sources of PFAS in southern Washington County and large scale regional groundwater sampling has been conducted surrounding these sites to an extent that is not typical of most sites. To allow for better comparison of Washington County Landfill and 3M Woodbury Disposal Site to the others sites evaluated for this study, and to prevent the large regional nature of the sampling from skewing summary statistics, only monitoring locations within approximately two miles of each of the these sites were used. Figure 1 shows the monitoring locations associated with these two sites and which monitoring locations were included for this study.

Table 2 presents the availability of groundwater data for PFAS and 1,4-dioxane amongst the different facility groups reviewed for this study and the percent of samples that had detections for each analyte. The dataset available for the CLP sites is much more comprehensive than the operating MSW and other solid waste facilities. MPCA has very limited data for 1,4-dioxane for facilities outside of the CLP. There are no available results of 1,4-dioxane in groundwater for currently operating landfills that accept mixed municipal solid waste. As would be expected, there are significantly more data for the five regulated PFAS (PFOA, PFOS, PFBS, PFBA, and PFHxS) compared to the non-regulated PFAS. The most commonly detected emerging contaminant for the closed landfill facilities was PFBA, which was detected at 88.0 percent of the closed landfill facilities and 60.4 percent of closed landfill monitoring locations.

PFOA, PFHpA, and 1,4-dioxane were detected at similar frequencies at closed landfill facilities. PFOA was detected at 80.0 percent of closed landfills and at 36.5 percent of closed landfill monitoring locations. PFHpA, which is not regulated, was detected at 84.0 percent of closed landfills and at 44.0 percent of monitoring locations. 1,4-dioxane was detected at 83.2 percent of closed landfills and at 38.6 percent of monitoring locations. Regulated PFAS were detected with greater frequency at operating landfills that currently accept MSW when compared to closed landfills, though the sample size from the operating MSW group is much smaller than what is available for the closed landfill group. Due to the lack of available data for non-regulated PFAS, the majority of the analyses conducted did not include non-regulated PFAS.







**Table 2 Availability of Data for PFAS and 1,4-Dioxane**

| Analyte                              | Facility Type     | Number of Samples | Percent of Samples with Detections | Number of Wells Sampled | Percent of Wells with Detections | Number of Facilities | Percent of Facilities with Detections |
|--------------------------------------|-------------------|-------------------|------------------------------------|-------------------------|----------------------------------|----------------------|---------------------------------------|
| 1,4-Dioxane                          | Closed Landfill   | 3624              | 40.0%                              | 1485                    | 38.6%                            | 101                  | 83.2%                                 |
|                                      | Operating MSW     | 0                 | --                                 | 0                       | --                               | 0                    | --                                    |
|                                      | Other Solid Waste | 34                | 2.9%                               | 27                      | 3.7%                             | 4                    | 25.0%                                 |
|                                      | East Metro PFAS   | 117               | 60.7%                              | 33                      | 60.6%                            | 1                    | 100.0%                                |
| Perfluorooctanoic acid (PFOA)        | Closed Landfill   | 994               | 35.3%                              | 616                     | 36.5%                            | 75                   | 80.0%                                 |
|                                      | Operating MSW     | 117               | 53.0%                              | 58                      | 63.8%                            | 9                    | 100.0%                                |
|                                      | Other Solid Waste | 147               | 34.0%                              | 81                      | 39.5%                            | 26                   | 73.1%                                 |
|                                      | East Metro PFAS   | 1743              | 67.7%                              | 253                     | 64.8%                            | 4                    | 100.0%                                |
| Perfluorooctane sulfonic acid (PFOS) | Closed Landfill   | 991               | 18.4%                              | 613                     | 20.2%                            | 75                   | 48.0%                                 |
|                                      | Operating MSW     | 117               | 36.8%                              | 58                      | 37.9%                            | 9                    | 55.6%                                 |
|                                      | Other Solid Waste | 147               | 8.8%                               | 81                      | 12.3%                            | 26                   | 34.6%                                 |
|                                      | East Metro PFAS   | 1760              | 50.0%                              | 253                     | 56.1%                            | 4                    | 100.0%                                |
| Perfluorobutane-sulfonate (PFBS)     | Closed Landfill   | 942               | 19.5%                              | 608                     | 21.2%                            | 75                   | 46.7%                                 |
|                                      | Operating MSW     | 117               | 43.6%                              | 58                      | 44.8%                            | 9                    | 66.7%                                 |
|                                      | Other Solid Waste | 147               | 17.7%                              | 81                      | 22.2%                            | 26                   | 50.0%                                 |
|                                      | East Metro PFAS   | 1816              | 40.7%                              | 253                     | 57.3%                            | 4                    | 100.0%                                |
| Perfluorobutanoic acid (PFBA)        | Closed Landfill   | 942               | 59.7%                              | 608                     | 60.4%                            | 75                   | 88.0%                                 |
|                                      | Operating MSW     | 117               | 80.3%                              | 58                      | 81.0%                            | 9                    | 100.0%                                |
|                                      | Other Solid Waste | 147               | 70.1%                              | 81                      | 76.5%                            | 26                   | 100.0%                                |
|                                      | East Metro PFAS   | 1606              | 85.9%                              | 249                     | 89.2%                            | 4                    | 100.0%                                |
| Perfluorohexane sulfonate (PFHxS)    | Closed Landfill   | 942               | 19.4%                              | 608                     | 19.9%                            | 75                   | 42.7%                                 |
|                                      | Operating MSW     | 117               | 36.8%                              | 58                      | 39.7%                            | 9                    | 66.7%                                 |
|                                      | Other Solid Waste | 147               | 24.5%                              | 81                      | 27.2%                            | 26                   | 50.0%                                 |
|                                      | East Metro PFAS   | 1329              | 50.9%                              | 232                     | 58.2%                            | 4                    | 100.0%                                |
| Perfluorodecane sulfonate (PFDS)     | Closed Landfill   | 5                 | 0.0%                               | 5                       | 0.0%                             | 1                    | 0.0%                                  |
|                                      | Operating MSW     | 60                | 6.7%                               | 24                      | 8.3%                             | 2                    | 50.0%                                 |
|                                      | Other Solid Waste | 0                 | --                                 | 0                       | --                               | 0                    | --                                    |
|                                      | East Metro PFAS   | 0                 | --                                 | 0                       | --                               | 0                    | --                                    |

**Table 2 (continued)**

| Analyte                                    | Facility Type     | Number of Samples | Percent of Samples with Detections | Number of Wells Sampled | Percent of Wells with Detections | Number of Facilities | Percent of Facilities with Detections |
|--------------------------------------------|-------------------|-------------------|------------------------------------|-------------------------|----------------------------------|----------------------|---------------------------------------|
| Perfluorodecanoic acid (PFDA)              | Closed Landfill   | 246               | 10.2%                              | 125                     | 12.8%                            | 25                   | 16.0%                                 |
|                                            | Operating MSW     | 117               | 2.6%                               | 58                      | 3.4%                             | 9                    | 11.1%                                 |
|                                            | Other Solid Waste | 145               | 4.8%                               | 79                      | 6.3%                             | 25                   | 12.0%                                 |
|                                            | East Metro PFAS   | 362               | 45.6%                              | 64                      | 71.9%                            | 3                    | 100.0%                                |
| Perfluorododecanoic acid (PFDoA / PFDoDA)  | Closed Landfill   | 246               | 10.2%                              | 125                     | 12.8%                            | 25                   | 16.0%                                 |
|                                            | Operating MSW     | 117               | 0.9%                               | 58                      | 1.7%                             | 9                    | 11.1%                                 |
|                                            | Other Solid Waste | 145               | 0.0%                               | 79                      | 0.0%                             | 25                   | 0.0%                                  |
|                                            | East Metro PFAS   | 370               | 15.9%                              | 64                      | 48.4%                            | 3                    | 100.0%                                |
| Perfluoroheptanoic acid (PFHpA)            | Closed Landfill   | 246               | 37.4%                              | 125                     | 44.0%                            | 25                   | 84.0%                                 |
|                                            | Operating MSW     | 117               | 48.7%                              | 58                      | 58.6%                            | 9                    | 77.8%                                 |
|                                            | Other Solid Waste | 145               | 30.3%                              | 79                      | 32.9%                            | 25                   | 64.0%                                 |
|                                            | East Metro PFAS   | 198               | 84.3%                              | 30                      | 86.7%                            | 2                    | 100.0%                                |
| Perfluorohexanoic acid (PFHxA)             | Closed Landfill   | 942               | 31.7%                              | 608                     | 31.7%                            | 75                   | 66.7%                                 |
|                                            | Operating MSW     | 117               | 70.9%                              | 58                      | 75.9%                            | 9                    | 100.0%                                |
|                                            | Other Solid Waste | 147               | 42.9%                              | 81                      | 45.7%                            | 26                   | 80.8%                                 |
|                                            | East Metro PFAS   | 1496              | 61.2%                              | 247                     | 63.2%                            | 4                    | 100.0%                                |
| Perfluorononanoic acid (PFNA)              | Closed Landfill   | 246               | 13.4%                              | 125                     | 16.8%                            | 25                   | 32.0%                                 |
|                                            | Operating MSW     | 117               | 4.3%                               | 58                      | 6.9%                             | 9                    | 22.2%                                 |
|                                            | Other Solid Waste | 145               | 5.5%                               | 79                      | 7.6%                             | 25                   | 12.0%                                 |
|                                            | East Metro PFAS   | 368               | 51.9%                              | 64                      | 75.0%                            | 3                    | 100.0%                                |
| Perfluorooctane-sulfonamide (PFOSA / FOSA) | Closed Landfill   | 246               | 11.0%                              | 125                     | 14.4%                            | 25                   | 16.0%                                 |
|                                            | Operating MSW     | 117               | 8.5%                               | 58                      | 13.8%                            | 9                    | 22.2%                                 |
|                                            | Other Solid Waste | 145               | 0.0%                               | 79                      | 0.0%                             | 25                   | 0.0%                                  |
|                                            | East Metro PFAS   | 0                 | --                                 | 0                       | --                               | 0                    | --                                    |
| Perfluoropentanoic acid (PFPeA)            | Closed Landfill   | 942               | 34.7%                              | 608                     | 37.2%                            | 75                   | 72.0%                                 |
|                                            | Operating MSW     | 117               | 65.0%                              | 58                      | 69.0%                            | 9                    | 77.8%                                 |
|                                            | Other Solid Waste | 0                 | --                                 | 0                       | --                               | 0                    | --                                    |
|                                            | East Metro PFAS   | 1497              | 63.7%                              | 247                     | 70.4%                            | 4                    | 100.0%                                |
| Perfluoroundecanoic acid (PFUnA / PFUnDA)  | Closed Landfill   | 246               | 10.6%                              | 125                     | 13.6%                            | 25                   | 20.0%                                 |
|                                            | Operating MSW     | 117               | 0.9%                               | 58                      | 1.7%                             | 9                    | 11.1%                                 |
|                                            | Other Solid Waste | 0                 | --                                 | 0                       | --                               | 0                    | --                                    |
|                                            | East Metro PFAS   | 367               | 18.5%                              | 64                      | 46.9%                            | 3                    | 66.7%                                 |

## 2.2 Temporal Availability of Data and Reporting Detection Limits

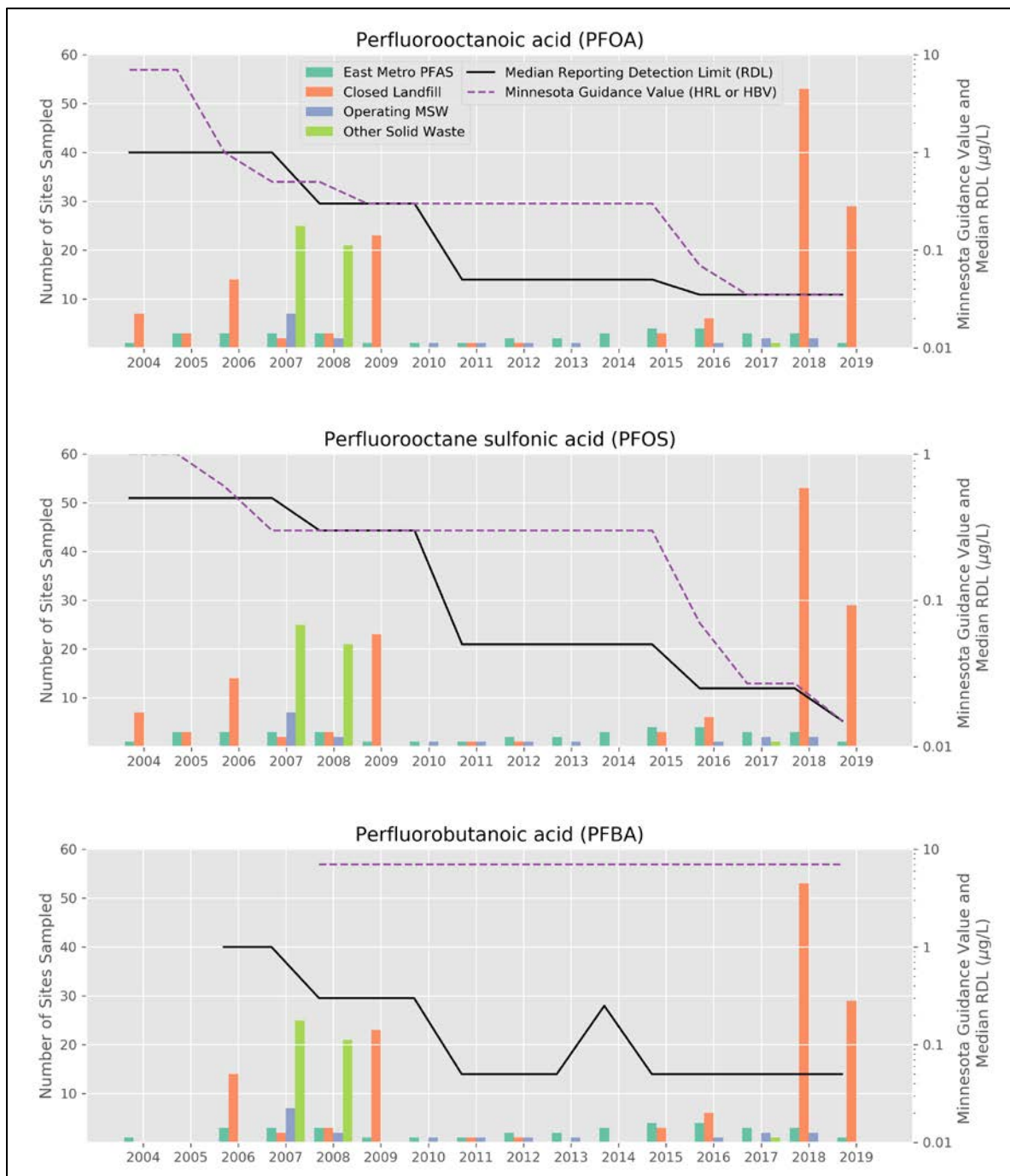
Over the last fifteen years, the laboratory detection limits for PFAS have decreased significantly. In parallel, the regulatory standards for PFAS in drinking water have also fallen. For several PFAS the median reporting detection limit for samples from 2007 and 2008 is an order of magnitude greater than the median reporting detection limits from samples collected in 2018 and 2019 (Table 3). In many cases the reported detection limits from 2007 and 2008 are over an order of magnitude greater than the current Minnesota drinking water guidance values.

Figure 2 shows the number of sites sampled for PFAS and 1,4-dioxane through time and how the median reporting detection limits (RDL) and Minnesota drinking water guidance values have changed. The majority of PFAS data in the closed landfill group are from 2018 and 2019 while the majority of PFAS data for the other groups is from 2006 and 2009. The data collected in 2007-2009 is primarily associated with an MPCA study of PFAS at solid waste facilities in Minnesota (MPCA, 2010). Since the time of that study significantly more data have been collected at closed landfills and the regulatory guidance values for PFAS have changed significantly.

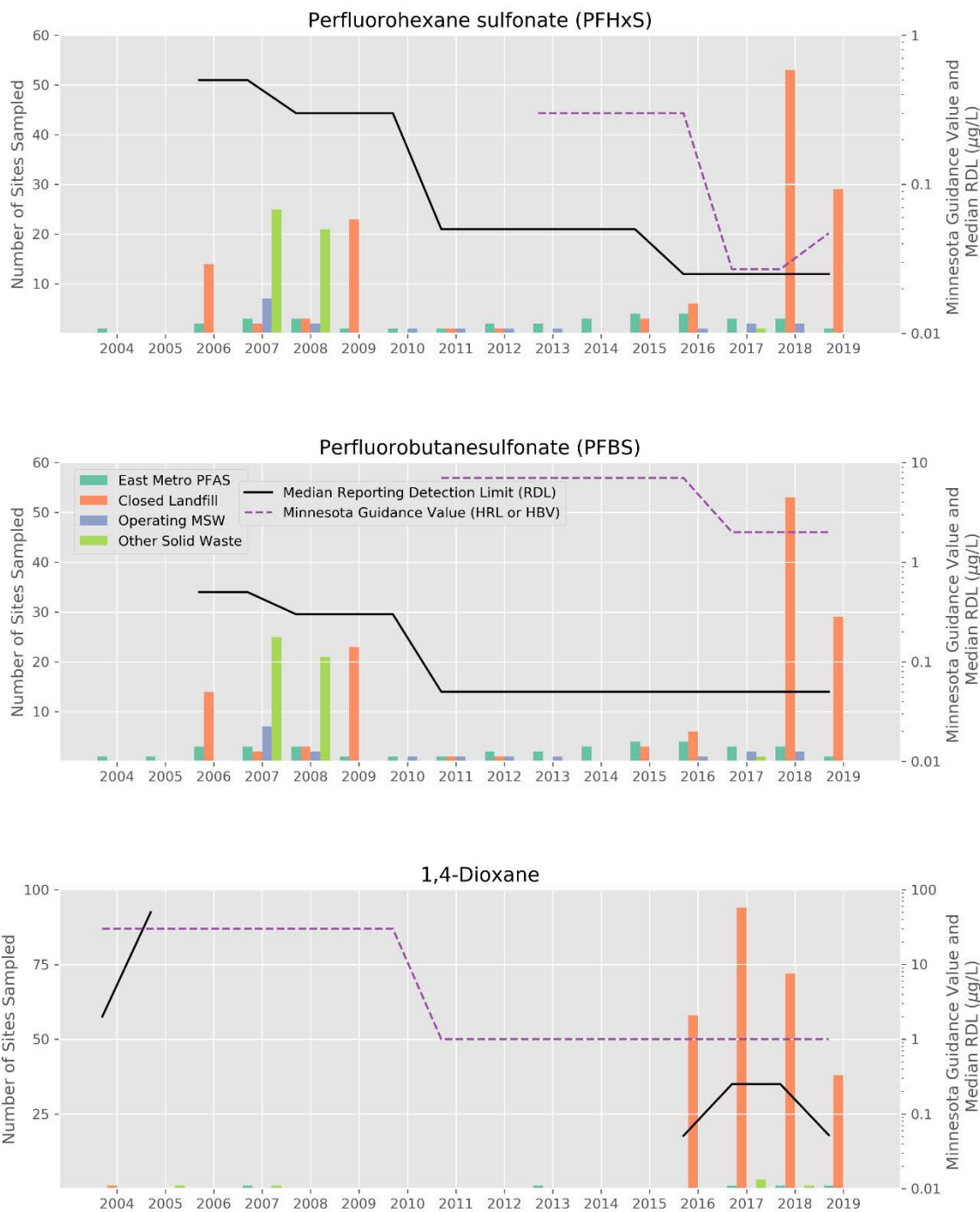
For 1,4-dioxane, nearly all the data available are from the last five years. The majority of 1,4-dioxane data available for the closed landfill program is from 2016-2019 and for the other groups the data are from 2017-2018. A Health-Based Guidance Value (HBV) for 1,4-dioxane was first established in 2002 at 30 µg/L. In 2011 the HBV was revised to 1 µg/L and adopted as a Health Risk Limit (HRL) in 2013.

**Table 3. PFAS Reporting Detection Limits and Minnesota Drinking Water Guidance Values in 2007-2008 Compared to 2018-2019**

| Chemical | Median Reporting Detection Limit from 2007-2008 (µg/L) | Median Reporting Detection Limit from 2018-2019 (µg/L) | Minnesota Drinking Water Guidance in 2007 (µg/L) | Minnesota Drinking Water Guidance 2019 (µg/L) |
|----------|--------------------------------------------------------|--------------------------------------------------------|--------------------------------------------------|-----------------------------------------------|
| PFOA     | 0.3                                                    | 0.035                                                  | 0.5                                              | 0.035                                         |
| PFBA     | 0.3                                                    | 0.05                                                   | 7                                                | 7                                             |
| PFHxS    | 0.3                                                    | 0.025                                                  | --                                               | 0.047                                         |
| PFOS     | 0.3                                                    | 0.025                                                  | 0.3                                              | 0.015                                         |
| PFBS     | 0.3                                                    | 0.05                                                   | 7                                                | 2                                             |



**Figure 2 Number of Sites Sampled Minnesota Drinking Water Guidance Values, and Reporting Detection Limits though time for PFAS and 1,4-Dioxane**



**Figure 2 (continued) Number of Sites Sampled Drinking Water Guidance Values, and Reporting Detection Limits though time for PFAS and 1,4-Dioxane**

### 3 PFAS and 1,4-Dioxane Summary Statistics

Summary statistics for regulated PFAS and 1,4-dioxane were determined for each site for comparison purposes. These include minimum and maximum concentrations, a measure of central tendency (an average or alternate measure for datasets for which there may be limitations affecting calculations of averages), the total number of samples collected, and the percentage of values with reported detections. All summary statistics are presented in Table A1 in Appendix A. The selection of the summary statistic used to compute the measure of central tendency was dictated by the percentage of detections. The decision process implemented is outlined in Table 4 below. These decisions are based on regulatory technical documents, including the EPA's Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities (Unified Guidance; U.S. EPA, 2009), the Statistical Software for Environmental Applications for Data Sets with and without Non-detect Observations (ProUCL Technical Guide; U.S. EPA, 2015), the ITRC Guidance Document: Groundwater Statistics and Monitoring Compliance (ITRC Guidance; ITRC, 2013), and project specific considerations.

**Table 4 Process to Determine Measure of Central Tendency for Data Containing Non-Detects with Variable Detection Limits**

| Non-Detect Frequency | Measure of Central Tendency                                          | Citations                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
|----------------------|----------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 0%                   | Arithmetic mean                                                      | For datasets with no non-detects, the Kaplan-Meier mean is equal to the arithmetic mean (Helsel, 2012).                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
| ≤50%                 | Kaplan-Meier (KM) mean                                               | <ul style="list-style-type: none"> <li>Kaplan Meier recommended (U.S. EPA 2009, pg. 15-3)<br/> <i>"The guidance generally favors the use of the ...Kaplan-Meier or Robust ROS [regression on order statistics] methods which can address the problem of multiple detection limits"</i></li> <li>Robust ROS ruled out (U.S. EPA 2009, pg. 8-24)<br/> Robust ROS underlying assumptions: <i>"Data must be normal or normalized..."</i></li> <li>Limit at 50% non-detects (U.S. EPA 2009, pg. 8-23)<br/> <i>"Kaplan-Meier should not be used when more than 50% of the data are non-detects."</i></li> </ul> |
| >51%                 | Median value. If median is a non-detect, report as a less-than value | <ul style="list-style-type: none"> <li>Project-specific method (U.S. EPA 2015, sec. 1.12):<br/> <i>"For data sets with low detection frequencies, other measures such as the median or mode represent better estimates (with lesser uncertainty) of the population measure of central tendency."</i></li> </ul>                                                                                                                                                                                                                                                                                           |
| 100%                 | Not reported (n/a)                                                   | For the purposes of this study the measure of central tendency for datasets consisting of 100% non-detect will be reported as the lowest detection limit associated with the non-detects.                                                                                                                                                                                                                                                                                                                                                                                                                 |

In addition to the quantitative summary statistics in Table A1, box-and-whisker plots of all data for many of the analytes were created to visually illustrate the distribution of the data and used as an initial screening to discern group differences. Box-and-whisker plots presented in Appendix B consist of a

central box, with the lower limit of the box indicating the first quartile (25th percentile of the data) and the upper limit of the box indicating the third quartile (75th percentile of the data). The height of the box (the difference between the first and third quartiles) is called the interquartile range. Within the box is a heavy line indicating the median (50th percentile of the data). Extending in each direction from the box are “whiskers,” which extend to values within one and a half times the interquartile range from each end of the box. Values beyond the whiskers are potential outliers. For each box-and-whisker plot in Appendix B individual measured values are plotted as points overlying the box-and-whiskers; non-detect values are plotted as blue points at their reporting detection limit and all measurements above the detection limit are plotted as green points.

Summary statistics from Table A1 are presented visually on as box-and-whisker plots of the measures of central tendency (Figure 3) and maximum value (Figure 4) for each of the PFAS with Minnesota drinking water guidance values and also for 1,4-dioxane. The dots overlying each box are the values for an individual site. The red lines on each box indicates the median and the horizontal purple dashed line shows the Minnesota drinking water guidance value. Values which are non-detects are included at the detection limit.

Based on review of Figure 3 and Figure 4, and the summary statistics presented in Table A1, the following are noted for PFAS and 1,4-dioxane amongst the different groups:

#### **PFOA**

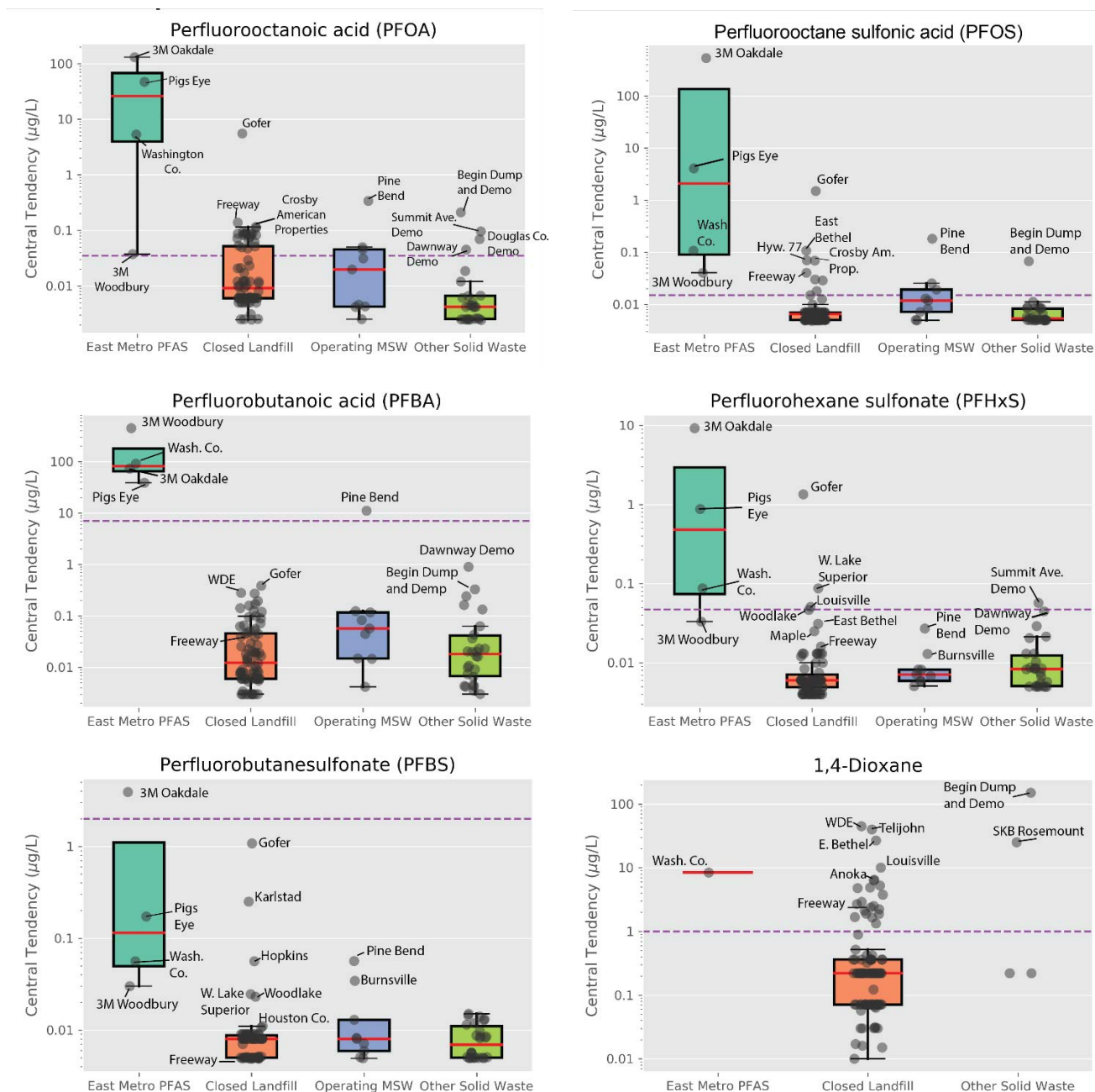
With the exception of Washington County Landfill, the east metro PFAS sites have measures of central tendency for PFOA that are one to two orders of magnitude greater than most other facilities. Washington County Landfill does have a maximum measured concentration of 82 µg/L which is greater than all other closed landfill facilities. Gofer Landfill, which is in the Closed Landfill Program, is an apparent outlier with a central tendency for PFOA of 5.5 µg/L and a maximum measured value of 47 µg/L. Pine Bend Sanitary Landfill is an apparent outlier within the operating MSW group for both the measure of central tendency and maximum value, 0.34 µg/L and 2.7 µg/L respectively. A total of 17 facilities within the closed landfill group have a measure of central tendency for PFOA greater than the Minnesota drinking water guidance value of 0.035 µg/L. An additional five facilities within the closed landfill group had a measure of central tendency of <0.087 µg/L, indicating non-detects but with a detection limits above the current guidance value.

#### **PFOS**

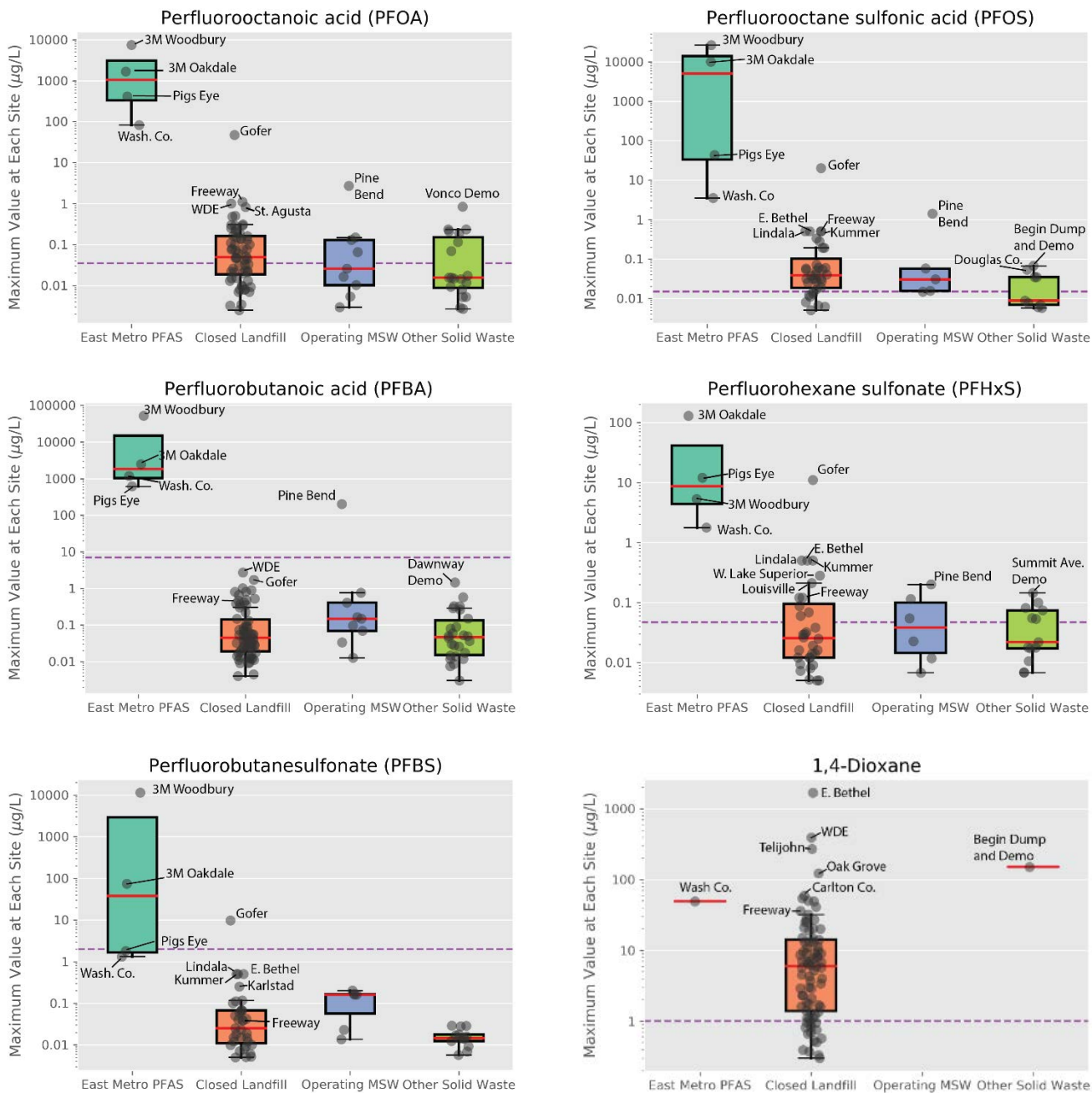
The east metro PFAS sites have a large range for the measures of central tendency, with 3M Woodbury Disposal Site (<0.04 µg/L) and Washington County Landfill (<0.1 µg/L) on the low end of the range. However, maximum measured values for all the east metro PFAS sites are higher than other facilities with the exception of Gofer Landfill (1.49 µg/L) which is an apparent outlier within the closed landfill group. Pine Bend Sanitary Landfill is an apparent outlier within the operating MSW group for both the measure of central tendency (0.18 µg/L) and maximum measured value (1.4 µg/L). Eight facilities within the closed landfill group have measures of central tendency greater than the



Minnesota drinking water guidance of 0.015  $\mu\text{g/L}$ . One facility within the other solid waste group, Begin Dump and Demolition Landfill, and two facilities within the operating MSW group, Pine Bend Sanitary Landfill and Burnsville Sanitary Landfill, had a measure of central tendency greater than the drinking water guidance. It is noted that only one sample (of two total) at Begin Dump and Demolition Landfill exceeded the drinking water guidance.



**Figure 3 Box-and-Whisker Plots of the Measure of Central Tendency for PFAS and 1,4-Dioxane**



**Figure 4 Box-and-Whisker Plots of the Maximum Value for PFAS and 1,4-Dioxane**

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## **PFBA**

The east metro PFAS sites and Pine Bend Sanitary Landfill are the only facilities with measures of central tendency and maximum measured values greater than the Minnesota drinking water guidance of 7 µg/L. The measure of central tendency for all the facilities within the closed landfill group are at least an order of magnitude below the drinking water guidance.

## **PFHxS**

The east metro PFAS sites have a large range for measures of central tendency for PFHxS, with Washington County Landfill (0.03 µg/L) and the 3M Woodbury Disposal Site (0.08 µg/L) falling on the low end. This is similar to the distribution observed for PFOS. Gofer Landfill is a significant outlier within the closed landfill group having a central tendency of 1.34 µg/L and maximum measured value of 11.0 µg/L.

Two facilities within the closed landfill group, Gofer Landfill and Western Lake Superior Sanitary District Landfill, had measures of central tendency greater than the Minnesota drinking water guidance of 0.047 µg/L. No facilities from the operating MSW group had measures of central tendency greater than the drinking water guidance. One facility from the other solid waste group, Summit Avenue Demolition Landfill, had a measure of central tendency greater than the drinking water guidance.

## **PFBS**

Only one facility, 3M Oakdale Disposal Site, had a central tendency greater than the Minnesota drinking water guidance for PFBS of 2 µg/L. Three facilities had maximum measured values greater than the drinking water guidance; 3M Oakdale Disposal Site, 3M Woodbury Disposal Site, and Gofer Sanitary Landfill. For most facilities the measure of central tendency is one to two orders of magnitude less than the drinking water guidance value.

## **1,4-Dioxane**

Limited data for 1,4-dioxane are available outside the closed landfill group to allow for meaningful comparisons. Within the closed landfill group, the central tendency for 20 facilities is greater than the Minnesota drinking water guidance value of 1 µg/L. The maximum value from 69 facilities was greater than the drinking water guidance value.

### **3.1 Composite Heath Risk Index for PFAS**

Due to the ubiquitous presence of potential PFAS containing materials in landfills, there are often multiple PFAS compounds that may be present in groundwater near these sites. The MDH uses an additive model to determine a Health Risk Index (HRI) associated with exposure to multiple chemicals. Using this

approach is useful for this study to better understand the distribution and potential risk associated with multiple PFAS at the different landfills.

The HRI for PFAS was determined as:

$$HRI = \frac{C_{PFBS}}{HBV_{PFBS}} + \frac{C_{PFHxS}}{HBV_{PFHxS}} + \frac{C_{PFOS}}{HBV_{PFOS}} + \frac{C_{PFBA}}{HRL_{PFBA}} + \frac{C_{PFOA}}{HRL_{PFOA}}$$

Where:

$C_{PXXX}$  is the concentration of a PFAS

$HBV_{PXXX}$  is the Health Base Value for a PFAS, where applicable

$HRL_{PXXX}$  is the Health Risk Limit for a PFAS, where applicable.

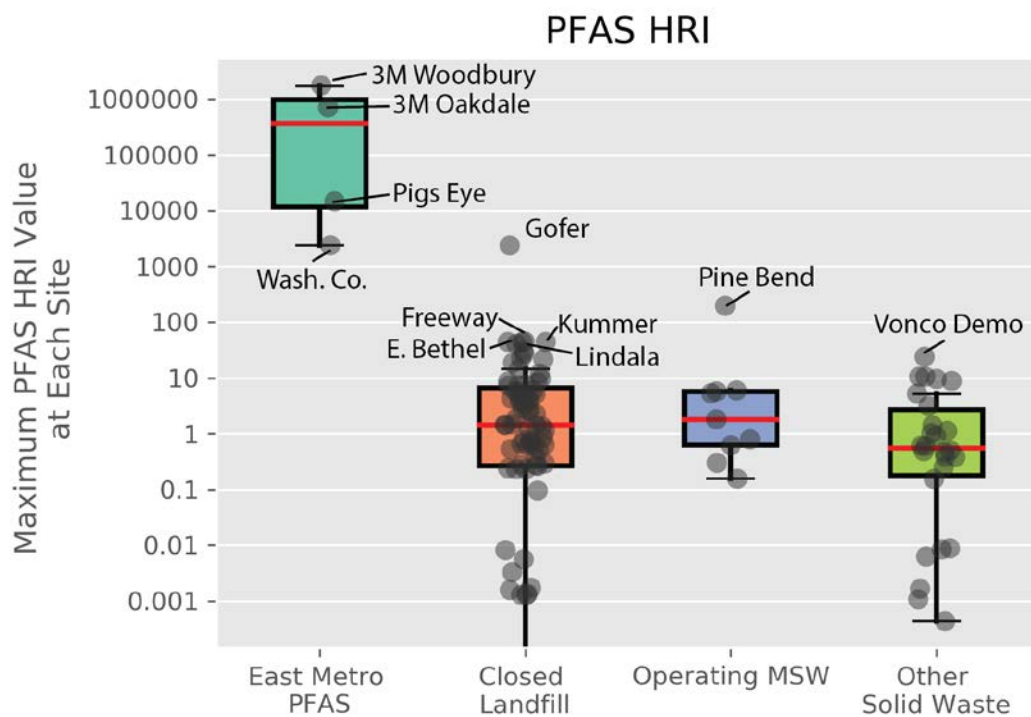
HRI values greater than 1.0 indicates possible exceedance of regulatory guidance (MDH, 2020).

To determine the HRI for PFAS, all non-detect values were assumed to be zero. HRI values for PFAS were determined for individual wells using results from individual sampling events. Samples from locations within the footprint of the waste were not included. A total of 5,426 HRI values were determined for 114 sites. The maximum HRI value at each site was compiled and used to compare different sites. Figure 5 and Table 5 summarize the maximum HRI for PFAS observed at each site grouped into different categories. The east metro PFAS sites show substantially higher maximum HRI values than other groups. The closed landfill group had a median HRI for PFAS of 1.4. A total of 42 closed landfills (56%) had a maximum HRI above 1.0 and 33 had a maximum HRI below 1.0.

The four east metro PFAS sites had the highest PFAS HRI of all the sites. Within the closed landfill group Gofer Sanitary Landfill is distinct and has a maximum PFAS HRI nearly two orders of magnitude greater than other landfills in the closed landfill program (with the exception of Washington County Landfill which is in the east metro PFAS group). Among the east metro PFAS sites the 3M Woodbury Disposal Site and 3M Oakdale Disposal Site had the highest maximum PFAS HRI.

There were six sites where the PFAS HRI was 0.0, meaning all samples for PFAS were below the detection limit. There were an additional nine closed landfills and seven solid waste facilities where the HRI for PFAS was below 0.1. At most of the sites where the HRI was below 0.1 only a few samples (typically just one) were available.

Figure 6 shows the maximum PFAS HRI values for each facility at its mapped geographic location. These data are also presented in Appendix E. Many of the facilities with higher PFAS HRI tend to be located within or near the Twin Cities Metropolitan Area. This may be partially explained by two factors associated with site operation and monitoring: 1) the facilities in the Twin Cities Metropolitan Area tend to be larger facilities (based on data from the CLP) and 2) facilities within the Twin Cities Metropolitan Area have larger data sets (more sampling locations) than many of the outstate facilities, due in part to their size. Figure 7 shows a plot of the maximum PFAS HRI value for each facility within the closed landfill group compared to the volume of waste at each facility. The volume of waste and the maximum PFAS HRI show a statistically significant positive correlation with an  $R^2$  of 0.37 and a p-value of 0.002. This suggests that sites with greater volume of waste are more likely to have higher maximum PFAS HRIs.



**Figure 5 Box-and-Whisker Plots of the Maximum PFAS Health Risk Index (HRI) for Groundwater**

**Table 5 Summary of PFAS Health Risk Index**

| Landfill Group        | Median HRI | Number of Sites with HRI > 1 | Number of Sites with HRI < 1 | Min HRI | Max HRI |
|-----------------------|------------|------------------------------|------------------------------|---------|---------|
| Closed Landfills      | 1.4        | 42                           | 33                           | 0.0     | 2381    |
| MSW                   | 1.8        | 5                            | 4                            | 0.16    | 197     |
| Other Solid Waste     | 0.6        | 10                           | 16                           | 0.0004  | 239     |
| East Metro PFAS Sites | 8565       | 4                            | 0                            | 14.8    | 1763998 |



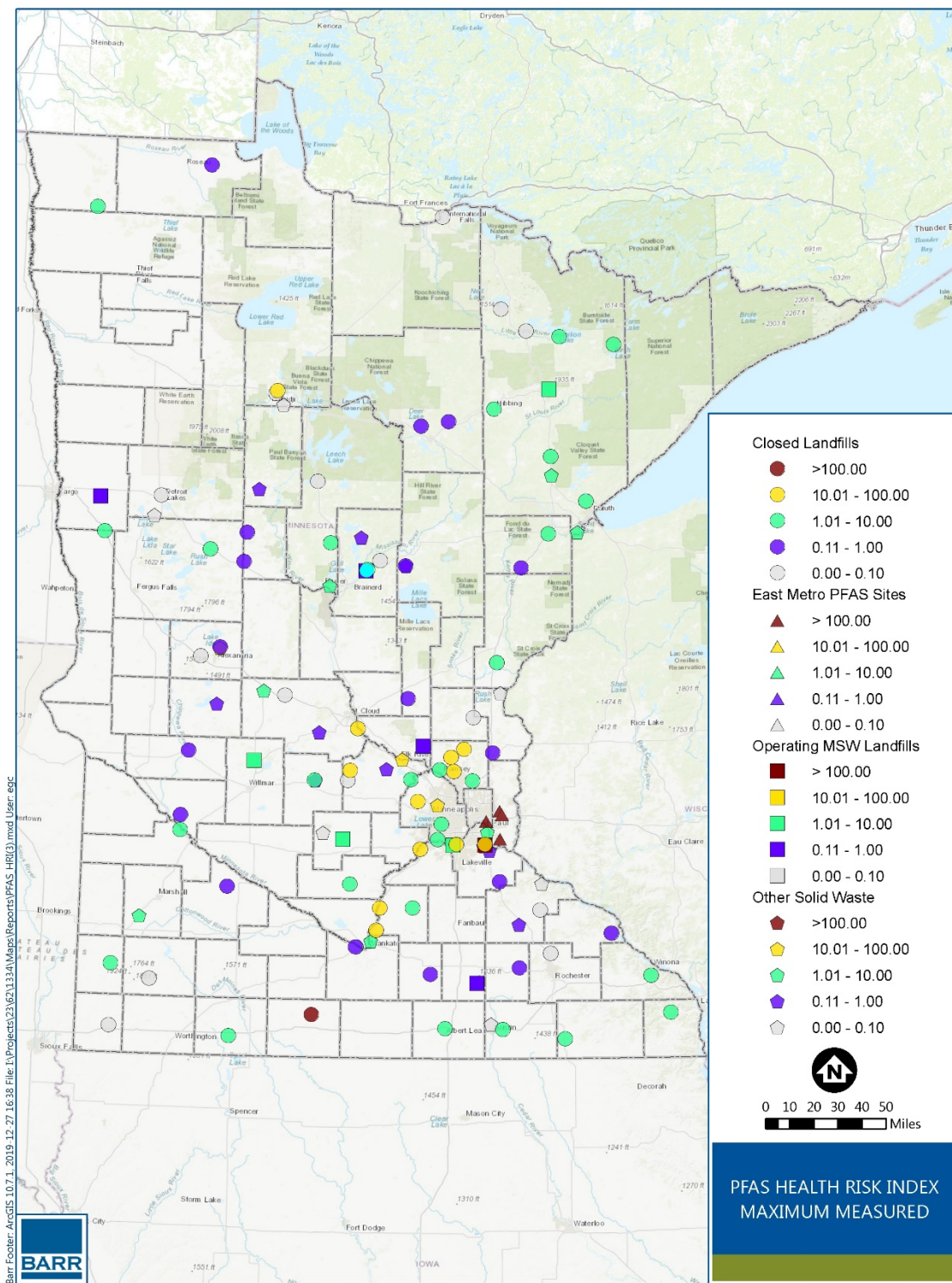
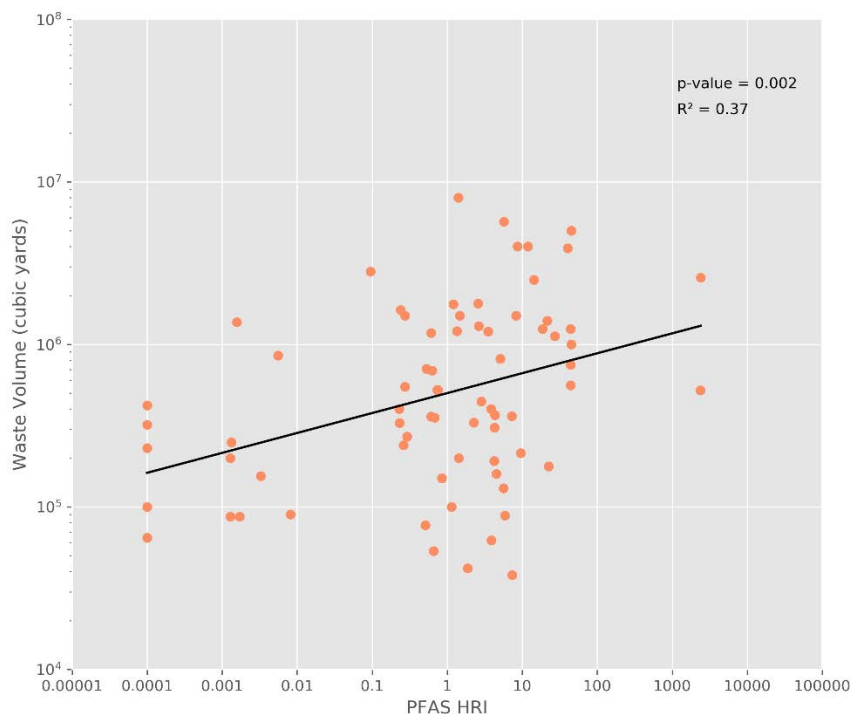


Figure 6. Spatial Distribution of PFAS Health Risk Index



**Figure 7 PFAS Health Risk Index (HRI) vs Volume of Waste, CLP Sites Only**

### 3.2 Comparison of PFAS and 1,4-dioxane distributions amongst different sites

Review of the summary statistics and box plots suggest there are differences in the distributions of PFAS and 1,4-dioxane between sites. The generalized Wilcoxon Test was used to compare distributions of PFAS and 1,4-dioxane amongst different sites as it is suited for datasets that are not normally distributed and contain non-detects (Helsel, 2012). The results of the Wilcoxon Test were used to determine if the observed differences in the distribution at different sites are statistically significant. The results of the test were used to calculate a p-value. A p-value less than 0.01 was taken to indicate distributions which are different at a statistically significant level.

Heat-maps of the Wilcoxon Test p-values are presented on Figures C1 to C6 in Appendix C. Review of the results indicates that the four east metro PFAS sites in addition to the Gofer Landfill have PFAS distributions that tend to be significantly different from other sites. Tellijohn Landfill (SW-67), Louisville Landfill (SW-32), and Anoka Municipal Landfill (SW-94) have distributions of 1,4-dioxane that are different at a statistically significant level from most sites.



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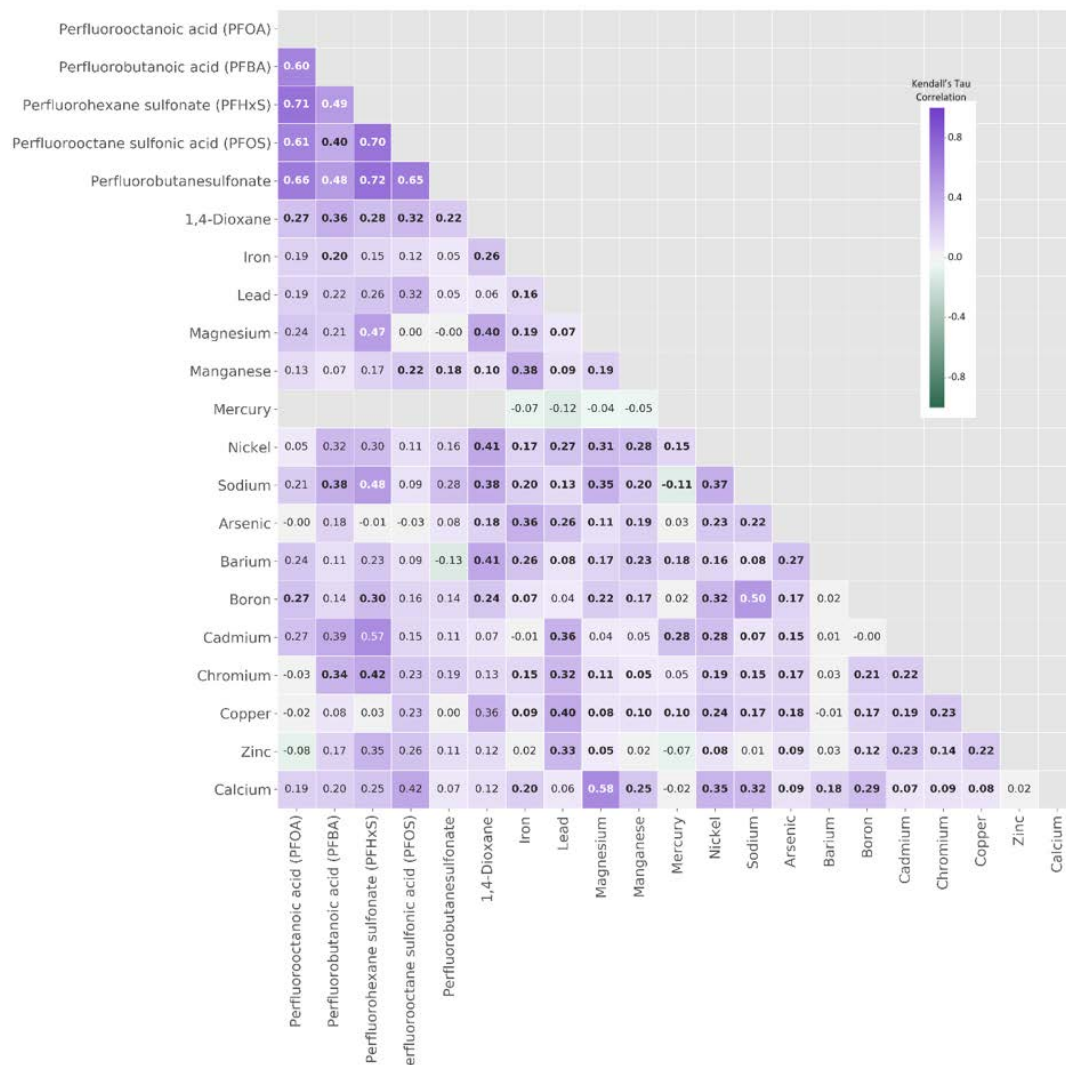
### 3.3 Correlation Analysis

Correlations between different analytes were evaluated by calculating Kendall's tau correlation coefficients. Kendall's tau correlation is a non-parametric statistical test used to assess whether the concentration of two parameters systematically increase (positive correlation) or decrease (negative correlation) together. A Kendall's tau correlation coefficient of 0 indicates that the data are perfectly uncorrelated, a Kendall's tau correlation coefficient of -1 indicates that the data are perfectly negatively correlated, and Kendall's tau correlation coefficient of 1 indicates that the data are perfectly positively correlated. For this analysis, two sample results were considered comparable only if from the same monitoring location and sampled for on the same day. All non-detects were excluded. If fewer than 10 sample pairs were available, a correlation coefficient was not calculated.

Results showing the Kendall's tau correlations for PFAS, 1,4-dioxane and metals is shown on Figure 8. All of the PFAS are positively correlated with each other. 1,4-dioxane is weakly correlated with PFAS; meaning they are likely not predictors of the other's presence. Some metals had a weak correlation with PFAS. However, overall metals are likely not a good predictor of the presence of PFAS. The strongest significant correlations of metals with 1,4-dioxane were barium, nickel, and magnesium. However, like PFAS, metals are likely not a good predictor of the presence of 1,4-dioxane.

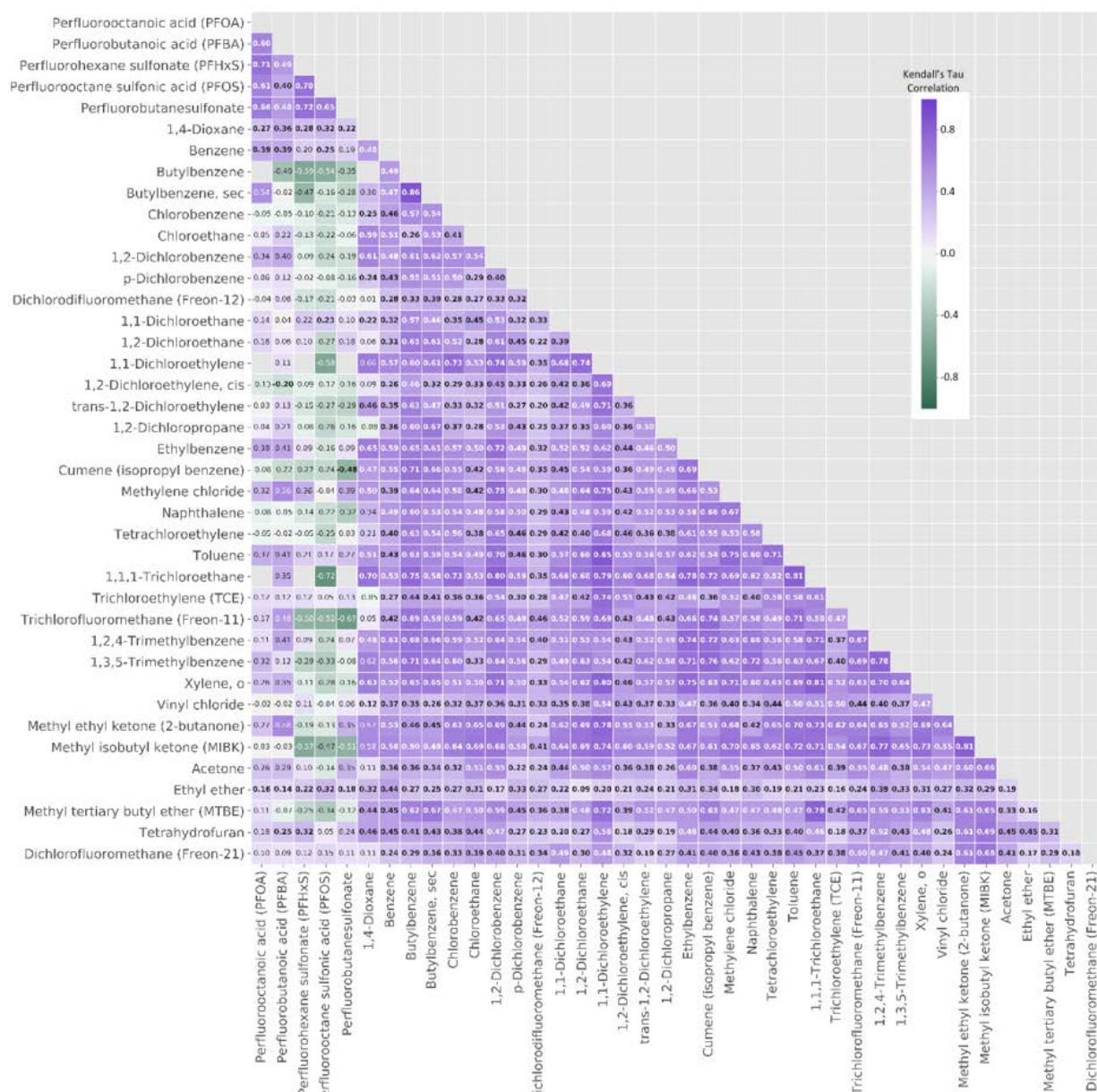
Figure 9 shows the Kendall tau correlation for PFAS, 1,4-dioxane, and volatile organic compounds (VOCs). Only four of the VOCs tested were found to have significant positive correlations with any of the PFAS compounds. These include: benzene, 1,1-dichlorobenzene, ethyl ether, and tetrahydrofuran. Of these benzene had the strongest correlation with a tau of 0.39 for both PFOA and PFBA.

1,4-dioxane was positively correlated with many VOCs. The strongest significant correlations for 1,4-dioxane were with 1,1,1-Trichloroethane (TCA), ethylbenzene, xylene, 1,2-dichlorobenzene, and chloroethane. 1,4-dioxane is commonly associated with TCA because it was often used as a stabilizer for chlorinated solvents. Some of these VOCs may be a good predictor of the presence of 1,4-dioxane.



Purple indicate positive correlations and green indicates negative correlations. Darker shading indicates stronger correlation. Values in **bold** indicate statistically significant correlations

**Figure 8 Kendall's Tau Correlation Coefficients, PFAS, 1,4-Dioxane, and Metals**



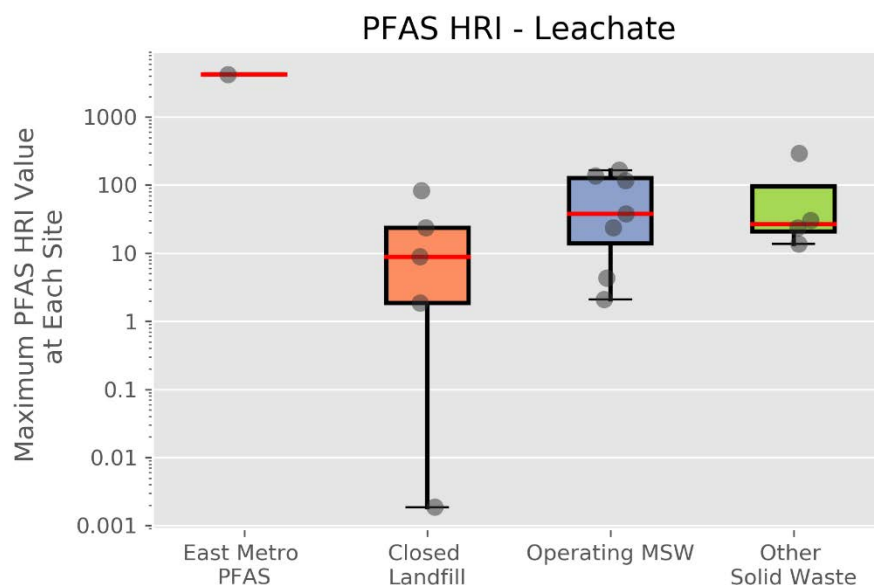
Purple indicate positive correlations and green indicates negative correlations. Darker shading indicates stronger correlation. Values in **bold** indicate statistically significant correlations

Figure 9. Kendall's Tau Correlation Coefficients, PFAS, 1,4-Dioxane, and VOCs

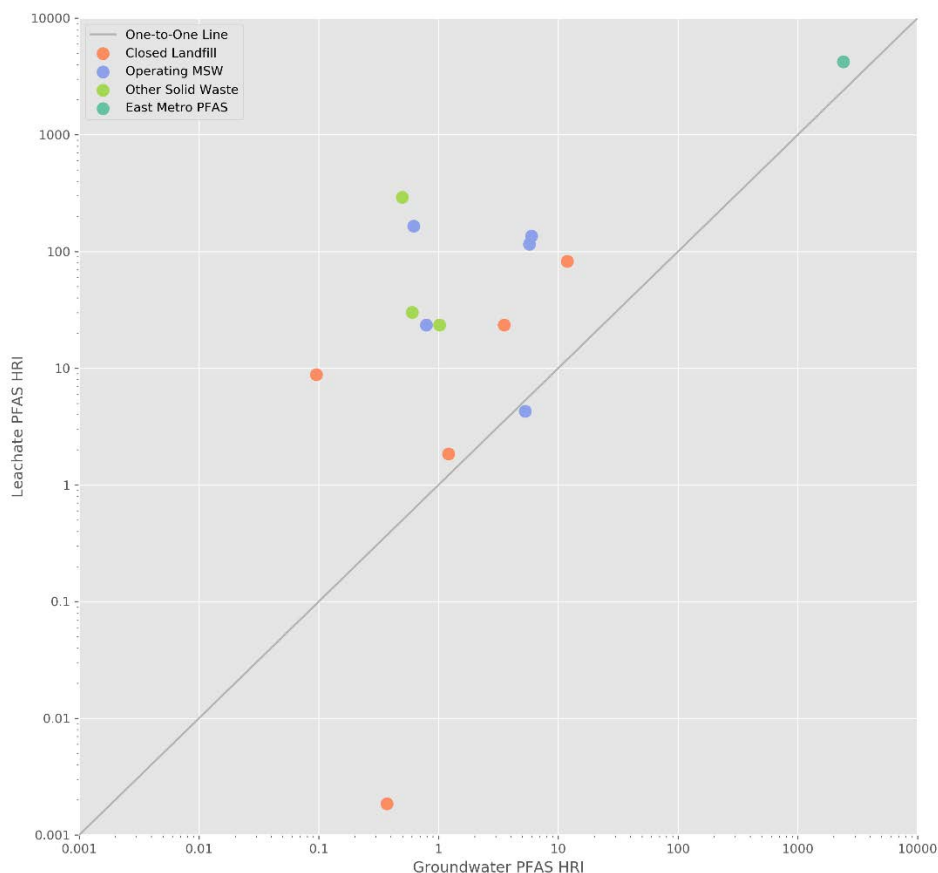
## 4 Leachate Data

There were limited data available for PFAS and 1,4-dioxane in waste leachate compared to the available EC data for groundwater. This lack of data is in part because only seven closed landfills have bottom liner systems where leachate can be contained and monitored. Figure 10 shows box-and-whisker plots of maximum PFAS HRI for each site calculated using leachate concentrations. Comparison of Figure 10 to Figure 5 indicates that PFAS HRI values calculated using leachate are typically higher than groundwater. However, on a site-by-site basis this relationship was not always true. Figure 11 shows maximum PFAS HRI for leachate vs maximum PFAS HRI for groundwater. If groundwater and leachate PFAS HRI values were identical for a site it would plot on the diagonal line (one-to-one line) on Figure 11. Most points plot above/left of the one-to-one line indicating the leachate PFAS HRI values are typically higher than HRI values calculated using groundwater. However, for two sites the highest groundwater HRI was greater than leachate HRI: Spruce Ridge Landfill, and Mille Lacs Landfill. The data were not sufficient to indicate why the leachate were less than groundwater but it may be due to timing of samples, sampling protocol, or misidentification of leachate or groundwater in the database.

The data were not sufficient to indicate trends regarding performance of different liner types for effectively mitigating the transport of PFAS from leachate to groundwater. No trends or clusters of facilities that indicated better or worse relative differences in PFAS leachate vs groundwater were observed. To better assess the effectiveness of different liner types on PFAS mitigation a specifically designed study with carefully chosen sampling locations would be necessary.



**Figure 10 Box-and-Whisker Plots of the Maximum PFAS Health Risk Index (HRI) for Leachate**



**Figure 11 Groundwater PFAS HRI vs. Leachate PFAS HRI**

## 5 Agglomerative Hierarchical Cluster Analysis

Agglomerative Hierarchical Cluster (AHC) analysis involves evaluating data for multiple analytes at once to try and identify which locations are similar to other locations based on the characteristics and distributions of the analytes. AHC analysis is a statistical iterative classification method that groups, or clusters, like-data based on statistical thresholds. The output from AHC analysis is commonly presented using a dendrogram (clustering tree) representing a hierarchy of similarities and dissimilarities. For this study AHC analysis was conducted using Scikit-learn (Pedregosa et. al., 2011) with Ward method linkage criteria. For all analytes evaluated, concentrations less than the reporting detection limit were set at a value of zero, as other methods of treating non-detect data can obfuscate clustering results due to varying reporting limits.

Several different cluster analyses were conducted with different groups of analytes: regulated PFAS; 1,4-Dioxane; and VOCs with 1,4-Dioxane. Dendrograms for these analyses are presented on Figures 12 to

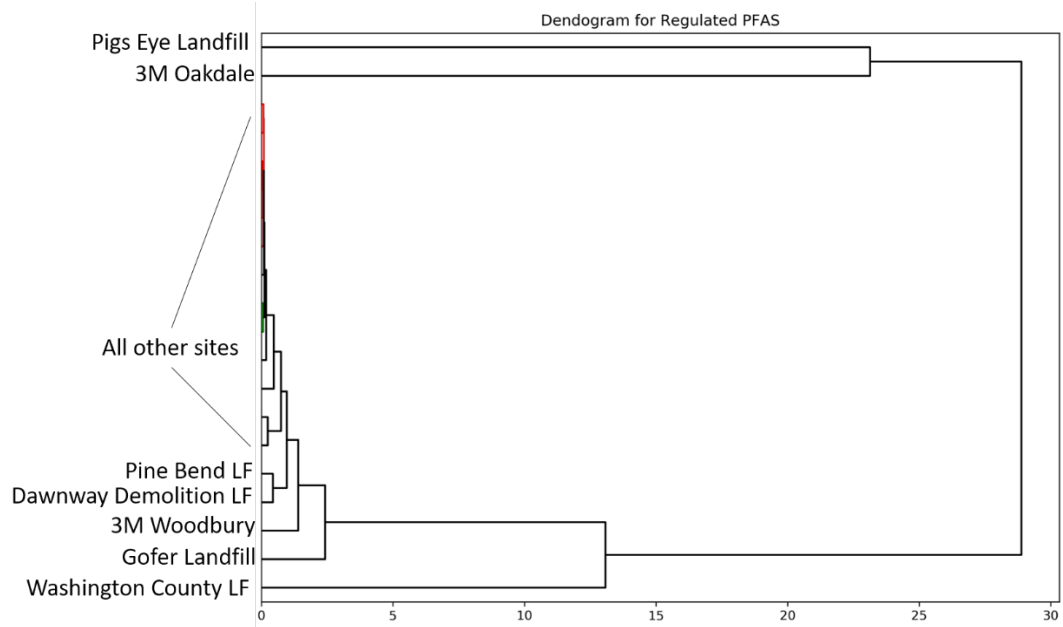
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14. The horizontal axis of the dendrograms represents the dissimilarity between clusters. For example, to compare how similar (or dissimilar) two sites are, determine where along the horizontal axis the two sites join. The further along the horizontal axis where two sites, or groups of sites, join the more dissimilar those sites or groups are.

Results of the AHC analysis suggest that for regulated PFAS six major groups could be identified based on similarities in PFAS. These are: 1) Washington County Landfill, 2) Pigs Eye Landfill and 3M Oakdale Disposal Site, 3) Pine Bend Landfill and Dawnway Demolition Landfill, 4) 3M Woodbury, 5) Gofer Landfill, and 6) all other sites. Comparing the AHC results and the measures of central tendency in Figure 3 shows that for many PFAS Pigs Eye Landfill and 3M Oakdale have central tendencies greater than other sites. However, when comparing maximum values the East Metro PFAS sites are more similar to each other. As described in Section 2.1 the geographic distribution of available data for 3M Woodbury and Washington County Landfill were much greater than other sites. Data collected approximately two miles from these sites were excluded from the analysis. However, this difference in data density and geographic distribution may still be skewing the AHC results to some degree.

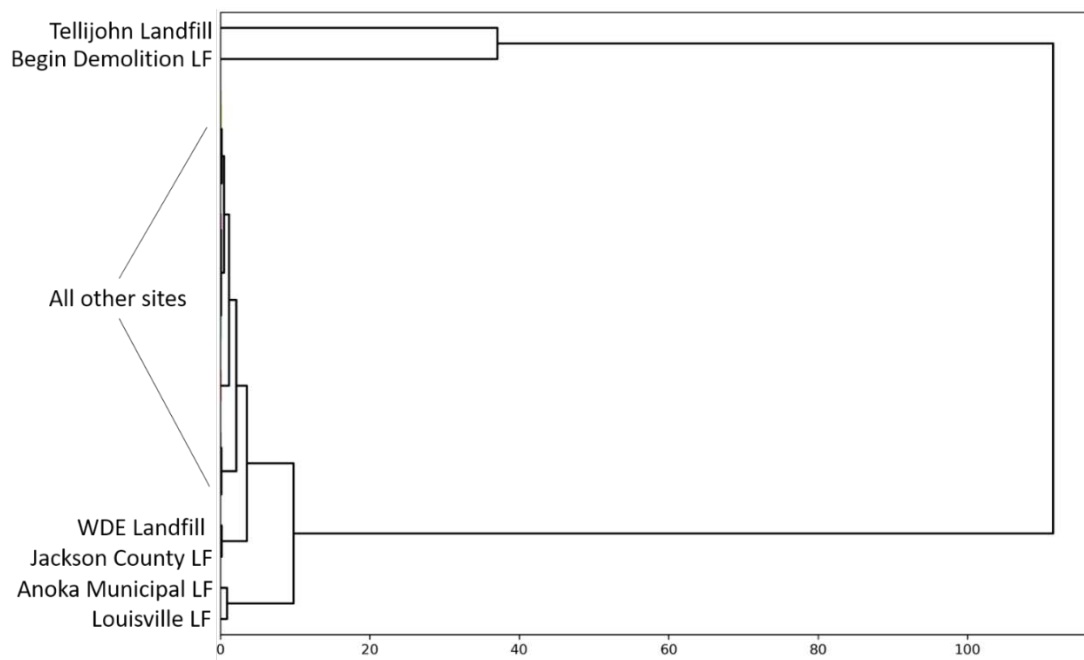
For 1,4-dioxane four groups were identified: 1) Tellijohn Landfill and Begin Dump and Demolition Landfill, 2) Louisville Landfill and Anoka Municipal Landfill, 3) Jackson County Landfill and WDE Landfill, and 4) all other sites. The classification of Begin Dump is suspect due to only two sample results available and only one of these being a detection.

The AHC analysis for 1,4-dioxane and VOC identified four groups: 1) Tellijohn Landfill and Begin Dump and Demolition Landfill, 2) Dodge County Landfill Salol Landfill, and Mankato Landfill 3) Anoka Municipal Landfill and Louisville Landfill, 4) Land Investors Landfill, and 5) all other sites. The results of this analysis were similar to the results for 1,4-dioxane by itself.

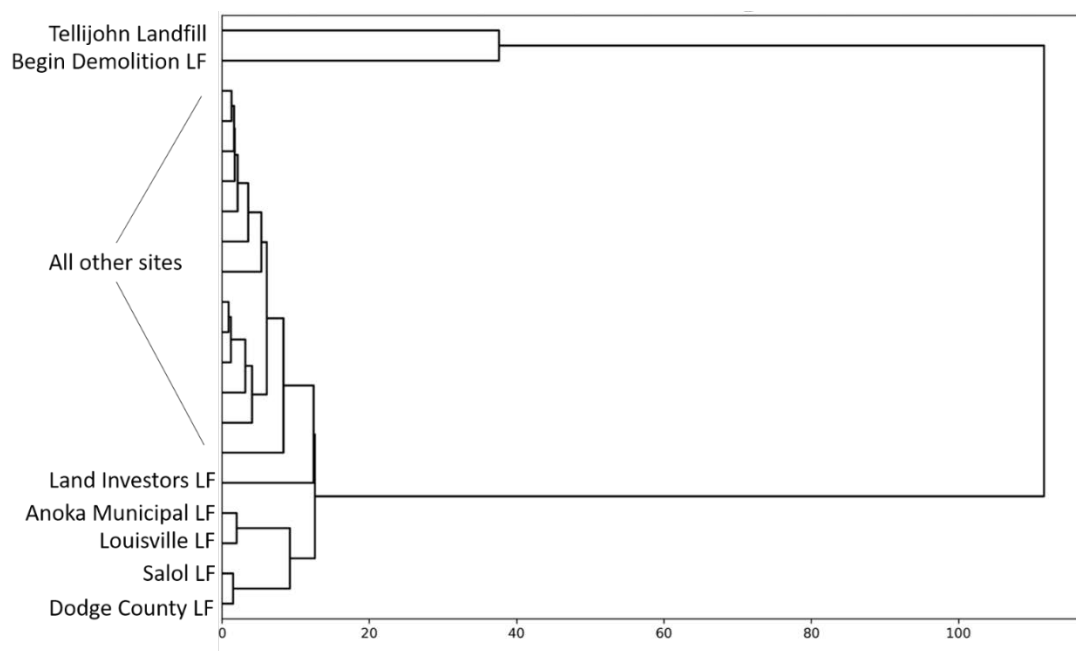


**Figure 12. Dendrogram Showing Results of AHC Analysis for PFAS**





**Figure 13 Dendrogram Showing Results of AHC Analysis for 1,4-Dioxane**



**Figure 14 Dendrogram Showing Results of AHC Analysis for 1,4-Dioxane and VOCs**

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## 6 Conclusions

The results from this study indicate that, based on available public data provided by the MPCA, the presence of emerging contaminants at waste disposal sites is variable. In regard to PFAS and 1,4-dioxane the following conclusions are provided:

### PFAS

- Much of the PFAS data for sites outside of the CLP is from 2007-2009 and had reporting detection limits an order of magnitude greater than current reporting detection limits. These data limitations likely resulted in more non-detect values than would be observed with current detection limits.
- Sites in the east metro PFAS group are significantly different than most other sites. These sites typically have average PFAS concentrations that are one to two orders of magnitude greater than most other sites. When comparing maximum measured concentration the difference between the east metro PFAS sites and other sites is even more pronounced. Gofer Landfill, Pine Bend Landfill, and Dawnway Demolition Landfill are also more distinct than most other sites.
- The closed landfill group had a median HRI for PFAS of 1.4 (as determined based on a maximum from each site). A total of 42 closed landfills (56%) had a maximum HRI above 1.0 and 33 had a maximum HRI below 1.0.
- Very few facilities had concentrations above drinking water guidance for PFBA and PFBS. For PFBA, the east metro PFAS sites and Pine Bend Sanitary Landfill were the only facilities with measures of central tendency and maximum measured values greater than the drinking water guidance. Only one facility, 3M Oakdale Disposal Site, had a central tendency greater than the Minnesota drinking water guidance for PFBS. Three facilities had maximum measured values greater than the drinking water guidance; 3M Oakdale Disposal Site, 3M Woodbury Disposal Site, and Gofer Sanitary Landfill.
- PFAS concentrations show a strong correlation with other PFAS but weak correlation with all other constituents evaluated in this study.
- PFAS in groundwater appear to be correlated with the size of the waste disposal area. Sites with larger waste volumes tend to have higher PFAS HRI values.
- No trends or clusters of facilities that indicated better or worse relative differences in PFAS leachate vs groundwater were observed. However, the data to evaluate these relationships were limited. To better assess the effectiveness of different liner types on PFAS mitigation a specifically designed study with carefully chosen sampling locations would be necessary.

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## 1,4-Dioxane

- Very little data for 1,4-dioxane are available for sites outside of the CLP.
- Within the closed landfill group, the average concentration in groundwater at 20 facilities is greater than the Minnesota drinking water guidance value of 1 µg/L. The maximum concentration from 69 facilities was greater than the drinking water guidance value.
- 1,4-Dioxane is positively correlated with several VOCs. The strongest correlation observed was with 1,1,1-Trichloroethane (TCA). 1,4-dioxane is commonly associated with TCA because it was often used as a stabilizer for chlorinated solvents.
- Tellijohn Landfill, Begin Demolition Landfill, WDE Landfill, Jackson County Landfill, Anoka Municipal Landfill and Louisville Landfill have different 1,4-dioxane distributions than most other landfills and tend to have higher groundwater concentrations.

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## 7 References

- 3M, 1999. Fluorochemical Use, Distribution and Release Overview. May 26, 1999.
- Busch, Jan. Ahrens, Lutz. Strum, Renate. Ebinghaus, Ralf. 2009. "Polyfluoroalkyl Compounds in Landfill Leachates." Environmental Pollution. Web. 18 July 2009.
- Helsel, D. R., 2012. Statistics for censored environmental data using Minitab and R (2nd ed.). Hoboken, New Jersey: Wiley.
- ITRC, 2013. ITRC Guidance Document: Groundwater Statistics and Monitoring Compliance.
- U.S. EPA, 2009. Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities: Unified Guidance. EPA 530/R-09-007. March 2009.
- U.S. EPA, 2015. ProUCL Version 5.1.002 Technical Guide: Statistical Software for Environmental Applications for Data Sets with and without Nondetect Observations. EPA/600/R-07/041. October 2015.
- Kissa, E., 2001. Fluorinated Surfactants and Repellents. CRC Press.
- Knepper, T.P. and F.T. Langue, editors; Polyfluorinated Chemicals and Transformation Products. 2012. The handbook of environmental chemistry (ISSN 1867-979X, 17
- MPCA. 2010. 2005-2008 Perfluorochemical Evaluation at Solid Waste Facilities in Minnesota. Technical Evaluation and Regulatory Management Approach, April 14, 2010.
- MDH, 2020. Minnesota Department of Health website for Guidance Values and Standards for Contaminants in Drinking Water. Accessed January 2, 2020.
- Pedregosa, Fabian, et al. 2010. Scikit-learn: Machine learning in Python. Journal of machine learning research no. 12 (Oct): 2825-2830.
- Weston, 2019. 2018 Annual Perfluorochemicals (PFCs) Groundwater Monitoring Report for the Oakdale Site, Oakdale, Minnesota. Prepared for 3M Company, June 2019



## **Appendix A**

### **Summary Statistics for PFAS and 1,4-Dioxane**

Table A-1  
Summary Statistics Regulated PFAS and 1,4-Dioxane

| Facility Code | Facility Type   | Facility Name                       | CAS RN      | Chemical Name                        | Total Sample Count | % Detect | Number of Sampled Wells | % Well Detect | Arithmetic Mean of Detects | Minimum Detect | Maximum Detect | Kaplan Meier Mean | Median of Detects and Non-Detects | Measure of Central Tendency |
|---------------|-----------------|-------------------------------------|-------------|--------------------------------------|--------------------|----------|-------------------------|---------------|----------------------------|----------------|----------------|-------------------|-----------------------------------|-----------------------------|
| SR0000055     | East Metro PFAS | Oakdale Dump Sites                  | 108427-53-8 | Perfluorohexane sulfonate (PFHxS)    | 196                | 84.2%    | 28                      | 89.3%         | 10.9136                    | 0.0250         | 129.0000       | 9.1915            | 1.8500                            | 9.1915                      |
|               |                 |                                     | 335-67-1    | Perfluorooctanoic acid (PFOA)        | 301                | 97.7%    | 30                      | 100.0%        | 133.1964                   | 0.0300         | 1660.0000      | 130.0995          | 19.4000                           | 130.0995                    |
|               |                 |                                     | 375-22-4    | Perfluorobutanoic acid (PFBA)        | 301                | 95.0%    | 30                      | 100.0%        | 95.4780                    | 0.0400         | 2460.0000      | 90.7222           | 12.0000                           | 90.7222                     |
|               |                 |                                     | 45187-15-3  | Perfluorobutanesulfonate (PFBS)      | 301                | 69.4%    | 30                      | 90.0%         | 5.6116                     | 0.0270         | 73.7000        | 3.9047            | 0.5430                            | 3.9047                      |
|               |                 |                                     | 45298-90-6  | Perfluorooctane sulfonic acid (PFOS) | 301                | 100.0%   | 30                      | 100.0%        | 533.7031                   | 0.0470         | 9980.0000      | 533.7031          | 23.7000                           | 533.7031                    |
| SR0000117     | East Metro PFAS | Pigs Eye Landfill                   | 108427-53-8 | Perfluorohexane sulfonate (PFHxS)    | 170                | 78.8%    | 47                      | 87.2%         | 1.0784                     | 0.0160         | 12.0000        | 0.8735            | 0.5000                            | 0.8735                      |
|               |                 |                                     | 335-67-1    | Perfluorooctanoic acid (PFOA)        | 168                | 92.3%    | 47                      | 95.7%         | 50.8555                    | 0.0510         | 410.0000       | 46.9315           | 20.0000                           | 46.9315                     |
|               |                 |                                     | 375-22-4    | Perfluorobutanoic acid (PFBA)        | 170                | 97.6%    | 47                      | 97.9%         | 39.5131                    | 0.0410         | 610.0000       | 38.5887           | 14.0000                           | 38.5887                     |
|               |                 |                                     | 45187-15-3  | Perfluorobutanesulfonate (PFBS)      | 169                | 72.2%    | 47                      | 85.1%         | 0.2034                     | 0.0110         | 1.8000         | 0.1720            | 0.1200                            | 0.172                       |
|               |                 |                                     | 45298-90-6  | Perfluorooctane sulfonic acid (PFOS) | 179                | 69.3%    | 47                      | 85.1%         | 5.8411                     | 0.0125         | 43.0000        | 4.0680            | <0.5                              | 4.068                       |
| SR0000365     | East Metro PFAS | 3M Woodbury                         | 108427-53-8 | Perfluorohexane sulfonate (PFHxS)    | 139                | 38.1%    | 90                      | 46.7%         | 0.1540                     | 0.0050         | 5.3000         | 0.0709            | 0.0330                            | 0.033                       |
|               |                 |                                     | 335-67-1    | Perfluorooctanoic acid (PFOA)        | 301                | 35.2%    | 108                     | 46.3%         | 172.6906                   | 0.0110         | 7400.0000      | 60.8305           | 0.0372                            | 0.0372                      |
|               |                 |                                     | 375-22-4    | Perfluorobutanoic acid (PFBA)        | 292                | 58.6%    | 102                     | 86.3%         | 759.0486                   | 0.0080         | 51700.0000     | 444.5297          | 0.3900                            | 444.5297                    |
|               |                 |                                     | 45187-15-3  | Perfluorobutanesulfonate (PFBS)      | 489                | 29.4%    | 108                     | 50.9%         | 314.9668                   | 0.0090         | 11400.0000     | 92.7817           | <0.03                             | <0.03                       |
|               |                 |                                     | 45298-90-6  | Perfluorooctane sulfonic acid (PFOS) | 308                | 29.9%    | 108                     | 38.9%         | 638.4778                   | 0.0200         | 26300.0000     | 190.7342          | <0.0403                           | <0.0403                     |
| SW-1          | East Metro PFAS | Washington County Sanitary Landfill | 108427-53-8 | Perfluorohexane sulfonate (PFHxS)    | 824                | 39.4%    | 67                      | 40.3%         | 0.1678                     | 0.0080         | 1.7700         | 0.0772            | 0.0870                            | 0.087                       |
|               |                 |                                     | 123-91-1    | 1,4-Dioxane                          | 117                | 60.7%    | 33                      | 60.6%         | 13.7865                    | 0.0550         | 49.0000        | 8.3901            | 0.6600                            | 8.3901                      |
|               |                 |                                     | 335-67-1    | Perfluorooctanoic acid (PFOA)        | 958                | 65.2%    | 67                      | 58.2%         | 8.1145                     | 0.0110         | 82.0000        | 5.3021            | 0.5150                            | 5.3021                      |
|               |                 |                                     | 375-22-4    | Perfluorobutanoic acid (PFBA)        | 825                | 91.6%    | 67                      | 86.6%         | 79.3481                    | 0.0090         | 1170.0000      | 72.7193           | 3.4000                            | 72.7193                     |
|               |                 |                                     | 45187-15-3  | Perfluorobutanesulfonate (PFBS)      | 824                | 32.2%    | 67                      | 34.3%         | 0.0994                     | 0.0090         | 1.3100         | 0.0416            | <0.056                            | <0.056                      |
| SW-100        | Closed Landfill | Waseca County Sanitary Landfill     | 45298-90-6  | Perfluorooctane sulfonic acid (PFOS) | 956                | 38.0%    | 67                      | 44.8%         | 0.3285                     | 0.0070         | 2.6900         | 0.1398            | <0.107                            | <0.107                      |
|               |                 |                                     | 108427-53-8 | Perfluorohexane sulfonate (PFHxS)    | 17                 | 0.0%     | 15                      | 0.0%          |                            |                |                | 0.0000            | <0.006                            | <0.004                      |
|               |                 |                                     | 123-91-1    | 1,4-Dioxane                          | 33                 | 36.4%    | 19                      | 31.6%         | 1.3900                     | 0.1500         | 6.8000         | 0.6009            | <0.071                            | <0.071                      |
|               |                 |                                     | 335-67-1    | Perfluorooctanoic acid (PFOA)        | 23                 | 4.3%     | 15                      | 6.7%          | 0.0080                     | 0.0080         | 0.0080         | 0.0080            | <0.087                            | <0.087                      |
|               |                 |                                     | 375-22-4    | Perfluorobutanoic acid (PFBA)        | 17                 | 23.5%    | 15                      | 26.7%         | 0.0185                     | 0.0030         | 0.0530         | 0.0086            | 0.0080                            | 0.008                       |
| SW-101        | Closed Landfill | Jackson County Sanitary Landfill    | 45187-15-3  | Perfluorobutanesulfonate (PFBS)      | 17                 | 0.0%     | 15                      | 0.0%          |                            |                |                | 0.0000            | <0.008                            | <0.005                      |
|               |                 |                                     | 45298-90-6  | Perfluorooctane sulfonic acid (PFOS) | 23                 | 0.0%     | 15                      | 0.0%          |                            |                |                | 0.0000            | <0.107                            | <0.005                      |
|               |                 |                                     | 108427-53-8 | Perfluorohexane sulfonate (PFHxS)    | 14                 | 0.0%     | 8                       | 0.0%          |                            |                |                | 0.0000            | <0.006                            | <0.004                      |
|               |                 |                                     | 123-91-1    | 1,4-Dioxane                          | 30                 | 60.0%    | 8                       | 62.5%         | 8.0167                     | 1.0400         | 25.1400        | 5.2260            | 1.9600                            | 5.226                       |
|               |                 |                                     | 335-67-1    | Perfluorooctanoic acid (PFOA)        | 14                 | 57.1%    | 8                       | 50.0%         | 0.1079                     | 0.0460         | 0.2900         | 0.0814            | 0.0520                            | 0.0814                      |
| SW-102        | Closed Landfill | Carlton County 2 Sanitary Landfill  | 375-22-4    | Perfluorobutanoic acid (PFBA)        | 14                 | 85.7%    | 8                       | 87.5%         | 0.0303                     | 0.0070         | 0.0640         | 0.0270            | 0.0255                            | 0.027                       |
|               |                 |                                     | 45187-15-3  | Perfluorobutanesulfonate (PFBS)      | 14                 | 14.3%    | 8                       | 25.0%         | 0.0100                     | 0.0100         | 0.0100         | 0.0100            | <0.008                            | <0.008                      |
|               |                 |                                     | 45298-90-6  | Perfluorooctane sulfonic acid (PFOS) | 14                 | 7.1%     | 8                       | 12.5%         | 0.0190                     | 0.0190         | 0.0190         | 0.0190            | <0.007                            | <0.007                      |
|               |                 |                                     | 108427-53-8 | Perfluorohexane sulfonate (PFHxS)    | 15                 | 13.3%    | 8                       | 12.5%         | 0.0066                     | 0.0059         | 0.0072         | 0.0060            | <0.0052                           | <0.0052                     |
|               |                 |                                     | 123-91-1    | 1,4-Dioxane                          | 84                 | 33.3%    | 25                      | 28.0%         | 19.1015                    | 0.0730         | 59.0000        | 6.4192            | <0.36                             | <0.36                       |
| SW-104        | Closed Landfill | Murray County Sanitary Landfill     | 335-67-1    | Perfluorooctanoic acid (PFOA)        | 15                 | 60.0%    | 8                       | 62.5%         | 0.0460                     | 0.0037         | 0.1340         | 0.0291            | 0.0059                            | 0.0291                      |
|               |                 |                                     | 375-22-4    | Perfluorobutanoic acid (PFBA)        | 15                 | 66.7%    | 8                       | 75.0%         | 0.0165                     | 0.0037         | 0.0307         | 0.0123            | 0.0049                            | 0.0123                      |
|               |                 |                                     | 45187-15-3  | Perfluorobutanesulfonate (PFBS)      | 15                 | 6.7%     | 8                       | 12.5%         | 0.0148                     | 0.0148         | 0.0148         | 0.0148            | <0.0052                           | <0.0052                     |
|               |                 |                                     | 45298-90-6  | Perfluorooctane sulfonic acid (PFOS) | 15                 | 13.3%    | 8                       | 12.5%         | 0.0127                     | 0.0086         | 0.0169         | 0.0091            | <0.0052                           | <0.0052                     |
|               |                 |                                     | 108427-53-8 | Perfluorohexane sulfonate (PFHxS)    | 2                  | 0.0%     | 2                       | 0.0%          |                            |                |                | 0.0000            | <0.004                            | <0.004                      |
| SW-111        | Closed Landfill | Crow Wing County Landfill           | 123-91-1    | 1,4-Dioxane                          | 16                 | 18.8%    | 11                      | 18.2%         | 0.5257                     | 0.0570         | 0.8300         | 0.1449            | <0.071                            | <0.071                      |
|               |                 |                                     | 335-67-1    | Perfluorooctanoic acid (PFOA)        | 2                  | 0.0%     | 2                       | 0.0%          |                            |                |                | 0.0000            | <0.005                            | <0.005                      |
|               |                 |                                     | 375-22-4    | Perfluorobutanoic acid (PFBA)        | 2                  | 0.0%     | 2                       | 0.0%          |                            |                |                | 0.0000            | <0.003                            | <0.003                      |
|               |                 |                                     | 45187-15-3  | Perfluorobutanesulfonate (PFBS)      | 2                  | 0.0%     | 2                       | 0.0%          |                            |                |                | 0.0000            | <0.005                            | <0.005                      |
|               |                 |                                     | 45298-90-6  | Perfluorooctane sulfonic acid (PFOS) | 2                  | 0.0%     | 2                       | 0.0%          |                            |                |                | 0.0000            | <0.007                            | <0.007                      |
| SW-111        | Closed Landfill | Crow Wing County Landfill           | 108427-53-8 | Perfluorohexane sulfonate (PFHxS)    | 49                 | 6.1%     | 32                      | 9.4%          | 0.0081                     | 0.0070         | 0.0094         | 0.0071            | <0.006                            | <0.006                      |
|               |                 |                                     | 123-91-1    | 1,4-Dioxane                          | 76                 | 76.3%    | 36                      | 72.2%         | 3.0724                     | 0.0820         | 28.0000        | 2.3644            | 1.0000                            | 2.3644                      |
|               |                 |                                     | 335-67-1    | Perfluorooctanoic acid (PFOA)        | 49                 | 18.4%    | 32                      | 25.0%         | 0.0192                     | 0.0070         | 0.0419         | 0.0092            | <0.006                            | <0.006                      |
|               |                 |                                     | 375-22-4    | Perfluorobutanoic acid (PFBA)        | 49                 | 53.1%    | 32                      | 59.4%         | 0.0434                     | 0.0130         | 0.1460         | 0.0291            | 0.0160                            | 0.0291                      |
|               |                 |                                     | 45187-15-3  | Perfluorobutanesulfonate (PFBS)      | 49                 | 30.6%    | 32                      | 40.6%         | 0.0236                     | 0.0053         | 0.0650         | 0.0109            | <0.008                            | <0.008                      |
| SW-111        | Closed Landfill | Crow Wing County Landfill           | 45298-90-6  | Perfluorooctane sulfonic acid (PFOS) | 49                 | 0.0%     | 32                      | 0.0%          |                            |                |                | 0.0000            | <0.005                            | <0.0008                     |

all concentrations in µg/L

pink shading indicates method used to determine measure of central tendency

bold indicates measure of central tendency above MN drinking water guidance



Table A-1 (continued)  
Summary Statistics Regulated PFAS and 1,4-Dioxane

| Facility Code | Facility Type   | Facility Name                           | CAS RN      | Chemical Name                        | Total Sample Count | % Detect | Number of Sampled Wells | % Well Detect | Arithmetic Mean of Detects | Minimum Detect | Maximum Detect | Kaplan Meier Mean | Median of Detects and Non-Detects | Measure of Central Tendency |
|---------------|-----------------|-----------------------------------------|-------------|--------------------------------------|--------------------|----------|-------------------------|---------------|----------------------------|----------------|----------------|-------------------|-----------------------------------|-----------------------------|
| SW-113        | Closed Landfill | Hansen Sanitary Landfill                | 108427-53-8 | Perfluorohexane sulfonate (PFHxS)    | 7                  | 0.0%     | 6                       | 0.0%          |                            |                |                | 0.0000            | <0.0052                           | <0.0049                     |
|               |                 |                                         | 123-91-1    | 1,4-Dioxane                          | 13                 | 15.4%    | 7                       | 14.3%         | 0.2800                     | 0.1700         | 0.3900         | 0.1869            | <0.071                            | <0.071                      |
|               |                 |                                         | 335-67-1    | Perfluorooctanoic acid (PFOA)        | 7                  | 14.3%    | 6                       | 16.7%         | 0.0092                     | 0.0092         | 0.0092         | 0.0092            | 0.0092                            | 0.0092                      |
|               |                 |                                         | 375-22-4    | Perfluorobutanoic acid (PFBA)        | 7                  | 57.1%    | 6                       | 66.7%         | 0.0097                     | 0.0039         | 0.0130         | 0.0072            | <0.008                            | 0.0072                      |
|               |                 |                                         | 45187-15-3  | Perfluorobutanesulfonate (PFBS)      | 7                  | 0.0%     | 6                       | 0.0%          |                            |                |                | 0.0000            | <0.0052                           | <0.0049                     |
|               |                 |                                         | 45298-90-6  | Perfluorooctane sulfonic acid (PFOS) | 7                  | 0.0%     | 6                       | 0.0%          |                            |                |                | 0.0000            | <0.0052                           | <0.0049                     |
| SW-114        | Closed Landfill | Anderson Sanitary Landfill              | 108427-53-8 | Perfluorohexane sulfonate (PFHxS)    | 1                  | 0.0%     | 1                       | 0.0%          |                            |                |                | 0.0000            | <0.006                            | <0.006                      |
|               |                 |                                         | 123-91-1    | 1,4-Dioxane                          | 15                 | 26.7%    | 8                       | 37.5%         | 3.3250                     | 1.1000         | 8.2000         | 2.0889            | 2.9000                            | 2.9                         |
|               |                 |                                         | 335-67-1    | Perfluorooctanoic acid (PFOA)        | 1                  | 100.0%   | 1                       | 100.0%        | 0.0230                     | 0.0230         | 0.0230         | 0.0230            | 0.0230                            | 0.023                       |
|               |                 |                                         | 375-22-4    | Perfluorobutanoic acid (PFBA)        | 1                  | 0.0%     | 1                       | 0.0%          |                            |                |                | 0.0000            | <0.006                            | <0.006                      |
|               |                 |                                         | 45187-15-3  | Perfluorobutanesulfonate (PFBS)      | 1                  | 0.0%     | 1                       | 0.0%          |                            |                |                | 0.0000            | <0.008                            | <0.008                      |
|               |                 |                                         | 45298-90-6  | Perfluorooctane sulfonic acid (PFOS) | 1                  | 0.0%     | 1                       | 0.0%          |                            |                |                | 0.0000            | <0.005                            | <0.005                      |
| SW-115        | Closed Landfill | Karlstad Sanitary Landfill              | 108427-53-8 | Perfluorohexane sulfonate (PFHxS)    | 2                  | 0.0%     | 2                       | 0.0%          |                            |                |                | 0.0000            | <0.013                            | <0.013                      |
|               |                 |                                         | 123-91-1    | 1,4-Dioxane                          | 6                  | 33.3%    | 5                       | 20.0%         | 11.2000                    | 8.4000         | 14.0000        | 9.3333            | <0.36                             | <0.36                       |
|               |                 |                                         | 335-67-1    | Perfluorooctanoic acid (PFOA)        | 2                  | 50.0%    | 2                       | 50.0%         | 0.0610                     | 0.0610         | 0.0610         | 0.0610            | 0.0610                            | 0.061                       |
|               |                 |                                         | 375-22-4    | Perfluorobutanoic acid (PFBA)        | 2                  | 100.0%   | 2                       | 100.0%        | 0.0205                     | 0.0130         | 0.0280         | 0.0205            | 0.0205                            | 0.0205                      |
|               |                 |                                         | 45187-15-3  | Perfluorobutanesulfonate (PFBS)      | 2                  | 50.0%    | 2                       | 50.0%         | 0.2500                     | 0.2500         | 0.2500         | 0.2500            | 0.2500                            | 0.25                        |
|               |                 |                                         | 45298-90-6  | Perfluorooctane sulfonic acid (PFOS) | 2                  | 0.0%     | 2                       | 0.0%          |                            |                |                | 0.0000            | <0.007                            | <0.007                      |
| SW-117        | Closed Landfill | Lindala Sanitary Landfill               | 108427-53-8 | Perfluorohexane sulfonate (PFHxS)    | 74                 | 9.5%     | 21                      | 33.3%         | 0.5000                     | 0.5000         | 0.5000         | 0.5000            | <0.0051                           | <0.0051                     |
|               |                 |                                         | 123-91-1    | 1,4-Dioxane                          | 62                 | 12.9%    | 23                      | 13.0%         | 5.1000                     | 0.4000         | 9.2000         | 1.2174            | <0.22                             | <0.22                       |
|               |                 |                                         | 335-67-1    | Perfluorooctanoic acid (PFOA)        | 81                 | 17.3%    | 21                      | 19.0%         | 0.0079                     | 0.0032         | 0.0153         | 0.0043            | <0.0031                           | <0.0031                     |
|               |                 |                                         | 375-22-4    | Perfluorobutanoic acid (PFBA)        | 74                 | 45.9%    | 21                      | 52.4%         | 0.0182                     | 0.0031         | 0.0516         | 0.0111            | 0.0074                            | 0.0074                      |
|               |                 |                                         | 45187-15-3  | Perfluorobutanesulfonate (PFBS)      | 74                 | 9.5%     | 21                      | 33.3%         | 0.5000                     | 0.5000         | 0.5000         | 0.5000            | <0.0051                           | <0.0051                     |
|               |                 |                                         | 45298-90-6  | Perfluorooctane sulfonic acid (PFOS) | 81                 | 17.3%    | 21                      | 33.3%         | 0.5000                     | 0.5000         | 0.5000         | 0.5000            | <0.0051                           | <0.0051                     |
| SW-120        | Closed Landfill | Pipestone County Sanitary Landfill      | 108427-53-8 | Perfluorohexane sulfonate (PFHxS)    | 3                  | 0.0%     | 3                       | 0.0%          |                            |                |                | 0.0000            | <0.006                            | <0.006                      |
|               |                 |                                         | 123-91-1    | 1,4-Dioxane                          | 9                  | 22.2%    | 9                       | 22.2%         | 1.0700                     | 0.8200         | 1.3200         | 0.8756            | <0.071                            | <0.071                      |
|               |                 |                                         | 335-67-1    | Perfluorooctanoic acid (PFOA)        | 3                  | 33.3%    | 3                       | 33.3%         | 0.1900                     | 0.1900         | 0.1900         | 0.1900            | <0.006                            | <0.006                      |
|               |                 |                                         | 375-22-4    | Perfluorobutanoic acid (PFBA)        | 3                  | 100.0%   | 3                       | 100.0%        | 0.0190                     | 0.0100         | 0.0360         | 0.0190            | 0.0110                            | 0.019                       |
|               |                 |                                         | 45187-15-3  | Perfluorobutanesulfonate (PFBS)      | 3                  | 33.3%    | 3                       | 33.3%         | 0.0120                     | 0.0120         | 0.0120         | 0.0120            | <0.008                            | <0.008                      |
|               |                 |                                         | 45298-90-6  | Perfluorooctane sulfonic acid (PFOS) | 3                  | 33.3%    | 3                       | 33.3%         | 0.0270                     | 0.0270         | 0.0270         | 0.0270            | <0.005                            | <0.005                      |
| SW-121        | Closed Landfill | Dodge County Sanitary Landfill          | 108427-53-8 | Perfluorohexane sulfonate (PFHxS)    | 5                  | 0.0%     | 5                       | 0.0%          |                            |                |                | 0.0000            | <0.006                            | <0.006                      |
|               |                 |                                         | 123-91-1    | 1,4-Dioxane                          | 31                 | 58.1%    | 14                      | 50.0%         | 2.6889                     | 0.2700         | 13.1200        | 1.6745            | 0.2900                            | 1.6745                      |
|               |                 |                                         | 335-67-1    | Perfluorooctanoic acid (PFOA)        | 5                  | 20.0%    | 5                       | 20.0%         | 0.0080                     | 0.0080         | 0.0080         | 0.0080            | <0.006                            | <0.006                      |
|               |                 |                                         | 375-22-4    | Perfluorobutanoic acid (PFBA)        | 5                  | 60.0%    | 5                       | 60.0%         | 0.0170                     | 0.0120         | 0.0250         | 0.0150            | 0.0120                            | 0.015                       |
|               |                 |                                         | 45187-15-3  | Perfluorobutanesulfonate (PFBS)      | 5                  | 0.0%     | 5                       | 0.0%          |                            |                |                | 0.0000            | <0.008                            | <0.008                      |
|               |                 |                                         | 45298-90-6  | Perfluorooctane sulfonic acid (PFOS) | 5                  | 0.0%     | 5                       | 0.0%          |                            |                |                | 0.0000            | <0.005                            | <0.005                      |
| SW-126        | Closed Landfill | Houston County Sanitary Landfill        | 108427-53-8 | Perfluorohexane sulfonate (PFHxS)    | 11                 | 63.6%    | 7                       | 57.1%         | 0.0128                     | 0.0049         | 0.0596         | 0.0100            | 0.0051                            | 0.01                        |
|               |                 |                                         | 123-91-1    | 1,4-Dioxane                          | 55                 | 40.0%    | 18                      | 61.1%         | 0.9779                     | 0.0520         | 8.6000         | 0.4228            | 0.0660                            | 0.066                       |
|               |                 |                                         | 335-67-1    | Perfluorooctanoic acid (PFOA)        | 11                 | 72.7%    | 7                       | 57.1%         | 0.0144                     | 0.0025         | 0.0763         | 0.0112            | 0.0025                            | 0.0112                      |
|               |                 |                                         | 375-22-4    | Perfluorobutanoic acid (PFBA)        | 11                 | 72.7%    | 7                       | 57.1%         | 0.0594                     | 0.0025         | 0.4140         | 0.0441            | 0.0051                            | 0.0441                      |
|               |                 |                                         | 45187-15-3  | Perfluorobutanesulfonate (PFBS)      | 11                 | 63.6%    | 7                       | 57.1%         | 0.0138                     | 0.0049         | 0.0665         | 0.0106            | 0.0051                            | 0.0106                      |
|               |                 |                                         | 45298-90-6  | Perfluorooctane sulfonic acid (PFOS) | 11                 | 63.6%    | 7                       | 57.1%         | 0.0128                     | 0.0049         | 0.0596         | 0.0100            | 0.0050                            | 0.01                        |
| SW-129        | Closed Landfill | Isanti-Chisago County Sanitary Landfill | 108427-53-8 | Perfluorohexane sulfonate (PFHxS)    | 1                  | 0.0%     | 1                       | 0.0%          |                            |                |                | 0.0000            | <0.087                            | <0.087                      |
|               |                 |                                         | 123-91-1    | 1,4-Dioxane                          | 48                 | 54.2%    | 19                      | 47.4%         | 0.5497                     | 0.0510         | 2.9000         | 0.3211            | 0.0555                            | 0.3211                      |
|               |                 |                                         | 335-67-1    | Perfluorooctanoic acid (PFOA)        | 1                  | 0.0%     | 1                       | 0.0%          |                            |                |                | 0.0000            | <0.087                            | <0.087                      |
|               |                 |                                         | 375-22-4    | Perfluorobutanoic acid (PFBA)        | 1                  | 0.0%     | 1                       | 0.0%          |                            |                |                | 0.0000            | <0.271                            | <0.271                      |
|               |                 |                                         | 45187-15-3  | Perfluorobutanesulfonate (PFBS)      | 1                  | 0.0%     | 1                       | 0.0%          |                            |                |                | 0.0000            | <0.056                            | <0.056                      |
|               |                 |                                         | 45298-90-6  | Perfluorooctane sulfonic acid (PFOS) | 1                  | 0.0%     | 1                       | 0.0%          |                            |                |                | 0.0000            | <0.107                            | <0.107                      |
| SW-131        | Operating MSW   | Steele County Sanitary Landfill         | 108427-53-8 | Perfluorohexane sulfonate (PFHxS)    | 5                  | 0.0%     | 5                       | 0.0%          |                            |                |                | 0.0000            | <0.0085                           | <0.0071                     |
|               |                 |                                         | 335-67-1    | Perfluorooctanoic acid (PFOA)        | 5                  | 20.0%    | 5                       | 20.0%         | 0.0103                     | 0.0103         | 0.0103         | 0.0103            | <0.0043                           | <0.0043                     |
|               |                 |                                         | 375-22-4    | Perfluorobutanoic acid (PFBA)        | 5                  | 60.0%    | 5                       | 60.0%         | 0.0182                     | 0.0098         | 0.0332         | 0.0148            | 0.0098                            | 0.0148                      |
|               |                 |                                         | 45187-15-3  | Perfluorobutanesulfonate (PFBS)      | 5                  | 0.0%     | 5                       | 0.0%          |                            |                |                | 0.0000            | <0.0085                           | <0.0071                     |
|               |                 |                                         | 45298-90-6  | Perfluorooctane sulfonic acid (PFOS) | 5                  | 0.0%     | 5                       | 0.0%          |                            |                |                | 0.0000            | <0.0085                           | <0.0071                     |

all concentrations in µg/L

pink shading indicates method used to determine measure of central tendency

bold indicates measure of central tendency above MN drinking water guidance

Table A-1 (continued)  
Summary Statistics Regulated PFAS and 1,4-Dioxane

| Facility Code | Facility Type     | Facility Name                       | CAS RN      | Chemical Name                        | Total Sample Count | % Detect | Number of Sampled Wells | % Well Detect | Arithmetic Mean of Detects | Minimum Detect | Maximum Detect | Kaplan Meier Mean | Median of Detects and Non-Detects | Measure of Central Tendency |
|---------------|-------------------|-------------------------------------|-------------|--------------------------------------|--------------------|----------|-------------------------|---------------|----------------------------|----------------|----------------|-------------------|-----------------------------------|-----------------------------|
| SW-134        | Other Solid Waste | Begin Dump and Demolition Landfill  | 108427-53-8 | Perfluorohexane sulfonate (PFHxS)    | 2                  | 0.0%     | 2                       | 0.0%          |                            |                |                | 0.0000            | <0.013                            | <0.013                      |
|               |                   |                                     | 123-91-1    | 1,4-Dioxane                          | 2                  | 50.0%    | 2                       | 50.0%         | 150.0000                   | 150.0000       | 150.0000       | 150.0000          | 150.0000                          | 150                         |
|               |                   |                                     | 335-67-1    | Perfluorooctanoic acid (PFOA)        | 2                  | 50.0%    | 2                       | 50.0%         | 0.2100                     | 0.2100         | 0.2100         | 0.2100            | 0.2100                            | 0.21                        |
|               |                   |                                     | 375-22-4    | Perfluorobutanoic acid (PFBA)        | 2                  | 100.0%   | 2                       | 100.0%        | 0.3275                     | 0.0850         | 0.5700         | 0.3275            | 0.3275                            | 0.3275                      |
|               |                   |                                     | 45187-15-3  | Perfluorobutanesulfonate (PFBS)      | 2                  | 50.0%    | 2                       | 50.0%         | 0.0140                     | 0.0140         | 0.0140         | 0.0140            | 0.0140                            | 0.014                       |
|               |                   |                                     | 45298-90-6  | Perfluorooctane sulfonic acid (PFOS) | 2                  | 50.0%    | 2                       | 50.0%         | 0.0670                     | 0.0670         | 0.0670         | 0.0670            | 0.0670                            | 0.067                       |
| SW-135        | Closed Landfill   | Grand Rapids Area Sanitary Landfill | 108427-53-8 | Perfluorohexane sulfonate (PFHxS)    | 10                 | 0.0%     | 10                      | 0.0%          |                            |                |                | 0.0000            | <0.013                            | <0.013                      |
|               |                   |                                     | 123-91-1    | 1,4-Dioxane                          | 71                 | 33.8%    | 29                      | 34.5%         | 3.2450                     | 0.2200         | 9.8000         | 1.2425            | <0.42                             | <0.42                       |
|               |                   |                                     | 335-67-1    | Perfluorooctanoic acid (PFOA)        | 10                 | 10.0%    | 10                      | 10.0%         | 0.0210                     | 0.0210         | 0.0210         | 0.0210            | <0.012                            | <0.012                      |
|               |                   |                                     | 375-22-4    | Perfluorobutanoic acid (PFBA)        | 10                 | 80.0%    | 10                      | 80.0%         | 0.0195                     | 0.0090         | 0.0550         | 0.0174            | 0.0110                            | 0.0174                      |
|               |                   |                                     | 45187-15-3  | Perfluorobutanesulfonate (PFBS)      | 10                 | 10.0%    | 10                      | 10.0%         | 0.0090                     | 0.0090         | 0.0090         | 0.0090            | 0.0090                            | 0.009                       |
|               |                   |                                     | 45298-90-6  | Perfluorooctane sulfonic acid (PFOS) | 10                 | 0.0%     | 10                      | 0.0%          |                            |                |                | 0.0000            | <0.007                            | <0.007                      |
| SW-137        | Closed Landfill   | Salol Landfill                      | 108427-53-8 | Perfluorohexane sulfonate (PFHxS)    | 5                  | 0.0%     | 5                       | 0.0%          |                            |                |                | 0.0000            | <0.005                            | <0.0049                     |
|               |                   |                                     | 123-91-1    | 1,4-Dioxane                          | 100                | 55.0%    | 39                      | 64.1%         | 2.3536                     | 0.0680         | 9.6000         | 1.3298            | 0.3950                            | 1.3298                      |
|               |                   |                                     | 335-67-1    | Perfluorooctanoic acid (PFOA)        | 5                  | 40.0%    | 5                       | 40.0%         | 0.0033                     | 0.0032         | 0.0035         | 0.0033            | <0.0025                           | <0.0025                     |
|               |                   |                                     | 375-22-4    | Perfluorobutanoic acid (PFBA)        | 5                  | 60.0%    | 5                       | 60.0%         | 0.0038                     | 0.0028         | 0.0045         | 0.0034            | 0.0028                            | 0.0034                      |
|               |                   |                                     | 45187-15-3  | Perfluorobutanesulfonate (PFBS)      | 5                  | 0.0%     | 5                       | 0.0%          |                            |                |                | 0.0000            | <0.005                            | <0.0049                     |
|               |                   |                                     | 45298-90-6  | Perfluorooctane sulfonic acid (PFOS) | 5                  | 20.0%    | 5                       | 20.0%         | 0.0065                     | 0.0065         | 0.0065         | 0.0065            | <0.005                            | <0.005                      |
| SW-14         | Closed Landfill   | Flying Cloud Sanitary Landfill      | 108427-53-8 | Perfluorohexane sulfonate (PFHxS)    | 7                  | 0.0%     | 7                       | 0.0%          |                            |                |                | 0.0000            | <0.0049                           | <0.0048                     |
|               |                   |                                     | 123-91-1    | 1,4-Dioxane                          | 32                 | 53.1%    | 19                      | 52.6%         | 8.9331                     | 0.0620         | 21.0000        | 4.7748            | 0.2310                            | 4.7748                      |
|               |                   |                                     | 335-67-1    | Perfluorooctanoic acid (PFOA)        | 11                 | 18.2%    | 8                       | 25.0%         | 0.0290                     | 0.0111         | 0.0468         | 0.0182            | <0.087                            | <0.087                      |
|               |                   |                                     | 375-22-4    | Perfluorobutanoic acid (PFBA)        | 7                  | 57.1%    | 7                       | 57.1%         | 0.1574                     | 0.0045         | 0.5180         | 0.0989            | 0.0941                            | 0.0989                      |
|               |                   |                                     | 45187-15-3  | Perfluorobutanesulfonate (PFBS)      | 7                  | 14.3%    | 7                       | 14.3%         | 0.0098                     | 0.0098         | 0.0098         | 0.0098            | <0.0049                           | <0.0049                     |
|               |                   |                                     | 45298-90-6  | Perfluorooctane sulfonic acid (PFOS) | 11                 | 0.0%     | 8                       | 0.0%          |                            |                |                | 0.0000            | <0.107                            | <0.0048                     |
| SW-141        | Closed Landfill   | La Grand Sanitary Landfill          | 108427-53-8 | Perfluorohexane sulfonate (PFHxS)    | 3                  | 0.0%     | 3                       | 0.0%          |                            |                |                | 0.0000            | <0.006                            | <0.006                      |
|               |                   |                                     | 123-91-1    | 1,4-Dioxane                          | 20                 | 10.0%    | 9                       | 22.2%         | 0.2750                     | 0.1800         | 0.3700         | 0.1895            | <0.22                             | <0.22                       |
|               |                   |                                     | 335-67-1    | Perfluorooctanoic acid (PFOA)        | 3                  | 0.0%     | 3                       | 0.0%          |                            |                |                | 0.0000            | <0.006                            | <0.006                      |
|               |                   |                                     | 375-22-4    | Perfluorobutanoic acid (PFBA)        | 3                  | 33.3%    | 3                       | 33.3%         | 0.0230                     | 0.0230         | 0.0230         | 0.0230            | <0.006                            | <0.006                      |
|               |                   |                                     | 45187-15-3  | Perfluorobutanesulfonate (PFBS)      | 3                  | 0.0%     | 3                       | 0.0%          |                            |                |                | 0.0000            | <0.008                            | <0.008                      |
|               |                   |                                     | 45298-90-6  | Perfluorooctane sulfonic acid (PFOS) | 3                  | 0.0%     | 3                       | 0.0%          |                            |                |                | 0.0000            | <0.005                            | <0.005                      |
| SW-145        | Closed Landfill   | Aitkin County Sanitary Landfill     | 108427-53-8 | Perfluorohexane sulfonate (PFHxS)    | 2                  | 0.0%     | 2                       | 0.0%          |                            |                |                | 0.0000            | <0.006                            | <0.006                      |
|               |                   |                                     | 123-91-1    | 1,4-Dioxane                          | 32                 | 31.3%    | 11                      | 36.4%         | 2.5420                     | 0.2800         | 4.5000         | 0.9869            | <0.22                             | <0.22                       |
|               |                   |                                     | 335-67-1    | Perfluorooctanoic acid (PFOA)        | 2                  | 50.0%    | 2                       | 50.0%         | 0.0100                     | 0.0100         | 0.0100         | 0.0100            | 0.0100                            | 0.01                        |
|               |                   |                                     | 375-22-4    | Perfluorobutanoic acid (PFBA)        | 2                  | 50.0%    | 2                       | 50.0%         | 0.0470                     | 0.0470         | 0.0470         | 0.0470            | 0.0470                            | 0.047                       |
|               |                   |                                     | 45187-15-3  | Perfluorobutanesulfonate (PFBS)      | 2                  | 0.0%     | 2                       | 0.0%          |                            |                |                | 0.0000            | <0.008                            | <0.008                      |
|               |                   |                                     | 45298-90-6  | Perfluorooctane sulfonic acid (PFOS) | 2                  | 0.0%     | 2                       | 0.0%          |                            |                |                | 0.0000            | <0.005                            | <0.005                      |
| SW-154        | Closed Landfill   | Wabasha County Sanitary Landfill    | 108427-53-8 | Perfluorohexane sulfonate (PFHxS)    | 4                  | 25.0%    | 4                       | 25.0%         | 0.0320                     | 0.0320         | 0.0320         | 0.0320            | <0.006                            | <0.006                      |
|               |                   |                                     | 123-91-1    | 1,4-Dioxane                          | 38                 | 26.3%    | 13                      | 23.1%         | 1.0803                     | 0.0630         | 3.0000         | 0.3307            | 0.0630                            | 0.063                       |
|               |                   |                                     | 335-67-1    | Perfluorooctanoic acid (PFOA)        | 4                  | 0.0%     | 4                       | 0.0%          |                            |                |                | 0.0000            | <0.006                            | <0.006                      |
|               |                   |                                     | 375-22-4    | Perfluorobutanoic acid (PFBA)        | 4                  | 25.0%    | 4                       | 25.0%         | 0.0280                     | 0.0280         | 0.0280         | 0.0280            | <0.006                            | <0.006                      |
|               |                   |                                     | 45187-15-3  | Perfluorobutanesulfonate (PFBS)      | 4                  | 0.0%     | 4                       | 0.0%          |                            |                |                | 0.0000            | <0.008                            | <0.008                      |
|               |                   |                                     | 45298-90-6  | Perfluorooctane sulfonic acid (PFOS) | 4                  | 0.0%     | 4                       | 0.0%          |                            |                |                | 0.0000            | <0.005                            | <0.005                      |
| SW-157        | Closed Landfill   | Goodhue Cooperative Landfill        | 108427-53-8 | Perfluorohexane sulfonate (PFHxS)    | 2                  | 0.0%     | 2                       | 0.0%          |                            |                |                | 0.0000            | <0.006                            | <0.006                      |
|               |                   |                                     | 123-91-1    | 1,4-Dioxane                          | 16                 | 50.0%    | 5                       | 60.0%         | 0.1491                     | 0.0950         | 0.3000         | 0.1221            | 0.0950                            | 0.1221                      |
|               |                   |                                     | 335-67-1    | Perfluorooctanoic acid (PFOA)        | 2                  | 0.0%     | 2                       | 0.0%          |                            |                |                | 0.0000            | <0.006                            | <0.006                      |
|               |                   |                                     | 375-22-4    | Perfluorobutanoic acid (PFBA)        | 2                  | 100.0%   | 2                       | 100.0%        | 0.0445                     | 0.0320         | 0.0570         | 0.0445            | 0.0445                            | 0.0445                      |
|               |                   |                                     | 45187-15-3  | Perfluorobutanesulfonate (PFBS)      | 2                  | 0.0%     | 2                       | 0.0%          |                            |                |                | 0.0000            | <0.008                            | <0.008                      |
|               |                   |                                     | 45298-90-6  | Perfluorooctane sulfonic acid (PFOS) | 2                  | 0.0%     | 2                       | 0.0%          |                            |                |                | 0.0000            | <0.005                            | <0.005                      |
| SW-16         | Closed Landfill   | Crosby American Properties Landfill | 108427-53-8 | Perfluorohexane sulfonate (PFHxS)    | 5                  | 40.0%    | 5                       | 40.0%         | 0.0090                     | 0.0060         | 0.0120         | 0.0072            | <0.004                            | <0.004                      |
|               |                   |                                     | 123-91-1    | 1,4-Dioxane                          | 38                 | 31.6%    | 11                      | 36.4%         | 10.4828                    | 0.0620         | 54.0000        | 3.3528            | <0.03                             | <0.03                       |
|               |                   |                                     | 335-67-1    | Perfluorooctanoic acid (PFOA)        | 5                  | 80.0%    | 5                       | 80.0%         | 0.1335                     | 0.0410         | 0.3000         | 0.1150            | 0.0930                            | 0.115                       |
|               |                   |                                     | 375-22-4    | Perfluorobutanoic acid (PFBA)        | 5                  | 100.0%   | 5                       | 100.0%        | 0.1940                     | 0.0600         | 0.4800         | 0.1940            | 0.1600                            | 0.194                       |
|               |                   |                                     | 45187-15-3  | Perfluorobutanesulfonate (PFBS)      | 5                  | 20.0%    | 5                       | 20.0%         | 0.0150                     | 0.0150         | 0.0150         | 0.0150            | <0.005                            | <0.005                      |
|               |                   |                                     | 45298-90-6  | Perfluorooctane sulfonic acid (PFOS) | 5                  | 80.0%    | 5                       | 80.0%         | 0.0833                     | 0.0110         | 0.1900         | 0.0688            | 0.0620                            | 0.0688                      |

all concentrations in µg/L

pink shading indicates method used to determine measure of central tendency

bold indicates measure of central tendency above MN drinking water guidance

Table A-1 (continued)  
Summary Statistics Regulated PFAS and 1,4-Dioxane

| Facility Code | Facility Type     | Facility Name                        | CAS RN      | Chemical Name                        | Total Sample Count | % Detect | Number of Sampled Wells | % Well Detect | Arithmetic Mean of Detects | Minimum Detect | Maximum Detect | Kaplan Meier Mean | Median of Detects and Non-Detects | Measure of Central Tendency |
|---------------|-------------------|--------------------------------------|-------------|--------------------------------------|--------------------|----------|-------------------------|---------------|----------------------------|----------------|----------------|-------------------|-----------------------------------|-----------------------------|
| SW-161        | Closed Landfill   | Hibbing Sanitary Landfill            | 108427-53-8 | Perfluorohexane sulfonate (PFHxS)    | 2                  | 0.0%     | 2                       | 0.0%          |                            |                |                | 0.0000            | <0.013                            | <0.013                      |
|               |                   |                                      | 123-91-1    | 1,4-Dioxane                          | 23                 | 13.0%    | 15                      | 20.0%         | 0.7800                     | 0.3100         | 1.1000         | 0.3713            | <0.36                             | <0.36                       |
|               |                   |                                      | 335-67-1    | Perfluorooctanoic acid (PFOA)        | 2                  | 50.0%    | 2                       | 50.0%         | 0.0470                     | 0.0470         | 0.0470         | 0.0470            | 0.0470                            | <b>0.047</b>                |
|               |                   |                                      | 375-22-4    | Perfluorobutanoic acid (PFBA)        | 2                  | 100.0%   | 2                       | 100.0%        | 0.0255                     | 0.0120         | 0.0390         | 0.0255            | 0.0255                            | 0.0255                      |
|               |                   |                                      | 45187-15-3  | Perfluorobutanesulfonate (PFBS)      | 2                  | 0.0%     | 2                       | 0.0%          |                            |                |                | 0.0000            | <0.009                            | <0.009                      |
|               |                   |                                      | 45298-90-6  | Perfluorooctane sulfonic acid (PFOS) | 2                  | 0.0%     | 2                       | 0.0%          |                            |                |                | 0.0000            | <0.007                            | <0.007                      |
| SW-174        | Other Solid Waste | Red Wing Land Disposal Facility      | 108427-53-8 | Perfluorohexane sulfonate (PFHxS)    | 3                  | 0.0%     | 3                       | 0.0%          |                            |                |                | 0.0000            | <0.0085                           | <0.0085                     |
|               |                   |                                      | 335-67-1    | Perfluorooctanoic acid (PFOA)        | 3                  | 0.0%     | 3                       | 0.0%          |                            |                |                | 0.0000            | <0.0043                           | <0.0042                     |
|               |                   |                                      | 375-22-4    | Perfluorobutanoic acid (PFBA)        | 3                  | 100.0%   | 3                       | 100.0%        | 0.0362                     | 0.0318         | 0.0437         | 0.0362            | 0.0330                            | 0.0362                      |
|               |                   |                                      | 45187-15-3  | Perfluorobutanesulfonate (PFBS)      | 3                  | 0.0%     | 3                       | 0.0%          |                            |                |                | 0.0000            | <0.0085                           | <0.0085                     |
|               |                   |                                      | 45298-90-6  | Perfluorooctane sulfonic acid (PFOS) | 3                  | 0.0%     | 3                       | 0.0%          |                            |                |                | 0.0000            | <0.0085                           | <0.0085                     |
|               |                   |                                      | 108427-53-8 | Perfluorohexane sulfonate (PFHxS)    | 5                  | 20.0%    | 4                       | 25.0%         | 0.0050                     | 0.0050         | 0.0050         | 0.0050            | 0.0050                            | 0.005                       |
| SW-175        | Closed Landfill   | Cotton Area Sanitary Landfill        | 123-91-1    | 1,4-Dioxane                          | 9                  | 44.4%    | 8                       | 37.5%         | 4.5500                     | 2.0000         | 7.0000         | 3.1333            | <0.36                             | <0.36                       |
|               |                   |                                      | 335-67-1    | Perfluorooctanoic acid (PFOA)        | 5                  | 40.0%    | 4                       | 25.0%         | 0.1365                     | 0.1100         | 0.1630         | 0.1206            | <0.006                            | <0.006                      |
|               |                   |                                      | 375-22-4    | Perfluorobutanoic acid (PFBA)        | 5                  | 60.0%    | 4                       | 50.0%         | 0.0227                     | 0.0141         | 0.0319         | 0.0192            | 0.0141                            | 0.0192                      |
|               |                   |                                      | 45187-15-3  | Perfluorobutanesulfonate (PFBS)      | 5                  | 20.0%    | 4                       | 25.0%         | 0.0387                     | 0.0387         | 0.0387         | 0.0387            | <0.008                            | <0.008                      |
|               |                   |                                      | 45298-90-6  | Perfluorooctane sulfonic acid (PFOS) | 5                  | 40.0%    | 4                       | 25.0%         | 0.0486                     | 0.0381         | 0.0590         | 0.0423            | <0.005                            | <0.005                      |
|               |                   |                                      | 108427-53-8 | Perfluorohexane sulfonate (PFHxS)    | 3                  | 33.3%    | 3                       | 33.3%         | 0.0300                     | 0.0300         | 0.0300         | 0.0300            | <0.006                            | <0.006                      |
| SW-178        | Closed Landfill   | Northeast Otter Tail Co. Landfill    | 123-91-1    | 1,4-Dioxane                          | 44                 | 36.4%    | 14                      | 50.0%         | 2.2067                     | 0.0770         | 5.7000         | 1.2128            | 1.6500                            | <b>1.65</b>                 |
|               |                   |                                      | 335-67-1    | Perfluorooctanoic acid (PFOA)        | 3                  | 100.0%   | 3                       | 100.0%        | 0.0717                     | 0.0300         | 0.1300         | 0.0717            | 0.0550                            | <b>0.0717</b>               |
|               |                   |                                      | 375-22-4    | Perfluorobutanoic acid (PFBA)        | 3                  | 100.0%   | 3                       | 100.0%        | 0.0193                     | 0.0100         | 0.0290         | 0.0193            | 0.0190                            | 0.0193                      |
|               |                   |                                      | 45187-15-3  | Perfluorobutanesulfonate (PFBS)      | 3                  | 33.3%    | 3                       | 33.3%         | 0.0590                     | 0.0590         | 0.0590         | 0.0590            | <0.008                            | <0.008                      |
|               |                   |                                      | 45298-90-6  | Perfluorooctane sulfonic acid (PFOS) | 3                  | 0.0%     | 3                       | 0.0%          |                            |                |                | 0.0000            | <0.005                            | <0.005                      |
|               |                   |                                      | 108427-53-8 | Perfluorohexane sulfonate (PFHxS)    | 1                  | 0.0%     | 1                       | 0.0%          |                            |                |                | 0.0000            | <0.006                            | <0.006                      |
| SW-179        | Closed Landfill   | Walker-Hackensack Landfill           | 123-91-1    | 1,4-Dioxane                          | 10                 | 10.0%    | 9                       | 11.1%         | 0.5300                     | 0.5300         | 0.5300         | 0.5300            | <10                               | <10                         |
|               |                   |                                      | 335-67-1    | Perfluorooctanoic acid (PFOA)        | 1                  | 0.0%     | 1                       | 0.0%          |                            |                |                | 0.0000            | <0.006                            | <0.006                      |
|               |                   |                                      | 375-22-4    | Perfluorobutanoic acid (PFBA)        | 1                  | 0.0%     | 1                       | 0.0%          |                            |                |                | 0.0000            | <0.006                            | <0.006                      |
|               |                   |                                      | 45187-15-3  | Perfluorobutanesulfonate (PFBS)      | 1                  | 0.0%     | 1                       | 0.0%          |                            |                |                | 0.0000            | <0.008                            | <0.008                      |
|               |                   |                                      | 45298-90-6  | Perfluorooctane sulfonic acid (PFOS) | 1                  | 0.0%     | 1                       | 0.0%          |                            |                |                | 0.0000            | <0.005                            | <0.005                      |
|               |                   |                                      | 108427-53-8 | Perfluorohexane sulfonate (PFHxS)    | 1                  | 0.0%     | 1                       | 0.0%          |                            |                |                | 0.0000            | <0.006                            | <0.006                      |
| SW-18         | Closed Landfill   | Bueckers #1 Sanitary Landfill        | 123-91-1    | 1,4-Dioxane                          | 16                 | 31.3%    | 7                       | 42.9%         | 0.7956                     | 0.0880         | 1.3400         | 0.3091            | <0.071                            | <0.071                      |
|               |                   |                                      | 335-67-1    | Perfluorooctanoic acid (PFOA)        | 1                  | 0.0%     | 1                       | 0.0%          |                            |                |                | 0.0000            | <0.006                            | <0.006                      |
|               |                   |                                      | 375-22-4    | Perfluorobutanoic acid (PFBA)        | 1                  | 0.0%     | 1                       | 0.0%          |                            |                |                | 0.0000            | <0.006                            | <0.006                      |
|               |                   |                                      | 45187-15-3  | Perfluorobutanesulfonate (PFBS)      | 1                  | 0.0%     | 1                       | 0.0%          |                            |                |                | 0.0000            | <0.008                            | <0.008                      |
|               |                   |                                      | 45298-90-6  | Perfluorooctane sulfonic acid (PFOS) | 1                  | 0.0%     | 1                       | 0.0%          |                            |                |                | 0.0000            | <0.005                            | <0.005                      |
|               |                   |                                      | 108427-53-8 | Perfluorohexane sulfonate (PFHxS)    | 1                  | 0.0%     | 1                       | 0.0%          |                            |                |                | 0.0000            | <0.006                            | <0.006                      |
| SW-181        | Closed Landfill   | Crosby Sanitary Landfill             | 123-91-1    | 1,4-Dioxane                          | 36                 | 8.3%     | 12                      | 25.0%         | 0.7767                     | 0.1100         | 1.6000         | 0.1900            | <0.22                             | <0.22                       |
|               |                   |                                      | 335-67-1    | Perfluorooctanoic acid (PFOA)        | 6                  | 0.0%     | 4                       | 0.0%          |                            |                |                | 0.0000            | <0.012                            | <0.006                      |
|               |                   |                                      | 375-22-4    | Perfluorobutanoic acid (PFBA)        | 6                  | 33.3%    | 4                       | 50.0%         | 0.0085                     | 0.0080         | 0.0090         | 0.0082            | <0.008                            | <0.008                      |
|               |                   |                                      | 45187-15-3  | Perfluorobutanesulfonate (PFBS)      | 6                  | 0.0%     | 4                       | 0.0%          |                            |                |                | 0.0000            | <0.009                            | <0.008                      |
|               |                   |                                      | 45298-90-6  | Perfluorooctane sulfonic acid (PFOS) | 6                  | 0.0%     | 4                       | 0.0%          |                            |                |                | 0.0000            | <0.007                            | <0.005                      |
|               |                   |                                      | 108427-53-8 | Perfluorohexane sulfonate (PFHxS)    | 5                  | 0.0%     | 4                       | 0.0%          |                            |                |                | 0.0000            | <0.004                            | <0.004                      |
| SW-19         | Closed Landfill   | Korf Brothers Sanitary Landfill      | 123-91-1    | 1,4-Dioxane                          | 51                 | 49.0%    | 13                      | 69.2%         | 1.6971                     | 0.0840         | 7.0000         | 0.8791            | <0.22                             | <0.22                       |
|               |                   |                                      | 335-67-1    | Perfluorooctanoic acid (PFOA)        | 5                  | 40.0%    | 4                       | 50.0%         | 0.0685                     | 0.0370         | 0.1000         | 0.0496            | <0.005                            | <0.005                      |
|               |                   |                                      | 375-22-4    | Perfluorobutanoic acid (PFBA)        | 5                  | 40.0%    | 4                       | 50.0%         | 0.0125                     | 0.0110         | 0.0140         | 0.0116            | <0.003                            | <0.003                      |
|               |                   |                                      | 45187-15-3  | Perfluorobutanesulfonate (PFBS)      | 5                  | 0.0%     | 4                       | 0.0%          |                            |                |                | 0.0000            | <0.005                            | <0.005                      |
|               |                   |                                      | 45298-90-6  | Perfluorooctane sulfonic acid (PFOS) | 5                  | 0.0%     | 4                       | 0.0%          |                            |                |                | 0.0000            | <0.007                            | <0.007                      |
|               |                   |                                      | 108427-53-8 | Perfluorohexane sulfonate (PFHxS)    | 1                  | 0.0%     | 1                       | 0.0%          |                            |                |                | 0.0000            | <0.013                            | <0.013                      |
| SW-191        | Closed Landfill   | Koochiching County Sanitary Landfill | 123-91-1    | 1,4-Dioxane                          | 7                  | 0.0%     | 7                       | 0.0%          |                            |                |                | 0.0000            | <0.22                             | <0.22                       |
|               |                   |                                      | 335-67-1    | Perfluorooctanoic acid (PFOA)        | 1                  | 0.0%     | 1                       | 0.0%          |                            |                |                | 0.0000            | <0.012                            | <0.012                      |
|               |                   |                                      | 375-22-4    | Perfluorobutanoic acid (PFBA)        | 1                  | 100.0%   | 1                       | 100.0%        | 0.0390                     | 0.0390         | 0.0390         | 0.0390            | 0.0390                            | 0.039                       |
|               |                   |                                      | 45187-15-3  | Perfluorobutanesulfonate (PFBS)      | 1                  | 0.0%     | 1                       | 0.0%          |                            |                |                | 0.0000            | <0.009                            | <0.009                      |
|               |                   |                                      | 45298-90-6  | Perfluorooctane sulfonic acid (PFOS) | 1                  | 0.0%     | 1                       | 0.0%          |                            |                |                | 0.0000            | <0.007                            | <0.007                      |
|               |                   |                                      | 108427-53-8 | Perfluorohexane sulfonate (PFHxS)    | 1                  | 0.0%     | 1                       | 0.0%          |                            |                |                | 0.0000            | <0.013                            | <0.013                      |

all concentrations in µg/L

pink shading indicates method used to determine measure of central tendency

bold indicates measure of central tendency above MN drinking water guidance

Table A-1 (continued)  
Summary Statistics Regulated PFAS and 1,4-Dioxane

| Facility Code | Facility Type   | Facility Name                              | CAS RN      | Chemical Name                        | Total Sample Count | % Detect | Number of Sampled Wells | % Well Detect | Arithmetic Mean of Detects | Minimum Detect | Maximum Detect | Kaplan Meier Mean | Median of Detects and Non-Detects | Measure of Central Tendency |
|---------------|-----------------|--------------------------------------------|-------------|--------------------------------------|--------------------|----------|-------------------------|---------------|----------------------------|----------------|----------------|-------------------|-----------------------------------|-----------------------------|
| SW-2          | Closed Landfill | Sibley County Sanitary Landfill            | 108427-53-8 | Perfluorohexane sulfonate (PFHxS)    | 11                 | 27.3%    | 7                       | 14.3%         | 0.0233                     | 0.0210         | 0.0260         | 0.0216            | <0.004                            | <0.004                      |
|               |                 |                                            | 123-91-1    | 1,4-Dioxane                          | 12                 | 50.0%    | 8                       | 25.0%         | 3.2100                     | 1.0000         | 6.3800         | 2.1050            | 1.0000                            | <b>2.105</b>                |
|               |                 |                                            | 335-67-1    | Perfluorooctanoic acid (PFOA)        | 11                 | 27.3%    | 7                       | 14.3%         | 0.0993                     | 0.0650         | 0.1400         | 0.0744            | <0.005                            | <0.005                      |
|               |                 |                                            | 375-22-4    | Perfluorobutanoic acid (PFBA)        | 11                 | 27.3%    | 7                       | 14.3%         | 0.0517                     | 0.0390         | 0.0700         | 0.0425            | <0.003                            | <0.003                      |
|               |                 |                                            | 45187-15-3  | Perfluorobutanesulfonate (PFBS)      | 11                 | 27.3%    | 7                       | 14.3%         | 0.0170                     | 0.0110         | 0.0250         | 0.0126            | <0.005                            | <0.005                      |
|               |                 |                                            | 45298-90-6  | Perfluorooctane sulfonic acid (PFOS) | 11                 | 9.1%     | 7                       | 14.3%         | 0.0120                     | 0.0120         | 0.0120         | 0.0120            | <0.007                            | <0.007                      |
| SW-204        | Closed Landfill | Orr Sanitary Landfill                      | 108427-53-8 | Perfluorohexane sulfonate (PFHxS)    | 1                  | 0.0%     | 1                       | 0.0%          |                            |                |                | 0.0000            | <0.005                            | <0.005                      |
|               |                 |                                            | 335-67-1    | Perfluorooctanoic acid (PFOA)        | 1                  | 0.0%     | 1                       | 0.0%          |                            |                |                | 0.0000            | <0.01                             | <0.01                       |
|               |                 |                                            | 375-22-4    | Perfluorobutanoic acid (PFBA)        | 1                  | 0.0%     | 1                       | 0.0%          |                            |                |                | 0.0000            | <0.008                            | <0.008                      |
|               |                 |                                            | 45187-15-3  | Perfluorobutanesulfonate (PFBS)      | 1                  | 0.0%     | 1                       | 0.0%          |                            |                |                | 0.0000            | <0.009                            | <0.009                      |
|               |                 |                                            | 45298-90-6  | Perfluorooctane sulfonic acid (PFOS) | 1                  | 0.0%     | 1                       | 0.0%          |                            |                |                | 0.0000            | <0.007                            | <0.007                      |
|               |                 |                                            |             |                                      |                    |          |                         |               |                            |                |                |                   |                                   |                             |
| SW-22         | Closed Landfill | Barnesville Sanitary Landfill              | 108427-53-8 | Perfluorohexane sulfonate (PFHxS)    | 5                  | 20.0%    | 3                       | 33.3%         | 0.0080                     | 0.0080         | 0.0080         | 0.0080            | <0.006                            | <0.006                      |
|               |                 |                                            | 123-91-1    | 1,4-Dioxane                          | 18                 | 38.9%    | 7                       | 42.9%         | 1.1443                     | 0.3400         | 2.1000         | 0.6528            | <0.22                             | <0.22                       |
|               |                 |                                            | 335-67-1    | Perfluorooctanoic acid (PFOA)        | 5                  | 40.0%    | 3                       | 33.3%         | 0.0740                     | 0.0730         | 0.0750         | 0.0734            | <0.006                            | <0.006                      |
|               |                 |                                            | 375-22-4    | Perfluorobutanoic acid (PFBA)        | 5                  | 60.0%    | 3                       | 66.7%         | 0.0127                     | 0.0070         | 0.0170         | 0.0104            | 0.0070                            | 0.0104                      |
|               |                 |                                            | 45187-15-3  | Perfluorobutanesulfonate (PFBS)      | 5                  | 0.0%     | 3                       | 0.0%          |                            |                |                | 0.0000            | <0.005                            | <0.005                      |
|               |                 |                                            | 45298-90-6  | Perfluorooctane sulfonic acid (PFOS) | 5                  | 40.0%    | 3                       | 33.3%         | 0.0225                     | 0.0180         | 0.0270         | 0.0198            | <0.007                            | <0.007                      |
| SW-232        | Closed Landfill | Western Lake Superior Sanitary District Lf | 108427-53-8 | Perfluorohexane sulfonate (PFHxS)    | 17                 | 58.8%    | 10                      | 80.0%         | 0.0702                     | 0.0130         | 0.2800         | 0.0508            | 0.0350                            | <b>0.0508</b>               |
|               |                 |                                            | 123-91-1    | 1,4-Dioxane                          | 39                 | 48.7%    | 24                      | 45.8%         | 15.1484                    | 0.3200         | 50.0000        | 7.5441            | <0.22                             | <0.22                       |
|               |                 |                                            | 335-67-1    | Perfluorooctanoic acid (PFOA)        | 18                 | 55.6%    | 10                      | 80.0%         | 0.0597                     | 0.0280         | 0.1100         | 0.0492            | 0.0620                            | <b>0.0492</b>               |
|               |                 |                                            | 375-22-4    | Perfluorobutanoic acid (PFBA)        | 17                 | 64.7%    | 10                      | 90.0%         | 0.2364                     | 0.0060         | 0.6600         | 0.1700            | 0.1600                            | 0.17                        |
|               |                 |                                            | 45187-15-3  | Perfluorobutanesulfonate (PFBS)      | 17                 | 47.1%    | 10                      | 60.0%         | 0.0148                     | 0.0090         | 0.0230         | 0.0123            | 0.0110                            | 0.011                       |
|               |                 |                                            | 45298-90-6  | Perfluorooctane sulfonic acid (PFOS) | 18                 | 44.4%    | 10                      | 70.0%         | 0.0211                     | 0.0100         | 0.0310         | 0.0164            | 0.0180                            | <b>0.018</b>                |
| SW-237        | Closed Landfill | Cook Area Sanitary Landfill                | 108427-53-8 | Perfluorohexane sulfonate (PFHxS)    | 1                  | 0.0%     | 1                       | 0.0%          |                            |                |                | 0.0000            | <0.006                            | <0.006                      |
|               |                 |                                            | 123-91-1    | 1,4-Dioxane                          | 9                  | 0.0%     | 7                       | 0.0%          |                            |                |                | 0.0000            | <0.22                             | <0.01                       |
|               |                 |                                            | 335-67-1    | Perfluorooctanoic acid (PFOA)        | 1                  | 0.0%     | 1                       | 0.0%          |                            |                |                | 0.0000            | <0.006                            | <0.006                      |
|               |                 |                                            | 375-22-4    | Perfluorobutanoic acid (PFBA)        | 1                  | 0.0%     | 1                       | 0.0%          |                            |                |                | 0.0000            | <0.006                            | <0.006                      |
|               |                 |                                            | 45187-15-3  | Perfluorobutanesulfonate (PFBS)      | 1                  | 0.0%     | 1                       | 0.0%          |                            |                |                | 0.0000            | <0.008                            | <0.008                      |
|               |                 |                                            | 45298-90-6  | Perfluorooctane sulfonic acid (PFOS) | 1                  | 0.0%     | 1                       | 0.0%          |                            |                |                | 0.0000            | <0.005                            | <0.005                      |
| SW-25         | Closed Landfill | Winona County Sanitary Landfill            | 108427-53-8 | Perfluorohexane sulfonate (PFHxS)    | 12                 | 0.0%     | 12                      | 0.0%          |                            |                |                | 0.0000            | <0.006                            | <0.006                      |
|               |                 |                                            | 123-91-1    | 1,4-Dioxane                          | 17                 | 35.3%    | 13                      | 46.2%         | 0.5733                     | 0.1100         | 1.2000         | 0.2735            | <0.071                            | <0.071                      |
|               |                 |                                            | 335-67-1    | Perfluorooctanoic acid (PFOA)        | 12                 | 8.3%     | 12                      | 8.3%          | 0.0510                     | 0.0510         | 0.0510         | 0.0510            | <0.006                            | <0.006                      |
|               |                 |                                            | 375-22-4    | Perfluorobutanoic acid (PFBA)        | 12                 | 16.7%    | 12                      | 16.7%         | 0.0715                     | 0.0330         | 0.1100         | 0.0394            | <0.006                            | <0.006                      |
|               |                 |                                            | 45187-15-3  | Perfluorobutanesulfonate (PFBS)      | 12                 | 8.3%     | 12                      | 8.3%          | 0.0190                     | 0.0190         | 0.0190         | 0.0190            | <0.008                            | <0.008                      |
|               |                 |                                            | 45298-90-6  | Perfluorooctane sulfonic acid (PFOS) | 12                 | 16.7%    | 12                      | 16.7%         | 0.0265                     | 0.0220         | 0.0310         | 0.0228            | <0.005                            | <0.005                      |
| SW-253        | Closed Landfill | Carlton South Sanitary Landfill            | 108427-53-8 | Perfluorohexane sulfonate (PFHxS)    | 12                 | 33.3%    | 4                       | 100.0%        | 0.0049                     | 0.0049         | 0.0050         | 0.0049            | 0.0050                            | 0.005                       |
|               |                 |                                            | 123-91-1    | 1,4-Dioxane                          | 7                  | 0.0%     | 7                       | 0.0%          |                            |                |                | 0.0000            | <0.22                             | <0.22                       |
|               |                 |                                            | 335-67-1    | Perfluorooctanoic acid (PFOA)        | 12                 | 33.3%    | 4                       | 100.0%        | 0.0025                     | 0.0024         | 0.0025         | 0.0025            | <0.0025                           | <0.0025                     |
|               |                 |                                            | 375-22-4    | Perfluorobutanoic acid (PFBA)        | 12                 | 58.3%    | 4                       | 100.0%        | 0.0087                     | 0.0025         | 0.0205         | 0.0061            | <0.0025                           | 0.0061                      |
|               |                 |                                            | 45187-15-3  | Perfluorobutanesulfonate (PFBS)      | 12                 | 33.3%    | 4                       | 100.0%        | 0.0049                     | 0.0049         | 0.0050         | 0.0049            | 0.0050                            | 0.005                       |
|               |                 |                                            | 45298-90-6  | Perfluorooctane sulfonic acid (PFOS) | 12                 | 33.3%    | 4                       | 100.0%        | 0.0049                     | 0.0049         | 0.0050         | 0.0049            | 0.0050                            | 0.005                       |
| SW-262        | Closed Landfill | Hwy 77 Sanitary Landfill                   | 108427-53-8 | Perfluorohexane sulfonate (PFHxS)    | 4                  | 50.0%    | 4                       | 50.0%         | 0.0090                     | 0.0060         | 0.0120         | 0.0075            | 0.0060                            | 0.0075                      |
|               |                 |                                            | 123-91-1    | 1,4-Dioxane                          | 14                 | 57.1%    | 7                       | 57.1%         | 3.1938                     | 0.1500         | 6.1000         | 1.8918            | 0.4000                            | <b>1.8918</b>               |
|               |                 |                                            | 335-67-1    | Perfluorooctanoic acid (PFOA)        | 4                  | 50.0%    | 4                       | 50.0%         | 0.0870                     | 0.0740         | 0.1000         | 0.0805            | 0.0740                            | <b>0.0805</b>               |
|               |                 |                                            | 375-22-4    | Perfluorobutanoic acid (PFBA)        | 4                  | 0.0%     | 4                       | 0.0%          |                            |                |                | 0.0000            | <0.003                            | <0.003                      |
|               |                 |                                            | 45187-15-3  | Perfluorobutanesulfonate (PFBS)      | 4                  | 0.0%     | 4                       | 0.0%          |                            |                |                | 0.0000            | <0.005                            | <0.005                      |
|               |                 |                                            | 45298-90-6  | Perfluorooctane sulfonic acid (PFOS) | 4                  | 50.0%    | 4                       | 50.0%         | 0.0445                     | 0.0360         | 0.0530         | 0.0403            | 0.0360                            | <b>0.0403</b>               |
| SW-263        | Solid Waste     | Wanamingo Demolition Landfill              | 108427-53-8 | Perfluorohexane sulfonate (PFHxS)    | 6                  | 16.7%    | 3                       | 33.3%         | 0.0218                     | 0.0218         | 0.0218         | 0.0218            | <0.0084                           | <0.0084                     |
|               |                 |                                            | 335-67-1    | Perfluorooctanoic acid (PFOA)        | 6                  | 50.0%    | 3                       | 66.7%         | 0.0081                     | 0.0040         | 0.0155         | 0.0061            | <0.0042                           | 0.0061                      |
|               |                 |                                            | 375-22-4    | Perfluorobutanoic acid (PFBA)        | 6                  | 83.3%    | 3                       | 100.0%        | 0.0185                     | 0.0043         | 0.0272         | 0.0161            | 0.0193                            | 0.0161                      |
|               |                 |                                            | 45187-15-3  | Perfluorobutanesulfonate (PFBS)      | 6                  | 0.0%     | 3                       | 0.0%          |                            |                |                | 0.0000            | <0.0084                           | <0.0049                     |
|               |                 |                                            | 45298-90-6  | Perfluorooctane sulfonic acid (PFOS) | 6                  | 0.0%     | 3                       | 0.0%          |                            |                |                | 0.0000            | <0.0084                           | <0.0049                     |

all concentrations in µg/L

pink shading indicates method used to determine measure of central tendency

bold indicates measure of central tendency above MN drinking water guidance

Table A-1 (continued)  
Summary Statistics Regulated PFAS and 1,4-Dioxane

| Facility Code | Facility Type     | Facility Name                          | CAS RN      | Chemical Name                        | Total Sample Count | % Detect | Number of Sampled Wells | % Well Detect | Arithmetic Mean of Detects | Minimum Detect | Maximum Detect | Kaplan Meier Mean | Median of Detects and Non-Detects | Measure of Central Tendency |
|---------------|-------------------|----------------------------------------|-------------|--------------------------------------|--------------------|----------|-------------------------|---------------|----------------------------|----------------|----------------|-------------------|-----------------------------------|-----------------------------|
| SW-28         | Closed Landfill   | Waste Disposal Engineering Landfill    | 108427-53-8 | Perfluorohexane sulfonate (PFHxS)    | 66                 | 36.4%    | 44                      | 34.1%         | 0.0240                     | 0.0050         | 0.0870         | 0.0121            | 0.0100                            | 0.01                        |
|               |                   |                                        | 123-91-1    | 1,4-Dioxane                          | 162                | 66.7%    | 59                      | 64.4%         | 66.9585                    | 0.0510         | 390.0000       | 44.6560           | 1.7500                            | 44.656                      |
|               |                   |                                        | 335-67-1    | Perfluorooctanoic acid (PFOA)        | 66                 | 51.5%    | 44                      | 47.7%         | 0.2066                     | 0.0080         | 1.0000         | 0.1103            | <0.012                            | 0.1103                      |
|               |                   |                                        | 375-22-4    | Perfluorobutanoic acid (PFBA)        | 66                 | 83.3%    | 44                      | 86.4%         | 0.3337                     | 0.0080         | 2.7000         | 0.2794            | 0.0375                            | 0.2794                      |
|               |                   |                                        | 45187-15-3  | Perfluorobutanesulfonate (PFBS)      | 66                 | 34.8%    | 44                      | 34.1%         | 0.0182                     | 0.0050         | 0.0400         | 0.0096            | <0.009                            | <0.009                      |
| SW-29         | Closed Landfill   | Kluver Sanitary Landfill               | 45298-90-6  | Perfluorooctane sulfonic acid (PFOS) | 66                 | 10.6%    | 44                      | 13.6%         | 0.0214                     | 0.0110         | 0.0710         | 0.0121            | <0.007                            | <0.007                      |
|               |                   |                                        | 108427-53-8 | Perfluorohexane sulfonate (PFHxS)    | 5                  | 0.0%     | 4                       | 0.0%          |                            |                |                | 0.0000            | <0.006                            | <0.006                      |
|               |                   |                                        | 123-91-1    | 1,4-Dioxane                          | 90                 | 46.7%    | 24                      | 58.3%         | 2.0243                     | 0.1100         | 9.2000         | 1.0120            | <0.22                             | <0.22                       |
|               |                   |                                        | 335-67-1    | Perfluorooctanoic acid (PFOA)        | 5                  | 40.0%    | 4                       | 50.0%         | 0.0205                     | 0.0150         | 0.0260         | 0.0172            | <0.006                            | <0.006                      |
|               |                   |                                        | 375-22-4    | Perfluorobutanoic acid (PFBA)        | 5                  | 80.0%    | 4                       | 75.0%         | 0.0523                     | 0.0400         | 0.0830         | 0.0498            | 0.0430                            | 0.0498                      |
| SW-291        | Other Solid Waste | Hengel Demolition Landfill             | 45187-15-3  | Perfluorobutanesulfonate (PFBS)      | 5                  | 0.0%     | 4                       | 0.0%          |                            |                |                | 0.0000            | <0.008                            | <0.008                      |
|               |                   |                                        | 45298-90-6  | Perfluorooctane sulfonic acid (PFOS) | 5                  | 0.0%     | 4                       | 0.0%          |                            |                |                | 0.0000            | <0.005                            | <0.005                      |
|               |                   |                                        | 108427-53-8 | Perfluorohexane sulfonate (PFHxS)    | 6                  | 66.7%    | 3                       | 66.7%         | 0.0119                     | 0.0071         | 0.0172         | 0.0103            | 0.0078                            | 0.0103                      |
|               |                   |                                        | 335-67-1    | Perfluorooctanoic acid (PFOA)        | 6                  | 50.0%    | 3                       | 66.7%         | 0.0101                     | 0.0031         | 0.0148         | 0.0066            | 0.0031                            | 0.0066                      |
|               |                   |                                        | 375-22-4    | Perfluorobutanoic acid (PFBA)        | 6                  | 66.7%    | 3                       | 66.7%         | 0.0098                     | 0.0079         | 0.0145         | 0.0091            | 0.0079                            | 0.0091                      |
| SW-303        | Other Solid Waste | Dawnway Demolition Landfill            | 45187-15-3  | Perfluorobutanesulfonate (PFBS)      | 6                  | 33.3%    | 3                       | 66.7%         | 0.0073                     | 0.0054         | 0.0093         | 0.0061            | <0.0057                           | <0.0057                     |
|               |                   |                                        | 45298-90-6  | Perfluorooctane sulfonic acid (PFOS) | 6                  | 16.7%    | 3                       | 33.3%         | 0.0060                     | 0.0060         | 0.0060         | 0.0060            | <0.0056                           | <0.0056                     |
|               |                   |                                        | 108427-53-8 | Perfluorohexane sulfonate (PFHxS)    | 8                  | 50.0%    | 3                       | 66.7%         | 0.0617                     | 0.0275         | 0.0808         | 0.0446            | 0.0275                            | 0.0446                      |
|               |                   |                                        | 123-91-1    | 1,4-Dioxane                          | 7                  | 0.0%     | 7                       | 0.0%          |                            |                |                | 0.0000            | <0.22                             | <0.22                       |
|               |                   |                                        | 335-67-1    | Perfluorooctanoic acid (PFOA)        | 8                  | 62.5%    | 3                       | 66.7%         | 0.0666                     | 0.0087         | 0.1150         | 0.0449            | 0.0116                            | 0.0449                      |
| SW-306        | Other Solid Waste | Beltrami County Demolition Landfill    | 375-22-4    | Perfluorobutanoic acid (PFBA)        | 8                  | 100.0%   | 3                       | 100.0%        | 0.8969                     | 0.3740         | 1.4400         | 0.8969            | 0.8185                            | 0.8969                      |
|               |                   |                                        | 45187-15-3  | Perfluorobutanesulfonate (PFBS)      | 8                  | 50.0%    | 3                       | 66.7%         | 0.0120                     | 0.0108         | 0.0143         | 0.0114            | 0.0108                            | 0.0114                      |
|               |                   |                                        | 45298-90-6  | Perfluorooctane sulfonic acid (PFOS) | 8                  | 12.5%    | 3                       | 33.3%         | 0.0087                     | 0.0087         | 0.0087         | 0.0087            | 0.0087                            | 0.0087                      |
|               |                   |                                        | 108427-53-8 | Perfluorohexane sulfonate (PFHxS)    | 6                  | 0.0%     | 3                       | 0.0%          |                            |                |                | 0.0000            | <0.0085                           | <0.0051                     |
|               |                   |                                        | 335-67-1    | Perfluorooctanoic acid (PFOA)        | 6                  | 0.0%     | 3                       | 0.0%          |                            |                |                | 0.0000            | <0.0042                           | <0.0026                     |
| SW-31         | Closed Landfill   | Kummer Sanitary Landfill               | 375-22-4    | Perfluorobutanoic acid (PFBA)        | 6                  | 50.0%    | 3                       | 66.7%         | 0.0090                     | 0.0058         | 0.0117         | 0.0074            | 0.0058                            | 0.0074                      |
|               |                   |                                        | 45187-15-3  | Perfluorobutanesulfonate (PFBS)      | 6                  | 16.7%    | 3                       | 33.3%         | 0.0159                     | 0.0159         | 0.0159         | 0.0159            | <0.0085                           | <0.0085                     |
|               |                   |                                        | 45298-90-6  | Perfluorooctane sulfonic acid (PFOS) | 6                  | 0.0%     | 3                       | 0.0%          |                            |                |                | 0.0000            | <0.0083                           | <0.0051                     |
|               |                   |                                        | 108427-53-8 | Perfluorohexane sulfonate (PFHxS)    | 19                 | 31.6%    | 14                      | 35.7%         | 0.2592                     | 0.0150         | 0.5000         | 0.0921            | <0.006                            | <0.006                      |
|               |                   |                                        | 123-91-1    | 1,4-Dioxane                          | 94                 | 28.7%    | 31                      | 45.2%         | 0.7304                     | 0.2500         | 2.3000         | 0.3880            | <0.22                             | <0.22                       |
| SW-318        | Solid Waste       | Hubbard Co So Transfer & Demo Landfill | 335-67-1    | Perfluorooctanoic acid (PFOA)        | 23                 | 30.4%    | 16                      | 31.3%         | 0.0317                     | 0.0150         | 0.0720         | 0.0223            | 0.0170                            | 0.017                       |
|               |                   |                                        | 375-22-4    | Perfluorobutanoic acid (PFBA)        | 19                 | 57.9%    | 14                      | 64.3%         | 0.1513                     | 0.0090         | 0.8100         | 0.0946            | 0.0150                            | 0.0946                      |
|               |                   |                                        | 45187-15-3  | Perfluorobutanesulfonate (PFBS)      | 19                 | 15.8%    | 14                      | 14.3%         | 0.5000                     | 0.5000         | 0.5000         | 0.5000            | <0.009                            | <0.009                      |
|               |                   |                                        | 45298-90-6  | Perfluorooctane sulfonic acid (PFOS) | 23                 | 30.4%    | 16                      | 25.0%         | 0.5000                     | 0.5000         | 0.5000         | 0.5000            | <0.007                            | <0.007                      |
|               |                   |                                        | 108427-53-8 | Perfluorohexane sulfonate (PFHxS)    | 6                  | 0.0%     | 3                       | 0.0%          |                            |                |                | 0.0000            | <0.0084                           | <0.005                      |
| SW-32         | Closed Landfill   | Louisville Landfill Inc.               | 335-67-1    | Perfluorooctanoic acid (PFOA)        | 6                  | 0.0%     | 3                       | 0.0%          |                            |                |                | 0.0000            | <0.0042                           | <0.0025                     |
|               |                   |                                        | 375-22-4    | Perfluorobutanoic acid (PFBA)        | 6                  | 50.0%    | 3                       | 66.7%         | 0.0055                     | 0.0032         | 0.0085         | 0.0043            | <0.0044                           | 0.0043                      |
|               |                   |                                        | 45187-15-3  | Perfluorobutanesulfonate (PFBS)      | 6                  | 0.0%     | 3                       | 0.0%          |                            |                |                | 0.0000            | <0.0084                           | <0.005                      |
|               |                   |                                        | 45298-90-6  | Perfluorooctane sulfonic acid (PFOS) | 6                  | 16.7%    | 3                       | 33.3%         | 0.0057                     | 0.0057         | 0.0057         | 0.0057            | 0.0057                            | 0.0057                      |
|               |                   |                                        | 108427-53-8 | Perfluorohexane sulfonate (PFHxS)    | 16                 | 75.0%    | 11                      | 90.9%         | 0.0548                     | 0.0070         | 0.2100         | 0.0464            | 0.0450                            | 0.0464                      |
| SW-33         | Closed Landfill   | Maple Landfill                         | 123-91-1    | 1,4-Dioxane                          | 37                 | 91.9%    | 10                      | 100.0%        | 7.0015                     | 0.0820         | 19.0000        | 6.4405            | 5.5000                            | 6.4405                      |
|               |                   |                                        | 335-67-1    | Perfluorooctanoic acid (PFOA)        | 16                 | 81.3%    | 11                      | 81.8%         | 0.0947                     | 0.0140         | 0.4800         | 0.0819            | 0.0560                            | 0.0819                      |
|               |                   |                                        | 375-22-4    | Perfluorobutanoic acid (PFBA)        | 16                 | 87.5%    | 11                      | 90.9%         | 0.1686                     | 0.0150         | 0.8900         | 0.1590            | 0.0920                            | 0.159                       |
|               |                   |                                        | 45187-15-3  | Perfluorobutanesulfonate (PFBS)      | 16                 | 37.5%    | 11                      | 54.5%         | 0.0245                     | 0.0070         | 0.0680         | 0.0140            | 0.0070                            | 0.007                       |
|               |                   |                                        | 45298-90-6  | Perfluorooctane sulfonic acid (PFOS) | 16                 | 43.8%    | 11                      | 63.6%         | 0.0853                     | 0.0100         | 0.3300         | 0.0449            | 0.0125                            | 0.0125                      |
| SW-333        | Other Solid Waste | TK Demolition Disposal LLC             | 108427-53-8 | Perfluorohexane sulfonate (PFHxS)    | 8                  | 12.5%    | 6                       | 16.7%         | 0.0160                     | 0.0160         | 0.0160         | 0.0160            | 0.0160                            | 0.016                       |
|               |                   |                                        | 123-91-1    | 1,4-Dioxane                          | 93                 | 34.4%    | 15                      | 33.3%         | 4.4527                     | 0.0860         | 20.0000        | 1.7280            | 0.4200                            | 0.42                        |
|               |                   |                                        | 335-67-1    | Perfluorooctanoic acid (PFOA)        | 13                 | 15.4%    | 7                       | 28.6%         | 0.0985                     | 0.0470         | 0.1500         | 0.0599            | <0.087                            | <0.087                      |
|               |                   |                                        | 375-22-4    | Perfluorobutanoic acid (PFBA)        | 8                  | 37.5%    | 6                       | 33.3%         | 0.0287                     | 0.0070         | 0.0650         | 0.0200            | 0.0395                            | 0.0395                      |
|               |                   |                                        | 45187-15-3  | Perfluorobutanesulfonate (PFBS)      | 8                  | 0.0%     | 6                       | 0.0%          |                            |                |                | 0.0000            | <0.009                            | <0.008                      |
| SW-333        | Other Solid Waste | TK Demolition Disposal LLC             | 45298-90-6  | Perfluorooctane sulfonic acid (PFOS) | 13                 | 0.0%     | 7                       | 0.0%          |                            |                |                | 0.0000            | <0.107                            | <0.005                      |
|               |                   |                                        | 108427-53-8 | Perfluorohexane sulfonate (PFHxS)    | 6                  | 33.3%    | 3                       | 33.3%         | 0.0090                     | 0.0074         | 0.0105         | 0.0079            | 0.0074                            | 0.0074                      |
|               |                   |                                        | 335-67-1    | Perfluorooctanoic acid (PFOA)        | 6                  | 33.3%    | 3                       | 66.7%         | 0.0039                     | 0.0026         | 0.0053         | 0.0030            | 0.0026                            | 0.0026                      |
|               |                   |                                        | 375-22-4    | Perfluorobutanoic acid (PFBA)        | 6                  | 66.7%    | 3                       | 66.7%         | 0.0258                     | 0.0097         | 0.0363         | 0.0204            | 0.0173                            | 0.0204                      |
|               |                   |                                        | 45187-15-3  | Perfluorobutanesulfonate (PFBS)      | 6                  | 33.3%    | 3                       | 33.3%         | 0.0135                     | 0.0125         | 0.0144         | 0.0128            | <0.0097                           | <0.0097                     |
| SW-333        | Other Solid Waste | TK Demolition Disposal LLC             | 45298-90-6  | Perfluorooctane sulfonic acid (PFOS) | 6                  | 0.0%     | 3                       | 0.0%          |                            |                |                | 0.0000            | <0.0057                           | <0.005                      |

all concentrations in µg/L

pink shading indicates method used to determine measure of central tendency

bold indicates measure of central tendency above MN drinking water guidance

Table A-1 (continued)  
Summary Statistics Regulated PFAS and 1,4-Dioxane

| Facility Code | Facility Type     | Facility Name                                  | CAS RN      | Chemical Name                        | Total Sample Count | % Detect | Number of Sampled Wells | % Well Detect | Arithmetic Mean of Detects | Minimum Detect | Maximum Detect | Kaplan Meier Mean | Median of Detects and Non-Detects | Measure of Central Tendency |
|---------------|-------------------|------------------------------------------------|-------------|--------------------------------------|--------------------|----------|-------------------------|---------------|----------------------------|----------------|----------------|-------------------|-----------------------------------|-----------------------------|
| SW-335        | Solid Waste       | Bueckers City Sanitation Services              | 108427-53-8 | Perfluorohexane sulfonate (PFHxS)    | 6                  | 66.7%    | 3                       | 66.7%         | 0.0261                     | 0.0094         | 0.0546         | 0.0205            | 0.0135                            | 0.0205                      |
|               |                   |                                                | 335-67-1    | Perfluorooctanoic acid (PFOA)        | 6                  | 66.7%    | 3                       | 66.7%         | 0.0238                     | 0.0079         | 0.0693         | 0.0185            | 0.0080                            | 0.0185                      |
|               |                   |                                                | 375-22-4    | Perfluorobutanoic acid (PFBA)        | 6                  | 83.3%    | 3                       | 100.0%        | 0.0264                     | 0.0050         | 0.0790         | 0.0230            | 0.0164                            | 0.023                       |
|               |                   |                                                | 45187-15-3  | Perfluorobutanesulfonate (PFBS)      | 6                  | 0.0%     | 3                       | 0.0%          |                            |                |                | 0.0000            | <0.0083                           | <0.005                      |
|               |                   |                                                | 45298-90-6  | Perfluorooctane sulfonic acid (PFOS) | 6                  | 0.0%     | 3                       | 0.0%          |                            |                |                | 0.0000            | <0.0057                           | <0.005                      |
| SW-34         | Operating MSW     | Clay County Sanitary Landfill                  | 108427-53-8 | Perfluorohexane sulfonate (PFHxS)    | 3                  | 0.0%     | 3                       | 0.0%          |                            |                |                | 0.0000            | <0.0083                           | <0.0082                     |
|               |                   |                                                | 335-67-1    | Perfluorooctanoic acid (PFOA)        | 3                  | 33.3%    | 3                       | 33.3%         | 0.0054                     | 0.0054         | 0.0054         | 0.0054            | <0.0042                           | <0.0042                     |
|               |                   |                                                | 375-22-4    | Perfluorobutanoic acid (PFBA)        | 3                  | 33.3%    | 3                       | 33.3%         | 0.0126                     | 0.0126         | 0.0126         | 0.0126            | <0.0042                           | <0.0042                     |
|               |                   |                                                | 45187-15-3  | Perfluorobutanesulfonate (PFBS)      | 3                  | 0.0%     | 3                       | 0.0%          |                            |                |                | 0.0000            | <0.0083                           | <0.0082                     |
|               |                   |                                                | 45298-90-6  | Perfluorooctane sulfonic acid (PFOS) | 3                  | 0.0%     | 3                       | 0.0%          |                            |                |                | 0.0000            | <0.0083                           | <0.0082                     |
| SW-343        | Other Solid Waste | SKB Rich Valley Demolition Waste Mgmt Facility | 108427-53-8 | Perfluorohexane sulfonate (PFHxS)    | 6                  | 0.0%     | 3                       | 0.0%          |                            |                |                | 0.0000            | <0.0056                           | <0.005                      |
|               |                   |                                                | 335-67-1    | Perfluorooctanoic acid (PFOA)        | 6                  | 16.7%    | 3                       | 33.3%         | 0.0027                     | 0.0027         | 0.0027         | 0.0027            | <0.0025                           | <0.0025                     |
|               |                   |                                                | 375-22-4    | Perfluorobutanoic acid (PFBA)        | 6                  | 100.0%   | 3                       | 100.0%        | 0.1624                     | 0.0996         | 0.2620         | 0.1624            | 0.1435                            | 0.1624                      |
|               |                   |                                                | 45187-15-3  | Perfluorobutanesulfonate (PFBS)      | 6                  | 0.0%     | 3                       | 0.0%          |                            |                |                | 0.0000            | <0.0056                           | <0.005                      |
|               |                   |                                                | 45298-90-6  | Perfluorooctane sulfonic acid (PFOS) | 6                  | 33.3%    | 3                       | 33.3%         | 0.0071                     | 0.0067         | 0.0076         | 0.0069            | 0.0067                            | 0.0067                      |
| SW-35         | Closed Landfill   | St. Augusta Sanitary Landfill                  | 108427-53-8 | Perfluorohexane sulfonate (PFHxS)    | 11                 | 9.1%     | 7                       | 14.3%         | 0.0160                     | 0.0160         | 0.0160         | 0.0160            | <0.006                            | <0.006                      |
|               |                   |                                                | 123-91-1    | 1,4-Dioxane                          | 22                 | 18.2%    | 10                      | 40.0%         | 5.3425                     | 0.9700         | 13.0000        | 1.7650            | <0.22                             | <0.22                       |
|               |                   |                                                | 335-67-1    | Perfluorooctanoic acid (PFOA)        | 11                 | 54.5%    | 7                       | 71.4%         | 0.1533                     | 0.0070         | 0.8210         | 0.0883            | 0.0120                            | <b>0.0883</b>               |
|               |                   |                                                | 375-22-4    | Perfluorobutanoic acid (PFBA)        | 11                 | 81.8%    | 7                       | 100.0%        | 0.0180                     | 0.0056         | 0.0535         | 0.0180            | 0.0150                            | 0.018                       |
|               |                   |                                                | 45187-15-3  | Perfluorobutanesulfonate (PFBS)      | 11                 | 36.4%    | 7                       | 57.1%         | 0.0288                     | 0.0080         | 0.0501         | 0.0172            | <0.008                            | <0.008                      |
|               |                   |                                                | 45298-90-6  | Perfluorooctane sulfonic acid (PFOS) | 11                 | 9.1%     | 7                       | 14.3%         | 0.0505                     | 0.0505         | 0.0505         | 0.0505            | <0.005                            | <0.005                      |
| SW-353        | Solid Waste       | Vonco Demolition Debris Landfill               | 108427-53-8 | Perfluorohexane sulfonate (PFHxS)    | 6                  | 16.7%    | 3                       | 33.3%         | 0.0068                     | 0.0068         | 0.0068         | 0.0068            | 0.0068                            | 0.0068                      |
|               |                   |                                                | 335-67-1    | Perfluorooctanoic acid (PFOA)        | 6                  | 33.3%    | 3                       | 33.3%         | 0.4242                     | 0.0113         | 0.8370         | 0.1489            | <0.0042                           | <0.0042                     |
|               |                   |                                                | 375-22-4    | Perfluorobutanoic acid (PFBA)        | 6                  | 83.3%    | 3                       | 100.0%        | 0.0511                     | 0.0031         | 0.0882         | 0.0431            | 0.0460                            | 0.0431                      |
|               |                   |                                                | 45187-15-3  | Perfluorobutanesulfonate (PFBS)      | 6                  | 16.7%    | 3                       | 33.3%         | 0.0057                     | 0.0057         | 0.0057         | 0.0057            | <0.0081                           | <0.0081                     |
|               |                   |                                                | 45298-90-6  | Perfluorooctane sulfonic acid (PFOS) | 6                  | 0.0%     | 3                       | 0.0%          |                            |                |                | 0.0000            | <0.0081                           | <0.005                      |
| SW-376        | Operating MSW     | Crow Wing County MMSW Landfill                 | 108427-53-8 | Perfluorohexane sulfonate (PFHxS)    | 20                 | 0.0%     | 5                       | 0.0%          |                            |                |                | 0.0000            | <0.0096                           | <0.0096                     |
|               |                   |                                                | 335-67-1    | Perfluorooctanoic acid (PFOA)        | 20                 | 5.0%     | 5                       | 20.0%         | 0.0258                     | 0.0258         | 0.0258         | 0.0350            | <0.0197                           | <0.0197                     |
|               |                   |                                                | 375-22-4    | Perfluorobutanoic acid (PFBA)        | 20                 | 60.0%    | 5                       | 60.0%         | 0.0794                     | 0.0371         | 0.1470         | 0.0569            | 0.0511                            | 0.0569                      |
|               |                   |                                                | 45187-15-3  | Perfluorobutanesulfonate (PFBS)      | 20                 | 60.0%    | 5                       | 60.0%         | 0.0789                     | 0.0354         | 0.1610         | 0.0563            | 0.0485                            | 0.0563                      |
|               |                   |                                                | 45298-90-6  | Perfluorooctane sulfonic acid (PFOS) | 20                 | 0.0%     | 5                       | 0.0%          |                            |                |                | 0.0000            | <0.0295                           | <0.0295                     |
| SW-383        | Other Solid Waste | SKB Rosemount Industrial Waste Facility        | 108427-53-8 | Perfluorohexane sulfonate (PFHxS)    | 4                  | 0.0%     | 4                       | 0.0%          |                            |                |                | 0.0000            | <0.0085                           | <0.0085                     |
|               |                   |                                                | 123-91-1    | 1,4-Dioxane                          | 19                 | 0.0%     | 15                      | 0.0%          |                            |                |                | 0.0000            | <25                               | <25                         |
|               |                   |                                                | 335-67-1    | Perfluorooctanoic acid (PFOA)        | 4                  | 75.0%    | 4                       | 75.0%         | 0.0129                     | 0.0091         | 0.0156         | 0.0119            | 0.0115                            | 0.0119                      |
|               |                   |                                                | 375-22-4    | Perfluorobutanoic acid (PFBA)        | 4                  | 100.0%   | 4                       | 100.0%        | 0.2400                     | 0.1970         | 0.2850         | 0.2400            | 0.2390                            | 0.24                        |
|               |                   |                                                | 45187-15-3  | Perfluorobutanesulfonate (PFBS)      | 4                  | 50.0%    | 4                       | 50.0%         | 0.0195                     | 0.0105         | 0.0284         | 0.0150            | 0.0105                            | 0.015                       |
|               |                   |                                                | 45298-90-6  | Perfluorooctane sulfonic acid (PFOS) | 4                  | 0.0%     | 4                       | 0.0%          |                            |                |                | 0.0000            | <0.0085                           | <0.0085                     |
| SW-387        | Other Solid Waste | Summit Avenue Demolition Landfill              | 108427-53-8 | Perfluorohexane sulfonate (PFHxS)    | 7                  | 85.7%    | 3                       | 100.0%        | 0.0646                     | 0.0110         | 0.1440         | 0.0569            | 0.0130                            | <b>0.0569</b>               |
|               |                   |                                                | 335-67-1    | Perfluorooctanoic acid (PFOA)        | 7                  | 71.4%    | 3                       | 100.0%        | 0.1320                     | 0.0042         | 0.2340         | 0.0955            | 0.0247                            | <b>0.0955</b>               |
|               |                   |                                                | 375-22-4    | Perfluorobutanoic acid (PFBA)        | 7                  | 100.0%   | 3                       | 100.0%        | 0.1330                     | 0.0044         | 0.3250         | 0.1330            | 0.0457                            | 0.133                       |
|               |                   |                                                | 45187-15-3  | Perfluorobutanesulfonate (PFBS)      | 7                  | 0.0%     | 3                       | 0.0%          |                            |                |                | 0.0000            | <0.0083                           | <0.005                      |
|               |                   |                                                | 45298-90-6  | Perfluorooctane sulfonic acid (PFOS) | 7                  | 42.9%    | 3                       | 66.7%         | 0.0236                     | 0.0112         | 0.0344         | 0.0165            | 0.0112                            | 0.0112                      |
| SW-405        | Operating MSW     | St Louis County Regional Landfill              | 108427-53-8 | Perfluorohexane sulfonate (PFHxS)    | 11                 | 36.4%    | 10                      | 30.0%         | 0.0549                     | 0.0103         | 0.1140         | 0.0265            | <0.0068                           | <0.0068                     |
|               |                   |                                                | 335-67-1    | Perfluorooctanoic acid (PFOA)        | 11                 | 54.5%    | 10                      | 50.0%         | 0.0742                     | 0.0205         | 0.1490         | 0.0498            | 0.0205                            | <b>0.0498</b>               |
|               |                   |                                                | 375-22-4    | Perfluorobutanoic acid (PFBA)        | 11                 | 72.7%    | 10                      | 70.0%         | 0.1589                     | 0.0031         | 0.7540         | 0.1166            | 0.0177                            | 0.1166                      |
|               |                   |                                                | 45187-15-3  | Perfluorobutanesulfonate (PFBS)      | 11                 | 45.5%    | 10                      | 50.0%         | 0.0978                     | 0.0324         | 0.2010         | 0.0621            | <0.008                            | <0.008                      |
|               |                   |                                                | 45298-90-6  | Perfluorooctane sulfonic acid (PFOS) | 11                 | 18.2%    | 10                      | 10.0%         | 0.0201                     | 0.0097         | 0.0304         | 0.0116            | <0.0118                           | <0.0118                     |
| SW-406        | Other Solid Waste | Douglas County Demolition Landfill             | 108427-53-8 | Perfluorohexane sulfonate (PFHxS)    | 6                  | 83.3%    | 3                       | 100.0%        | 0.0337                     | 0.0055         | 0.0737         | 0.0290            | 0.0114                            | 0.029                       |
|               |                   |                                                | 335-67-1    | Perfluorooctanoic acid (PFOA)        | 6                  | 100.0%   | 3                       | 100.0%        | 0.0692                     | 0.0105         | 0.1890         | 0.0692            | 0.0632                            | <b>0.0692</b>               |
|               |                   |                                                | 375-22-4    | Perfluorobutanoic acid (PFBA)        | 6                  | 100.0%   | 3                       | 100.0%        | 0.0630                     | 0.0140         | 0.1480         | 0.0630            | 0.0494                            | 0.063                       |
|               |                   |                                                | 45187-15-3  | Perfluorobutanesulfonate (PFBS)      | 6                  | 66.7%    | 3                       | 66.7%         | 0.0175                     | 0.0081         | 0.0278         | 0.0143            | 0.0087                            | 0.0143                      |
|               |                   |                                                | 45298-90-6  | Perfluorooctane sulfonic acid (PFOS) | 6                  | 33.3%    | 3                       | 33.3%         | 0.0365                     | 0.0197         | 0.0532         | 0.0253            | <0.0056                           | <0.0056                     |

all concentrations in µg/L

pink shading indicates method used to determine measure of central tendency

bold indicates measure of central tendency above MN drinking water guidance



Table A-1 (continued)  
Summary Statistics Regulated PFAS and 1,4-Dioxane

| Facility Code | Facility Type     | Facility Name                            | CAS RN      | Chemical Name                        | Total Sample Count | % Detect | Number of Sampled Wells | % Well Detect | Arithmetic Mean of Detects | Minimum Detect | Maximum Detect | Kaplan Meier Mean | Median of Detects and Non-Detects | Measure of Central Tendency |
|---------------|-------------------|------------------------------------------|-------------|--------------------------------------|--------------------|----------|-------------------------|---------------|----------------------------|----------------|----------------|-------------------|-----------------------------------|-----------------------------|
| SW-407        | Other Solid Waste | Lakes Area Demolition Landfill           | 108427-53-8 | Perfluorohexane sulfonate (PFHxS)    | 3                  | 0.0%     | 3                       | 0.0%          |                            |                |                | 0.0000            | <0.0084                           | <0.0082                     |
|               |                   |                                          | 335-67-1    | Perfluorooctanoic acid (PFOA)        | 3                  | 0.0%     | 3                       | 0.0%          |                            |                |                | 0.0000            | <0.0042                           | <0.0041                     |
|               |                   |                                          | 375-22-4    | Perfluorobutanoic acid (PFBA)        | 3                  | 33.3%    | 3                       | 33.3%         | 0.0116                     | 0.0116         | 0.0116         | 0.0116            | <0.0042                           | <0.0042                     |
|               |                   |                                          | 45187-15-3  | Perfluorobutanesulfonate (PFBS)      | 3                  | 0.0%     | 3                       | 0.0%          |                            |                |                | 0.0000            | <0.0084                           | <0.0082                     |
|               |                   |                                          | 45298-90-6  | Perfluorooctane sulfonic acid (PFOS) | 3                  | 0.0%     | 3                       | 0.0%          |                            |                |                | 0.0000            | <0.0084                           | <0.0082                     |
| SW-408        | Solid Waste       | Glenwood Demolition Disposal LLC         | 108427-53-8 | Perfluorohexane sulfonate (PFHxS)    | 6                  | 16.7%    | 3                       | 33.3%         | 0.0177                     | 0.0177         | 0.0177         | 0.0177            | <0.0057                           | <0.0057                     |
|               |                   |                                          | 335-67-1    | Perfluorooctanoic acid (PFOA)        | 6                  | 16.7%    | 3                       | 33.3%         | 0.0029                     | 0.0029         | 0.0029         | 0.0029            | <0.0025                           | <0.0025                     |
|               |                   |                                          | 375-22-4    | Perfluorobutanoic acid (PFBA)        | 6                  | 83.3%    | 3                       | 100.0%        | 0.0109                     | 0.0049         | 0.0300         | 0.0099            | 0.0060                            | 0.0099                      |
|               |                   |                                          | 45187-15-3  | Perfluorobutanesulfonate (PFBS)      | 6                  | 16.7%    | 3                       | 33.3%         | 0.0123                     | 0.0123         | 0.0123         | 0.0123            | <0.0056                           | <0.0056                     |
|               |                   |                                          | 45298-90-6  | Perfluorooctane sulfonic acid (PFOS) | 6                  | 0.0%     | 3                       | 0.0%          |                            |                |                | 0.0000            | <0.0057                           | <0.0049                     |
| SW-412        | Other Solid Waste | Crosslake Construction Demolition Debris | 108427-53-8 | Perfluorohexane sulfonate (PFHxS)    | 4                  | 0.0%     | 2                       | 0.0%          |                            |                |                | 0.0000            | <0.0057                           | <0.005                      |
|               |                   |                                          | 335-67-1    | Perfluorooctanoic acid (PFOA)        | 4                  | 50.0%    | 2                       | 50.0%         | 0.0052                     | 0.0050         | 0.0053         | 0.0051            | 0.0050                            | 0.0051                      |
|               |                   |                                          | 375-22-4    | Perfluorobutanoic acid (PFBA)        | 4                  | 50.0%    | 2                       | 50.0%         | 0.0129                     | 0.0085         | 0.0173         | 0.0107            | 0.0085                            | 0.0107                      |
|               |                   |                                          | 45187-15-3  | Perfluorobutanesulfonate (PFBS)      | 4                  | 0.0%     | 2                       | 0.0%          |                            |                |                | 0.0000            | <0.0056                           | <0.005                      |
|               |                   |                                          | 45298-90-6  | Perfluorooctane sulfonic acid (PFOS) | 4                  | 0.0%     | 2                       | 0.0%          |                            |                |                | 0.0000            | <0.0057                           | <0.005                      |
| SW-42         | Closed Landfill   | Yellow Medicine County Sanitary Landfill | 108427-53-8 | Perfluorohexane sulfonate (PFHxS)    | 5                  | 0.0%     | 5                       | 0.0%          |                            |                |                | 0.0000            | <0.006                            | <0.006                      |
|               |                   |                                          | 123-91-1    | 1,4-Dioxane                          | 17                 | 35.3%    | 11                      | 36.4%         | 3.9883                     | 0.3000         | 11.1500        | 1.6018            | <0.071                            | <0.071                      |
|               |                   |                                          | 335-67-1    | Perfluorooctanoic acid (PFOA)        | 5                  | 20.0%    | 5                       | 20.0%         | 0.0790                     | 0.0790         | 0.0790         | 0.0790            | <0.006                            | <0.006                      |
|               |                   |                                          | 375-22-4    | Perfluorobutanoic acid (PFBA)        | 5                  | 20.0%    | 5                       | 20.0%         | 0.0880                     | 0.0880         | 0.0880         | 0.0880            | <0.006                            | <0.006                      |
|               |                   |                                          | 45187-15-3  | Perfluorobutanesulfonate (PFBS)      | 5                  | 0.0%     | 5                       | 0.0%          |                            |                |                | 0.0000            | <0.008                            | <0.008                      |
| SW-428        | Other Solid Waste | Voyageur Disposal & Processing Inc       | 45298-90-6  | Perfluorooctane sulfonic acid (PFOS) | 5                  | 0.0%     | 5                       | 0.0%          |                            |                |                | 0.0000            | <0.005                            | <0.005                      |
|               |                   |                                          | 108427-53-8 | Perfluorohexane sulfonate (PFHxS)    | 8                  | 12.5%    | 4                       | 25.0%         | 0.0068                     | 0.0068         | 0.0068         | 0.0068            | <0.0056                           | <0.0056                     |
|               |                   |                                          | 335-67-1    | Perfluorooctanoic acid (PFOA)        | 8                  | 25.0%    | 4                       | 25.0%         | 0.0112                     | 0.0081         | 0.0144         | 0.0088            | <0.0026                           | <0.0026                     |
|               |                   |                                          | 375-22-4    | Perfluorobutanoic acid (PFBA)        | 8                  | 87.5%    | 4                       | 100.0%        | 0.0182                     | 0.0031         | 0.0520         | 0.0163            | 0.0060                            | 0.0163                      |
|               |                   |                                          | 45187-15-3  | Perfluorobutanesulfonate (PFBS)      | 8                  | 25.0%    | 4                       | 25.0%         | 0.0063                     | 0.0056         | 0.0069         | 0.0058            | <0.0056                           | <0.0056                     |
| SW-429        | Other Solid Waste | DKV Demolition Landfill                  | 45298-90-6  | Perfluorooctane sulfonic acid (PFOS) | 8                  | 12.5%    | 4                       | 25.0%         | 0.0068                     | 0.0068         | 0.0068         | 0.0068            | <0.0056                           | <0.0056                     |
|               |                   |                                          | 108427-53-8 | Perfluorohexane sulfonate (PFHxS)    | 6                  | 0.0%     | 3                       | 0.0%          |                            |                |                | 0.0000            | <0.0056                           | <0.005                      |
|               |                   |                                          | 335-67-1    | Perfluorooctanoic acid (PFOA)        | 6                  | 0.0%     | 3                       | 0.0%          |                            |                |                | 0.0000            | <0.0025                           | <0.0024                     |
|               |                   |                                          | 375-22-4    | Perfluorobutanoic acid (PFBA)        | 6                  | 100.0%   | 3                       | 100.0%        | 0.0200                     | 0.0074         | 0.0588         | 0.0200            | 0.0135                            | 0.02                        |
|               |                   |                                          | 45187-15-3  | Perfluorobutanesulfonate (PFBS)      | 6                  | 0.0%     | 3                       | 0.0%          |                            |                |                | 0.0000            | <0.0055                           | <0.005                      |
| SW-43         | Closed Landfill   | Oak Grove Sanitary Landfill              | 45298-90-6  | Perfluorooctane sulfonic acid (PFOS) | 6                  | 0.0%     | 3                       | 0.0%          |                            |                |                | 0.0000            | <0.0056                           | <0.005                      |
|               |                   |                                          | 108427-53-8 | Perfluorohexane sulfonate (PFHxS)    | 39                 | 2.6%     | 23                      | 4.3%          | 0.0190                     | 0.0190         | 0.0190         | 0.0190            | <0.004                            | <0.004                      |
|               |                   |                                          | 123-91-1    | 1,4-Dioxane                          | 73                 | 37.0%    | 28                      | 28.6%         | 41.2886                    | 0.0790         | 270.0000       | 15.3209           | <0.031                            | <0.031                      |
|               |                   |                                          | 335-67-1    | Perfluorooctanoic acid (PFOA)        | 39                 | 10.3%    | 23                      | 8.7%          | 0.1655                     | 0.0080         | 0.5000         | 0.0242            | <0.006                            | <0.006                      |
|               |                   |                                          | 375-22-4    | Perfluorobutanoic acid (PFBA)        | 39                 | 41.0%    | 23                      | 47.8%         | 0.0982                     | 0.0060         | 0.8000         | 0.0438            | <0.006                            | <0.006                      |
| SW-44         | Closed Landfill   | Lindenfelser Demolition Landfill         | 45187-15-3  | Perfluorobutanesulfonate (PFBS)      | 39                 | 2.6%     | 23                      | 4.3%          | 0.0060                     | 0.0060         | 0.0060         | 0.0060            | <0.005                            | <0.005                      |
|               |                   |                                          | 45298-90-6  | Perfluorooctane sulfonic acid (PFOS) | 39                 | 5.1%     | 23                      | 4.3%          | 0.0415                     | 0.0300         | 0.0530         | 0.0306            | <0.007                            | <0.007                      |
|               |                   |                                          | 108427-53-8 | Perfluorohexane sulfonate (PFHxS)    | 12                 | 0.0%     | 8                       | 0.0%          |                            |                |                | 0.0000            | <0.006                            | <0.0049                     |
|               |                   |                                          | 123-91-1    | 1,4-Dioxane                          | 51                 | 49.0%    | 17                      | 47.1%         | 3.2338                     | 0.0550         | 25.0000        | 1.6132            | <0.017                            | <0.017                      |
|               |                   |                                          | 335-67-1    | Perfluorooctanoic acid (PFOA)        | 12                 | 25.0%    | 8                       | 37.5%         | 0.0130                     | 0.0090         | 0.0200         | 0.0100            | <0.006                            | <0.006                      |
| SW-45         | Operating MSW     | Pine Bend Sanitary Landfill              | 375-22-4    | Perfluorobutanoic acid (PFBA)        | 12                 | 75.0%    | 8                       | 75.0%         | 0.0208                     | 0.0040         | 0.0459         | 0.0166            | 0.0100                            | 0.0166                      |
|               |                   |                                          | 45187-15-3  | Perfluorobutanesulfonate (PFBS)      | 12                 | 0.0%     | 8                       | 0.0%          |                            |                |                | 0.0000            | <0.008                            | <0.0049                     |
|               |                   |                                          | 45298-90-6  | Perfluorooctane sulfonic acid (PFOS) | 12                 | 8.3%     | 8                       | 12.5%         | 0.0310                     | 0.0310         | 0.0310         | 0.0310            | <0.005                            | <0.005                      |
|               |                   |                                          | 108427-53-8 | Perfluorohexane sulfonate (PFHxS)    | 43                 | 69.8%    | 19                      | 73.7%         | 0.0354                     | 0.0077         | 0.2000         | 0.0270            | 0.0190                            | 0.027                       |
|               |                   |                                          | 335-67-1    | Perfluorooctanoic acid (PFOA)        | 43                 | 79.1%    | 19                      | 84.2%         | 0.4205                     | 0.0234         | 2.7000         | 0.3374            | 0.2400                            | <b>0.3374</b>               |
| SW-47         | Closed Landfill   | East Bethel Demolition/Sanitary Landfill | 375-22-4    | Perfluorobutanoic acid (PFBA)        | 43                 | 95.3%    | 19                      | 94.7%         | 11.5880                    | 0.0290         | 200.0000       | 11.0504           | 1.1000                            | <b>11.0504</b>              |
|               |                   |                                          | 45187-15-3  | Perfluorobutanesulfonate (PFBS)      | 43                 | 62.8%    | 19                      | 68.4%         | 0.0501                     | 0.0076         | 0.1600         | 0.0343            | 0.0260                            | 0.0343                      |
|               |                   |                                          | 45298-90-6  | Perfluorooctane sulfonic acid (PFOS) | 43                 | 72.1%    | 19                      | 78.9%         | 0.2464                     | 0.0140         | 1.4000         | 0.1816            | 0.0890                            | <b>0.1816</b>               |
|               |                   |                                          | 108427-53-8 | Perfluorohexane sulfonate (PFHxS)    | 24                 | 37.5%    | 17                      | 41.2%         | 0.1304                     | 0.0190         | 0.5000         | 0.0614            | 0.0250                            | 0.025                       |
|               |                   |                                          | 123-91-1    | 1,4-Dioxane                          | 182                | 63.2%    | 59                      | 61.0%         | 42.2174                    | 0.0490         | 1680.0000      | 26.6939           | 0.5600                            | <b>26.6939</b>              |
| SW-47         | Closed Landfill   | East Bethel Demolition/Sanitary Landfill | 335-67-1    | Perfluorooctanoic acid (PFOA)        | 33                 | 36.4%    | 21                      | 38.1%         | 0.1285                     | 0.0540         | 0.2500         | 0.0872            | <0.087                            | <b>&lt;0.087</b>            |
|               |                   |                                          | 375-22-4    | Perfluorobutanoic acid (PFBA)        | 24                 | 70.8%    | 17                      | 64.7%         | 0.1345                     | 0.0120         | 0.3600         | 0.1258            | 0.1750                            | 0.1258                      |
|               |                   |                                          | 45187-15-3  | Perfluorobutanesulfonate (PFBS)      | 24                 | 29.2%    | 17                      | 35.3%         | 0.1501                     | 0.0090         | 0.5000         | 0.0503            | 0.0090                            | 0.009                       |
|               |                   |                                          | 45298-90-6  | Perfluorooctane sulfonic acid (PFOS) | 33                 | 45.5%    | 21                      | 61.9%         | 0.3771                     | 0.0100         | 0.5000         | 0.1779            | 0.0700                            | <b>0.07</b>                 |

all concentrations in µg/L

pink shading indicates method used to determine measure of central tendency

bold indicates measure of central tendency above MN drinking water guidance

Table A-1 (continued)  
Summary Statistics Regulated PFAS and 1,4-Dioxane

| Facility Code | Facility Type     | Facility Name                              | CAS RN      | Chemical Name                        | Total Sample Count | % Detect | Number of Sampled Wells | % Well Detect | Arithmetic Mean of Detects | Minimum Detect | Maximum Detect | Kaplan Meier Mean | Median of Detects and Non-Detects | Measure of Central Tendency |
|---------------|-------------------|--------------------------------------------|-------------|--------------------------------------|--------------------|----------|-------------------------|---------------|----------------------------|----------------|----------------|-------------------|-----------------------------------|-----------------------------|
| SW-486        | Other Solid Waste | Meeker County Demolition Landfill          | 108427-53-8 | Perfluorohexane sulfonate (PFHxS)    | 6                  | 33.3%    | 3                       | 33.3%         | 0.0154                     | 0.0130         | 0.0178         | 0.0138            | 0.0130                            | 0.013                       |
|               |                   |                                            | 335-67-1    | Perfluorooctanoic acid (PFOA)        | 6                  | 33.3%    | 3                       | 33.3%         | 0.0085                     | 0.0077         | 0.0094         | 0.0079            | <0.0066                           | <0.0066                     |
|               |                   |                                            | 375-22-4    | Perfluorobutanoic acid (PFBA)        | 6                  | 33.3%    | 3                       | 33.3%         | 0.0247                     | 0.0236         | 0.0257         | 0.0240            | <0.0066                           | <0.0066                     |
|               |                   |                                            | 45187-15-3  | Perfluorobutanesulfonate (PFBS)      | 6                  | 33.3%    | 3                       | 33.3%         | 0.0172                     | 0.0167         | 0.0177         | 0.0169            | <0.0131                           | <0.0131                     |
|               |                   |                                            | 45298-90-6  | Perfluorooctane sulfonic acid (PFOS) | 6                  | 0.0%     | 3                       | 0.0%          |                            |                |                | 0.0000            | <0.0126                           | <0.005                      |
| SW-49         | Closed Landfill   | Ironwood Sanitary Landfill                 | 108427-53-8 | Perfluorohexane sulfonate (PFHxS)    | 24                 | 0.0%     | 24                      | 0.0%          |                            |                |                | 0.0000            | <0.004                            | <0.004                      |
|               |                   |                                            | 123-91-1    | 1,4-Dioxane                          | 75                 | 49.3%    | 36                      | 50.0%         | 2.9053                     | 0.0680         | 13.0000        | 1.4677            | <0.071                            | <0.071                      |
|               |                   |                                            | 335-67-1    | Perfluorooctanoic acid (PFOA)        | 24                 | 12.5%    | 24                      | 12.5%         | 0.0210                     | 0.0050         | 0.0310         | 0.0070            | <0.005                            | <0.005                      |
|               |                   |                                            | 375-22-4    | Perfluorobutanoic acid (PFBA)        | 24                 | 12.5%    | 24                      | 12.5%         | 0.0083                     | 0.0040         | 0.0120         | 0.0045            | <0.003                            | <0.003                      |
|               |                   |                                            | 45187-15-3  | Perfluorobutanesulfonate (PFBS)      | 24                 | 0.0%     | 24                      | 0.0%          |                            |                |                | 0.0000            | <0.005                            | <0.005                      |
|               |                   |                                            | 45298-90-6  | Perfluorooctane sulfonic acid (PFOS) | 24                 | 4.2%     | 24                      | 4.2%          | 0.0080                     | 0.0080         | 0.0080         | 0.0080            | <0.007                            | <0.007                      |
|               |                   |                                            | 45298-90-6  | Perfluorooctane sulfonic acid (PFOS) | 24                 | 4.2%     | 24                      | 4.2%          | 0.0080                     | 0.0080         | 0.0080         | 0.0080            | <0.007                            | <0.007                      |
| SW-5          | Closed Landfill   | Olmsted County - Oronoco Sanitary Landfill | 108427-53-8 | Perfluorohexane sulfonate (PFHxS)    | 18                 | 0.0%     | 10                      | 0.0%          |                            |                |                | 0.0000            | <0.005                            | <0.004                      |
|               |                   |                                            | 123-91-1    | 1,4-Dioxane                          | 97                 | 35.1%    | 22                      | 45.5%         | 0.1977                     | 0.0510         | 0.5700         | 0.1025            | 0.0570                            | 0.057                       |
|               |                   |                                            | 335-67-1    | Perfluorooctanoic acid (PFOA)        | 18                 | 5.6%     | 10                      | 10.0%         | 0.0032                     | 0.0032         | 0.0032         | 0.0032            | <0.005                            | <0.005                      |
|               |                   |                                            | 375-22-4    | Perfluorobutanoic acid (PFBA)        | 22                 | 77.3%    | 10                      | 80.0%         | 0.0157                     | 0.0030         | 0.0251         | 0.0128            | 0.0125                            | 0.0128                      |
|               |                   |                                            | 45187-15-3  | Perfluorobutanesulfonate (PFBS)      | 18                 | 0.0%     | 10                      | 0.0%          |                            |                |                | 0.0000            | <0.005                            | <0.005                      |
|               |                   |                                            | 45298-90-6  | Perfluorooctane sulfonic acid (PFOS) | 18                 | 0.0%     | 10                      | 0.0%          |                            |                |                | 0.0000            | <0.005                            | <0.005                      |
|               |                   |                                            | 45298-90-6  | Perfluorooctane sulfonic acid (PFOS) | 18                 | 0.0%     | 10                      | 0.0%          |                            |                |                | 0.0000            | <0.005                            | <0.005                      |
| SW-50         | Closed Landfill   | Dakhue Sanitary Landfill                   | 108427-53-8 | Perfluorohexane sulfonate (PFHxS)    | 10                 | 0.0%     | 8                       | 0.0%          |                            |                |                | 0.0000            | <0.004                            | <0.004                      |
|               |                   |                                            | 123-91-1    | 1,4-Dioxane                          | 52                 | 26.9%    | 18                      | 27.8%         | 1.0907                     | 0.0530         | 5.7000         | 0.3324            | <0.03                             | <0.03                       |
|               |                   |                                            | 335-67-1    | Perfluorooctanoic acid (PFOA)        | 10                 | 10.0%    | 8                       | 12.5%         | 0.0070                     | 0.0070         | 0.0070         | 0.0070            | 0.0070                            | 0.007                       |
|               |                   |                                            | 375-22-4    | Perfluorobutanoic acid (PFBA)        | 10                 | 80.0%    | 8                       | 87.5%         | 0.1293                     | 0.0570         | 0.4600         | 0.1198            | 0.0945                            | 0.1198                      |
|               |                   |                                            | 45187-15-3  | Perfluorobutanesulfonate (PFBS)      | 10                 | 10.0%    | 8                       | 12.5%         | 0.0150                     | 0.0150         | 0.0150         | 0.0150            | <0.009                            | <0.009                      |
|               |                   |                                            | 45298-90-6  | Perfluorooctane sulfonic acid (PFOS) | 10                 | 0.0%     | 8                       | 0.0%          |                            |                |                | 0.0000            | <0.007                            | <0.007                      |
|               |                   |                                            | 45298-90-6  | Perfluorooctane sulfonic acid (PFOS) | 10                 | 0.0%     | 8                       | 0.0%          |                            |                |                | 0.0000            | <0.007                            | <0.007                      |
| SW-501        | Other Solid Waste | Lyon County Demolition Landfill            | 108427-53-8 | Perfluorohexane sulfonate (PFHxS)    | 9                  | 22.2%    | 6                       | 33.3%         | 0.0551                     | 0.0110         | 0.0991         | 0.0208            | <0.0086                           | <0.0086                     |
|               |                   |                                            | 335-67-1    | Perfluorooctanoic acid (PFOA)        | 9                  | 22.2%    | 6                       | 33.3%         | 0.1191                     | 0.0042         | 0.2340         | 0.0297            | <0.0042                           | <0.0042                     |
|               |                   |                                            | 375-22-4    | Perfluorobutanoic acid (PFBA)        | 9                  | 33.3%    | 6                       | 50.0%         | 0.1250                     | 0.0044         | 0.3250         | 0.0446            | <0.0043                           | <0.0043                     |
|               |                   |                                            | 45187-15-3  | Perfluorobutanesulfonate (PFBS)      | 9                  | 0.0%     | 6                       | 0.0%          |                            |                |                | 0.0000            | <0.0083                           | <0.0051                     |
|               |                   |                                            | 45298-90-6  | Perfluorooctane sulfonic acid (PFOS) | 9                  | 11.1%    | 6                       | 16.7%         | 0.0344                     | 0.0344         | 0.0344         | 0.0344            | <0.0083                           | <0.0083                     |
|               |                   |                                            | 45298-90-6  | Perfluorooctane sulfonic acid (PFOS) | 9                  | 11.1%    | 6                       | 16.7%         | 0.0344                     | 0.0344         | 0.0344         | 0.0344            | <0.0083                           | <0.0083                     |
| SW-51         | Closed Landfill   | Eighty Acres Sanitary Landfill             | 108427-53-8 | Perfluorohexane sulfonate (PFHxS)    | 1                  | 0.0%     | 1                       | 0.0%          |                            |                |                | 0.0000            | <0.006                            | <0.006                      |
|               |                   |                                            | 123-91-1    | 1,4-Dioxane                          | 12                 | 0.0%     | 9                       | 0.0%          |                            |                |                | 0.0000            | <0.36                             | <0.015                      |
|               |                   |                                            | 335-67-1    | Perfluorooctanoic acid (PFOA)        | 1                  | 0.0%     | 1                       | 0.0%          |                            |                |                | 0.0000            | <0.006                            | <0.006                      |
|               |                   |                                            | 375-22-4    | Perfluorobutanoic acid (PFBA)        | 1                  | 100.0%   | 1                       | 100.0%        | 0.0120                     | 0.0120         | 0.0120         | 0.0120            | 0.0120                            | 0.012                       |
|               |                   |                                            | 45187-15-3  | Perfluorobutanesulfonate (PFBS)      | 1                  | 0.0%     | 1                       | 0.0%          |                            |                |                | 0.0000            | <0.008                            | <0.008                      |
|               |                   |                                            | 45298-90-6  | Perfluorooctane sulfonic acid (PFOS) | 1                  | 0.0%     | 1                       | 0.0%          |                            |                |                | 0.0000            | <0.005                            | <0.005                      |
| SW-52         | Closed Landfill   | Chippewa County Sanitary Landfill          | 108427-53-8 | Perfluorohexane sulfonate (PFHxS)    | 3                  | 0.0%     | 3                       | 0.0%          |                            |                |                | 0.0000            | <0.006                            | <0.006                      |
|               |                   |                                            | 123-91-1    | 1,4-Dioxane                          | 13                 | 15.4%    | 13                      | 15.4%         | 3.3250                     | 3.2600         | 3.3900         | 3.2700            | <0.071                            | <0.071                      |
|               |                   |                                            | 335-67-1    | Perfluorooctanoic acid (PFOA)        | 3                  | 66.7%    | 3                       | 66.7%         | 0.0210                     | 0.0200         | 0.0220         | 0.0207            | 0.0200                            | 0.0207                      |
|               |                   |                                            | 375-22-4    | Perfluorobutanoic acid (PFBA)        | 3                  | 0.0%     | 3                       | 0.0%          |                            |                |                | 0.0000            | <0.006                            | <0.006                      |
|               |                   |                                            | 45187-15-3  | Perfluorobutanesulfonate (PFBS)      | 3                  | 0.0%     | 3                       | 0.0%          |                            |                |                | 0.0000            | <0.008                            | <0.008                      |
|               |                   |                                            | 45298-90-6  | Perfluorooctane sulfonic acid (PFOS) | 3                  | 0.0%     | 3                       | 0.0%          |                            |                |                | 0.0000            | <0.005                            | <0.005                      |
| SW-536        | Solid Waste       | Vonco V - Duluth                           | 108427-53-8 | Perfluorohexane sulfonate (PFHxS)    | 6                  | 50.0%    | 3                       | 66.7%         | 0.0365                     | 0.0063         | 0.0531         | 0.0214            | 0.0063                            | 0.0214                      |
|               |                   |                                            | 335-67-1    | Perfluorooctanoic acid (PFOA)        | 6                  | 33.3%    | 3                       | 33.3%         | 0.0091                     | 0.0065         | 0.0118         | 0.0074            | <0.0025                           | <0.0025                     |
|               |                   |                                            | 375-22-4    | Perfluorobutanoic acid (PFBA)        | 6                  | 83.3%    | 3                       | 100.0%        | 0.0266                     | 0.0055         | 0.0491         | 0.0231            | 0.0197                            | 0.0231                      |
|               |                   |                                            | 45187-15-3  | Perfluorobutanesulfonate (PFBS)      | 6                  | 16.7%    | 3                       | 33.3%         | 0.0168                     | 0.0168         | 0.0168         | 0.0168            | <0.0128                           | <0.0128                     |
|               |                   |                                            | 45298-90-6  | Perfluorooctane sulfonic acid (PFOS) | 6                  | 0.0%     | 3                       | 0.0%          |                            |                |                | 0.0000            | <0.0057                           | <0.0049                     |
|               |                   |                                            | 45298-90-6  | Perfluorooctane sulfonic acid (PFOS) | 6                  | 0.0%     | 3                       | 0.0%          |                            |                |                | 0.0000            | <0.0057                           | <0.0049                     |
| SW-541        | Other Solid Waste | Oak Ridge Demolition Landfill              | 108427-53-8 | Perfluorohexane sulfonate (PFHxS)    | 6                  | 0.0%     | 3                       | 0.0%          |                            |                |                | 0.0000            | <0.0057                           | <0.0051                     |
|               |                   |                                            | 335-67-1    | Perfluorooctanoic acid (PFOA)        | 6                  | 50.0%    | 3                       | 66.7%         | 0.0057                     | 0.0033         | 0.0080         | 0.0045            | 0.0033                            | 0.0045                      |
|               |                   |                                            | 375-22-4    | Perfluorobutanoic acid (PFBA)        | 6                  | 66.7%    | 3                       | 66.7%         | 0.0271                     | 0.0063         | 0.0498         | 0.0202            | 0.0162                            | 0.0202                      |
|               |                   |                                            | 45187-15-3  | Perfluorobutanesulfonate (PFBS)      | 6                  | 50.0%    | 3                       | 66.7%         | 0.0182                     | 0.0055         | 0.0288         | 0.0118            | <0.0092                           | 0.0118                      |
|               |                   |                                            | 45298-90-6  | Perfluorooctane sulfonic acid (PFOS) | 6                  | 0.0%     | 3                       | 0.0%          |                            |                |                | 0.0000            | <0.0057                           | <0.0051                     |
| SW-542        | Other Solid Waste | Vonco 4 - Austin Demolition Landfill       | 108427-53-8 | Perfluorohexane sulfonate (PFHxS)    | 6                  | 0.0%     | 3                       | 0.0%          |                            |                |                | 0.0000            | <0.0086                           | <0.005                      |
|               |                   |                                            | 335-67-1    | Perfluorooctanoic acid (PFOA)        | 6                  | 0.0%     | 3                       | 0.0%          |                            |                |                | 0.0000            | <0.0043                           | <0.0025                     |
|               |                   |                                            | 375-22-4    | Perfluorobutanoic acid (PFBA)        | 6                  | 16.7%    | 3                       | 33.3%         | 0.0030                     | 0.0030         | 0.0030         | 0.0030            | 0.0030                            | 0.003                       |
|               |                   |                                            | 45187-15-3  | Perfluorobutanesulfonate (PFBS)      | 6                  | 0.0%     | 3                       | 0.0%          |                            |                |                | 0.0000            | <0.0086                           | <0.005                      |
|               |                   |                                            | 45298-90-6  | Perfluorooctane sulfonic acid (PFOS) | 6                  | 0.0%     | 3                       | 0.0%          |                            |                |                | 0.0000            | <0.0086                           | <0.005                      |

all concentrations in µg/L

pink shading indicates method used to determine measure of central tendency

bold indicates measure of central tendency above MN drinking water guidance



Table A-1 (continued)  
Summary Statistics Regulated PFAS and 1,4-Dioxane

| Facility Code | Facility Type     | Facility Name                                       | CAS RN      | Chemical Name                        | Total Sample Count | % Detect | Number of Sampled Wells | % Well Detect | Arithmetic Mean of Detects | Minimum Detect | Maximum Detect | Kaplan Meier Mean | Median of Detects and Non-Detects | Measure of Central Tendency |
|---------------|-------------------|-----------------------------------------------------|-------------|--------------------------------------|--------------------|----------|-------------------------|---------------|----------------------------|----------------|----------------|-------------------|-----------------------------------|-----------------------------|
| SW-548        | Other Solid Waste | Waste Management Demolition Landfill                | 108427-53-8 | Perfluorohexane sulfonate (PFHxS)    | 6                  | 0.0%     | 3                       | 0.0%          |                            |                |                | 0.0000            | <0.007                            | <0.0049                     |
|               |                   |                                                     | 335-67-1    | Perfluorooctanoic acid (PFOA)        | 6                  | 0.0%     | 3                       | 0.0%          |                            |                |                | 0.0000            | <0.0035                           | <0.0025                     |
|               |                   |                                                     | 375-22-4    | Perfluorobutanoic acid (PFBA)        | 6                  | 16.7%    | 3                       | 33.3%         | 0.0075                     | 0.0075         | 0.0075         | 0.0075            | <0.0035                           | <0.0035                     |
|               |                   |                                                     | 45187-15-3  | Perfluorobutanesulfonate (PFBS)      | 6                  | 0.0%     | 3                       | 0.0%          |                            |                |                | 0.0000            | <0.007                            | <0.0049                     |
|               |                   |                                                     | 45298-90-6  | Perfluorooctane sulfonic acid (PFOS) | 6                  | 0.0%     | 3                       | 0.0%          |                            |                |                | 0.0000            | <0.007                            | <0.0049                     |
| SW-56         | Operating MSW     | Burnsville Sanitary Landfill                        | 108427-53-8 | Perfluorohexane sulfonate (PFHxS)    | 9                  | 44.4%    | 4                       | 75.0%         | 0.0079                     | 0.0052         | 0.0117         | 0.0068            | 0.0059                            | 0.0059                      |
|               |                   |                                                     | 335-67-1    | Perfluorooctanoic acid (PFOA)        | 9                  | 100.0%   | 4                       | 100.0%        | 0.0311                     | 0.0072         | 0.0655         | 0.0311            | 0.0230                            | 0.0311                      |
|               |                   |                                                     | 375-22-4    | Perfluorobutanoic acid (PFBA)        | 9                  | 88.9%    | 4                       | 100.0%        | 0.0900                     | 0.0214         | 0.1630         | 0.0824            | 0.0755                            | 0.0824                      |
|               |                   |                                                     | 45187-15-3  | Perfluorobutanesulfonate (PFBS)      | 9                  | 22.2%    | 4                       | 50.0%         | 0.0097                     | 0.0059         | 0.0135         | 0.0067            | 0.0059                            | 0.0059                      |
|               |                   |                                                     | 45298-90-6  | Perfluorooctane sulfonic acid (PFOS) | 9                  | 66.7%    | 4                       | 100.0%        | 0.0260                     | 0.0053         | 0.0572         | 0.0192            | <0.0124                           | 0.0192                      |
| SW-57         | Closed Landfill   | Freeway Sanitary Landfill                           | 108427-53-8 | Perfluorohexane sulfonate (PFHxS)    | 36                 | 36.1%    | 30                      | 36.7%         | 0.0323                     | 0.0060         | 0.1200         | 0.0157            | 0.0120                            | 0.012                       |
|               |                   |                                                     | 123-91-1    | 1,4-Dioxane                          | 34                 | 55.9%    | 28                      | 57.1%         | 4.7151                     | 0.0970         | 36.0000        | 2.6777            | 0.2650                            | 2.6777                      |
|               |                   |                                                     | 335-67-1    | Perfluorooctanoic acid (PFOA)        | 41                 | 56.1%    | 30                      | 60.0%         | 0.2260                     | 0.0160         | 1.1000         | 0.1379            | 0.0770                            | 0.1379                      |
|               |                   |                                                     | 375-22-4    | Perfluorobutanoic acid (PFBA)        | 36                 | 94.4%    | 30                      | 93.3%         | 0.0584                     | 0.0140         | 0.3800         | 0.0559            | 0.0275                            | 0.0559                      |
|               |                   |                                                     | 45187-15-3  | Perfluorobutanesulfonate (PFBS)      | 36                 | 38.9%    | 30                      | 40.0%         | 0.0124                     | 0.0060         | 0.0380         | 0.0087            | <0.009                            | <0.009                      |
|               |                   |                                                     | 45298-90-6  | Perfluorooctane sulfonic acid (PFOS) | 41                 | 48.8%    | 30                      | 50.0%         | 0.1019                     | 0.0130         | 0.5000         | 0.0592            | 0.0300                            | 0.03                        |
|               |                   |                                                     | 108427-53-8 | Perfluorohexane sulfonate (PFHxS)    | 26                 | 50.0%    | 16                      | 50.0%         | 0.0095                     | 0.0058         | 0.0248         | 0.0084            | 0.0075                            | 0.0084                      |
| SW-58         | Closed Landfill   | Hopkins Sanitary Landfill                           | 123-91-1    | 1,4-Dioxane                          | 82                 | 80.5%    | 24                      | 83.3%         | 6.0358                     | 0.0560         | 41.0000        | 4.8690            | 0.1850                            | 4.869                       |
|               |                   |                                                     | 335-67-1    | Perfluorooctanoic acid (PFOA)        | 26                 | 69.2%    | 16                      | 62.5%         | 0.0660                     | 0.0070         | 0.2900         | 0.0509            | 0.0533                            | 0.0509                      |
|               |                   |                                                     | 375-22-4    | Perfluorobutanoic acid (PFBA)        | 26                 | 84.6%    | 16                      | 81.3%         | 0.0930                     | 0.0120         | 0.2230         | 0.0895            | 0.1050                            | 0.0895                      |
|               |                   |                                                     | 45187-15-3  | Perfluorobutanesulfonate (PFBS)      | 26                 | 50.0%    | 16                      | 50.0%         | 0.0378                     | 0.0080         | 0.1110         | 0.0245            | 0.0298                            | 0.0245                      |
|               |                   |                                                     | 45298-90-6  | Perfluorooctane sulfonic acid (PFOS) | 26                 | 50.0%    | 16                      | 43.8%         | 0.0173                     | 0.0090         | 0.0372         | 0.0150            | 0.0178                            | 0.015                       |
| SW-59         | Closed Landfill   | French Lake Sanitary Landfill                       | 108427-53-8 | Perfluorohexane sulfonate (PFHxS)    | 2                  | 0.0%     | 2                       | 0.0%          |                            |                |                | 0.0000            | <0.006                            | <0.006                      |
|               |                   |                                                     | 123-91-1    | 1,4-Dioxane                          | 21                 | 0.0%     | 7                       | 0.0%          |                            |                |                | 0.0000            | <0.22                             | <0.22                       |
|               |                   |                                                     | 335-67-1    | Perfluorooctanoic acid (PFOA)        | 2                  | 0.0%     | 2                       | 0.0%          |                            |                |                | 0.0000            | <0.006                            | <0.006                      |
|               |                   |                                                     | 375-22-4    | Perfluorobutanoic acid (PFBA)        | 2                  | 50.0%    | 2                       | 50.0%         | 0.0090                     | 0.0090         | 0.0090         | 0.0090            | 0.0090                            | 0.009                       |
|               |                   |                                                     | 45187-15-3  | Perfluorobutanesulfonate (PFBS)      | 2                  | 0.0%     | 2                       | 0.0%          |                            |                |                | 0.0000            | <0.008                            | <0.008                      |
| SW-6          | Operating MSW     | Spruce Ridge Resource Management                    | 45298-90-6  | Perfluorooctane sulfonic acid (PFOS) | 2                  | 0.0%     | 2                       | 0.0%          |                            |                |                | 0.0000            | <0.005                            | <0.005                      |
|               |                   |                                                     | 108427-53-8 | Perfluorohexane sulfonate (PFHxS)    | 6                  | 16.7%    | 6                       | 16.7%         | 0.0225                     | 0.0225         | 0.0225         | 0.0225            | <0.0129                           | <0.0129                     |
|               |                   |                                                     | 335-67-1    | Perfluorooctanoic acid (PFOA)        | 6                  | 100.0%   | 6                       | 100.0%        | 0.0450                     | 0.0078         | 0.1300         | 0.0450            | 0.0312                            | 0.045                       |
|               |                   |                                                     | 375-22-4    | Perfluorobutanoic acid (PFBA)        | 6                  | 83.3%    | 6                       | 83.3%         | 0.1392                     | 0.0233         | 0.4040         | 0.1235            | 0.0576                            | 0.1235                      |
|               |                   |                                                     | 45187-15-3  | Perfluorobutanesulfonate (PFBS)      | 6                  | 33.3%    | 6                       | 33.3%         | 0.0210                     | 0.0191         | 0.0229         | 0.0197            | <0.0129                           | <0.0129                     |
| SW-60         | Other Solid Waste | Advanced Disposal Services - Rolling Hills Landfill | 45298-90-6  | Perfluorooctane sulfonic acid (PFOS) | 6                  | 16.7%    | 6                       | 16.7%         | 0.0155                     | 0.0155         | 0.0155         | 0.0155            | <0.0129                           | <0.0129                     |
|               |                   |                                                     | 108427-53-8 | Perfluorohexane sulfonate (PFHxS)    | 3                  | 0.0%     | 3                       | 0.0%          |                            |                |                | 0.0000            | <0.0088                           | <0.0087                     |
|               |                   |                                                     | 335-67-1    | Perfluorooctanoic acid (PFOA)        | 3                  | 33.3%    | 3                       | 33.3%         | 0.0174                     | 0.0174         | 0.0174         | 0.0174            | <0.0045                           | <0.0045                     |
|               |                   |                                                     | 375-22-4    | Perfluorobutanoic acid (PFBA)        | 3                  | 33.3%    | 3                       | 33.3%         | 0.0139                     | 0.0139         | 0.0139         | 0.0139            | <0.0045                           | <0.0045                     |
|               |                   |                                                     | 45187-15-3  | Perfluorobutanesulfonate (PFBS)      | 3                  | 0.0%     | 3                       | 0.0%          |                            |                |                | 0.0000            | <0.0088                           | <0.0087                     |
| SW-61         | Closed Landfill   | Woodlake Sanitary Landfill                          | 45298-90-6  | Perfluorooctane sulfonic acid (PFOS) | 3                  | 0.0%     | 3                       | 0.0%          |                            |                |                | 0.0000            | <0.0088                           | <0.0087                     |
|               |                   |                                                     | 108427-53-8 | Perfluorohexane sulfonate (PFHxS)    | 44                 | 18.2%    | 22                      | 9.1%          | 0.0848                     | 0.0310         | 0.1200         | 0.0424            | 0.0310                            | 0.031                       |
|               |                   |                                                     | 123-91-1    | 1,4-Dioxane                          | 66                 | 22.7%    | 37                      | 21.6%         | 3.0109                     | 0.0780         | 27.0000        | 0.7446            | <0.03                             | <0.03                       |
|               |                   |                                                     | 335-67-1    | Perfluorooctanoic acid (PFOA)        | 44                 | 27.3%    | 22                      | 18.2%         | 0.1008                     | 0.0043         | 0.2300         | 0.0318            | 0.0750                            | 0.075                       |
|               |                   |                                                     | 375-22-4    | Perfluorobutanoic acid (PFBA)        | 44                 | 40.9%    | 22                      | 31.8%         | 0.3642                     | 0.0029         | 1.0000         | 0.1541            | 0.0655                            | 0.0655                      |
| SW-62         | Closed Landfill   | Red Rock Sanitary Landfill                          | 45187-15-3  | Perfluorobutanesulfonate (PFBS)      | 44                 | 11.4%    | 22                      | 9.1%          | 0.0489                     | 0.0230         | 0.1000         | 0.0262            | 0.0230                            | 0.023                       |
|               |                   |                                                     | 45298-90-6  | Perfluorooctane sulfonic acid (PFOS) | 44                 | 6.8%     | 22                      | 9.1%          | 0.0185                     | 0.0062         | 0.0400         | 0.0076            | <0.007                            | <0.007                      |
|               |                   |                                                     | 108427-53-8 | Perfluorohexane sulfonate (PFHxS)    | 21                 | 0.0%     | 15                      | 0.0%          |                            |                |                | 0.0000            | <0.006                            | <0.004                      |
|               |                   |                                                     | 123-91-1    | 1,4-Dioxane                          | 35                 | 51.4%    | 20                      | 45.0%         | 0.9475                     | 0.0590         | 4.2800         | 0.5161            | <0.071                            | 0.5161                      |
|               |                   |                                                     | 335-67-1    | Perfluorooctanoic acid (PFOA)        | 21                 | 42.9%    | 15                      | 33.3%         | 0.0270                     | 0.0090         | 0.0480         | 0.0167            | <0.012                            | <0.012                      |
| SW-63         | Closed Landfill   | Minnesota Sanitation Services Landfill              | 375-22-4    | Perfluorobutanoic acid (PFBA)        | 21                 | 42.9%    | 15                      | 40.0%         | 0.0217                     | 0.0090         | 0.0910         | 0.0144            | <0.008                            | <0.008                      |
|               |                   |                                                     | 45187-15-3  | Perfluorobutanesulfonate (PFBS)      | 21                 | 0.0%     | 15                      | 0.0%          |                            |                |                | 0.0000            | <0.008                            | <0.005                      |
|               |                   |                                                     | 45298-90-6  | Perfluorooctane sulfonic acid (PFOS) | 18                 | 5.6%     | 12                      | 8.3%          | 0.0250                     | 0.0250         | 0.0250         | 0.0250            | <0.007                            | <0.007                      |
|               |                   |                                                     | 108427-53-8 | Perfluorohexane sulfonate (PFHxS)    | 8                  | 37.5%    | 5                       | 40.0%         | 0.0210                     | 0.0080         | 0.0290         | 0.0129            | <0.006                            | <0.006                      |
|               |                   |                                                     | 123-91-1    | 1,4-Dioxane                          | 8                  | 100.0%   | 4                       | 100.0%        | 1.8688                     | 0.2900         | 5.1300         | 1.8688            | 0.9700                            | 1.8688                      |
| SW-63         | Closed Landfill   | Minnesota Sanitation Services Landfill              | 335-67-1    | Perfluorooctanoic acid (PFOA)        | 8                  | 100.0%   | 5                       | 100.0%        | 0.0678                     | 0.0150         | 0.3100         | 0.0678            | 0.0190                            | 0.0678                      |
|               |                   |                                                     | 375-22-4    | Perfluorobutanoic acid (PFBA)        | 8                  | 37.5%    | 5                       | 60.0%         | 0.0150                     | 0.0050         | 0.0230         | 0.0088            | <0.006                            | <0.006                      |
|               |                   |                                                     | 45187-15-3  | Perfluorobutanesulfonate (PFBS)      | 8                  | 37.5%    | 5                       | 40.0%         | 0.0207                     | 0.0090         | 0.0420         | 0.0134            | <0.008                            | <0.008                      |
|               |                   |                                                     | 45298-90-6  | Perfluorooctane sulfonic acid (PFOS) | 8                  | 37.5%    | 5                       | 40.0%         | 0.1350                     | 0.0250         | 0.2800         | 0.0663            | <0.007                            | <0.007                      |

all concentrations in µg/L

pink shading indicates method used to determine measure of central tendency

bold indicates measure of central tendency above MN drinking water guidance

Table A-1 (continued)  
Summary Statistics Regulated PFAS and 1,4-Dioxane

| Facility Code | Facility Type   | Facility Name                   | CAS RN      | Chemical Name                        | Total Sample Count | % Detect | Number of Sampled Wells | % Well Detect | Arithmetic Mean of Detects | Minimum Detect | Maximum Detect | Kaplan Meier Mean | Median of Detects and Non-Detects | Measure of Central Tendency |
|---------------|-----------------|---------------------------------|-------------|--------------------------------------|--------------------|----------|-------------------------|---------------|----------------------------|----------------|----------------|-------------------|-----------------------------------|-----------------------------|
| SW-64         | Closed Landfill | Mankato Sanitary Landfill       | 108427-53-8 | Perfluorohexane sulfonate (PFHxS)    | 8                  | 0.0%     | 8                       | 0.0%          |                            |                |                | 0.0000            | <0.0051                           | <0.0049                     |
|               |                 |                                 | 123-91-1    | 1,4-Dioxane                          | 29                 | 41.4%    | 10                      | 40.0%         | 1.0133                     | 0.1300         | 2.9000         | 0.4955            | <0.071                            | <0.071                      |
|               |                 |                                 | 335-67-1    | Perfluorooctanoic acid (PFOA)        | 8                  | 62.5%    | 8                       | 62.5%         | 0.0076                     | 0.0043         | 0.0150         | 0.0063            | 0.0045                            | 0.0063                      |
|               |                 |                                 | 375-22-4    | Perfluorobutanoic acid (PFBA)        | 8                  | 50.0%    | 8                       | 50.0%         | 0.0073                     | 0.0037         | 0.0148         | 0.0055            | 0.0037                            | 0.0055                      |
|               |                 |                                 | 45187-15-3  | Perfluorobutanesulfonate (PFBS)      | 8                  | 12.5%    | 8                       | 12.5%         | 0.0051                     | 0.0051         | 0.0051         | 0.0051            | 0.0051                            | 0.0051                      |
|               |                 |                                 | 45298-90-6  | Perfluorooctane sulfonic acid (PFOS) | 8                  | 50.0%    | 8                       | 50.0%         | 0.0090                     | 0.0056         | 0.0148         | 0.0073            | 0.0056                            | 0.0073                      |
| SW-67         | Closed Landfill | Tellijohn Sanitary Landfill     | 108427-53-8 | Perfluorohexane sulfonate (PFHxS)    | 6                  | 33.3%    | 6                       | 33.3%         | 0.0350                     | 0.0320         | 0.0380         | 0.0330            | <0.013                            | <0.013                      |
|               |                 |                                 | 123-91-1    | 1,4-Dioxane                          | 23                 | 78.3%    | 10                      | 50.0%         | 50.4222                    | 1.2900         | 121.8000       | 39.7413           | 37.9000                           | 39.7413                     |
|               |                 |                                 | 335-67-1    | Perfluorooctanoic acid (PFOA)        | 6                  | 66.7%    | 6                       | 66.7%         | 0.1263                     | 0.0280         | 0.2100         | 0.0935            | 0.0525                            | 0.0935                      |
|               |                 |                                 | 375-22-4    | Perfluorobutanoic acid (PFBA)        | 6                  | 83.3%    | 6                       | 83.3%         | 0.0826                     | 0.0160         | 0.1300         | 0.0715            | 0.0785                            | 0.0715                      |
|               |                 |                                 | 45187-15-3  | Perfluorobutanesulfonate (PFBS)      | 6                  | 33.3%    | 6                       | 33.3%         | 0.0150                     | 0.0120         | 0.0180         | 0.0130            | <0.009                            | <0.009                      |
|               |                 |                                 | 45298-90-6  | Perfluorooctane sulfonic acid (PFOS) | 6                  | 16.7%    | 6                       | 16.7%         | 0.1900                     | 0.1900         | 0.1900         | 0.1900            | <0.007                            | <0.007                      |
| SW-68         | Closed Landfill | Northwoods Sanitary Landfill    | 108427-53-8 | Perfluorohexane sulfonate (PFHxS)    | 3                  | 33.3%    | 3                       | 33.3%         | 0.0140                     | 0.0140         | 0.0140         | 0.0140            | <0.004                            | <0.004                      |
|               |                 |                                 | 123-91-1    | 1,4-Dioxane                          | 27                 | 51.9%    | 16                      | 50.0%         | 4.5814                     | 0.2600         | 14.7000        | 2.5007            | <0.46                             | 2.5007                      |
|               |                 |                                 | 335-67-1    | Perfluorooctanoic acid (PFOA)        | 3                  | 66.7%    | 3                       | 66.7%         | 0.0270                     | 0.0090         | 0.0450         | 0.0210            | 0.0090                            | 0.021                       |
|               |                 |                                 | 375-22-4    | Perfluorobutanoic acid (PFBA)        | 3                  | 33.3%    | 3                       | 33.3%         | 0.0130                     | 0.0130         | 0.0130         | 0.0130            | <0.003                            | <0.003                      |
|               |                 |                                 | 45187-15-3  | Perfluorobutanesulfonate (PFBS)      | 3                  | 33.3%    | 3                       | 33.3%         | 0.0070                     | 0.0070         | 0.0070         | 0.0070            | <0.005                            | <0.005                      |
|               |                 |                                 | 45298-90-6  | Perfluorooctane sulfonic acid (PFOS) | 3                  | 66.7%    | 3                       | 66.7%         | 0.0315                     | 0.0230         | 0.0400         | 0.0287            | 0.0230                            | 0.0287                      |
| SW-7          | Closed Landfill | Wadena Sanitary Landfill        | 108427-53-8 | Perfluorohexane sulfonate (PFHxS)    | 5                  | 0.0%     | 5                       | 0.0%          |                            |                |                | 0.0000            | <0.004                            | <0.004                      |
|               |                 |                                 | 123-91-1    | 1,4-Dioxane                          | 45                 | 11.1%    | 12                      | 25.0%         | 0.1886                     | 0.0640         | 0.5000         | 0.0846            | <0.22                             | <0.22                       |
|               |                 |                                 | 335-67-1    | Perfluorooctanoic acid (PFOA)        | 5                  | 20.0%    | 5                       | 20.0%         | 0.0070                     | 0.0070         | 0.0070         | 0.0070            | <0.005                            | <0.005                      |
|               |                 |                                 | 375-22-4    | Perfluorobutanoic acid (PFBA)        | 5                  | 20.0%    | 5                       | 20.0%         | 0.0040                     | 0.0040         | 0.0040         | 0.0040            | <0.003                            | <0.003                      |
|               |                 |                                 | 45187-15-3  | Perfluorobutanesulfonate (PFBS)      | 5                  | 0.0%     | 5                       | 0.0%          |                            |                |                | 0.0000            | <0.005                            | <0.005                      |
|               |                 |                                 | 45298-90-6  | Perfluorooctane sulfonic acid (PFOS) | 5                  | 40.0%    | 5                       | 40.0%         | 0.0105                     | 0.0100         | 0.0110         | 0.0102            | <0.007                            | <0.007                      |
| SW-70         | Closed Landfill | Meeker County Sanitary Landfill | 108427-53-8 | Perfluorohexane sulfonate (PFHxS)    | 14                 | 0.0%     | 10                      | 0.0%          |                            |                |                | 0.0000            | <0.0051                           | <0.004                      |
|               |                 |                                 | 123-91-1    | 1,4-Dioxane                          | 14                 | 0.0%     | 14                      | 0.0%          |                            |                |                | 0.0000            | <0.071                            | <0.071                      |
|               |                 |                                 | 335-67-1    | Perfluorooctanoic acid (PFOA)        | 15                 | 20.0%    | 10                      | 10.0%         | 0.0102                     | 0.0060         | 0.0131         | 0.0068            | <0.006                            | <0.006                      |
|               |                 |                                 | 375-22-4    | Perfluorobutanoic acid (PFBA)        | 15                 | 20.0%    | 10                      | 20.0%         | 0.0152                     | 0.0110         | 0.0176         | 0.0118            | <0.003                            | <0.003                      |
|               |                 |                                 | 45187-15-3  | Perfluorobutanesulfonate (PFBS)      | 14                 | 0.0%     | 10                      | 0.0%          |                            |                |                | 0.0000            | <0.0051                           | <0.0049                     |
|               |                 |                                 | 45298-90-6  | Perfluorooctane sulfonic acid (PFOS) | 15                 | 26.7%    | 10                      | 10.0%         | 0.0394                     | 0.0178         | 0.0570         | 0.0236            | <0.007                            | <0.007                      |
| SW-72         | Closed Landfill | Pine Lane Sanitary Landfill     | 108427-53-8 | Perfluorohexane sulfonate (PFHxS)    | 2                  | 0.0%     | 2                       | 0.0%          |                            |                |                | 0.0000            | <0.006                            | <0.006                      |
|               |                 |                                 | 123-91-1    | 1,4-Dioxane                          | 18                 | 50.0%    | 8                       | 50.0%         | 1.7030                     | 0.0770         | 8.0000         | 0.8900            | 0.0770                            | 0.89                        |
|               |                 |                                 | 335-67-1    | Perfluorooctanoic acid (PFOA)        | 2                  | 50.0%    | 2                       | 50.0%         | 0.0080                     | 0.0080         | 0.0080         | 0.0080            | 0.0080                            | 0.008                       |
|               |                 |                                 | 375-22-4    | Perfluorobutanoic acid (PFBA)        | 2                  | 100.0%   | 2                       | 100.0%        | 0.0515                     | 0.0300         | 0.0730         | 0.0515            | 0.0515                            | 0.0515                      |
|               |                 |                                 | 45187-15-3  | Perfluorobutanesulfonate (PFBS)      | 2                  | 0.0%     | 2                       | 0.0%          |                            |                |                | 0.0000            | <0.008                            | <0.008                      |
|               |                 |                                 | 45298-90-6  | Perfluorooctane sulfonic acid (PFOS) | 2                  | 0.0%     | 2                       | 0.0%          |                            |                |                | 0.0000            | <0.005                            | <0.005                      |
| SW-73         | Closed Landfill | Iron Range Sanitary Landfill    | 108427-53-8 | Perfluorohexane sulfonate (PFHxS)    | 3                  | 33.3%    | 3                       | 33.3%         | 0.0090                     | 0.0090         | 0.0090         | 0.0090            | <0.004                            | <0.004                      |
|               |                 |                                 | 123-91-1    | 1,4-Dioxane                          | 10                 | 30.0%    | 6                       | 16.7%         | 5.4000                     | 4.4000         | 7.0000         | 4.7000            | <0.36                             | <0.36                       |
|               |                 |                                 | 335-67-1    | Perfluorooctanoic acid (PFOA)        | 3                  | 33.3%    | 3                       | 33.3%         | 0.0230                     | 0.0230         | 0.0230         | 0.0230            | <0.005                            | <0.005                      |
|               |                 |                                 | 375-22-4    | Perfluorobutanoic acid (PFBA)        | 3                  | 33.3%    | 3                       | 33.3%         | 0.0110                     | 0.0110         | 0.0110         | 0.0110            | <0.003                            | <0.003                      |
|               |                 |                                 | 45187-15-3  | Perfluorobutanesulfonate (PFBS)      | 3                  | 0.0%     | 3                       | 0.0%          |                            |                |                | 0.0000            | <0.005                            | <0.005                      |
|               |                 |                                 | 45298-90-6  | Perfluorooctane sulfonic acid (PFOS) | 3                  | 0.0%     | 3                       | 0.0%          |                            |                |                | 0.0000            | <0.007                            | <0.007                      |
| SW-74         | Operating MSW   | Elk River Landfill              | 108427-53-8 | Perfluorohexane sulfonate (PFHxS)    | 8                  | 12.5%    | 4                       | 25.0%         | 0.0067                     | 0.0067         | 0.0067         | 0.0067            | <0.0082                           | <0.0082                     |
|               |                 |                                 | 335-67-1    | Perfluorooctanoic acid (PFOA)        | 8                  | 37.5%    | 4                       | 50.0%         | 0.0089                     | 0.0046         | 0.0164         | 0.0062            | 0.0046                            | 0.0046                      |
|               |                 |                                 | 375-22-4    | Perfluorobutanoic acid (PFBA)        | 8                  | 87.5%    | 4                       | 100.0%        | 0.0504                     | 0.0033         | 0.0958         | 0.0445            | 0.0390                            | 0.0445                      |
|               |                 |                                 | 45187-15-3  | Perfluorobutanesulfonate (PFBS)      | 8                  | 0.0%     | 4                       | 0.0%          |                            |                |                | 0.0000            | <0.0082                           | <0.0049                     |
|               |                 |                                 | 45298-90-6  | Perfluorooctane sulfonic acid (PFOS) | 8                  | 0.0%     | 4                       | 0.0%          |                            |                |                | 0.0000            | <0.0082                           | <0.0049                     |
|               |                 |                                 |             |                                      |                    |          |                         |               |                            |                |                |                   |                                   |                             |
| SW-76         | Closed Landfill | Gofer Sanitary Landfill         | 108427-53-8 | Perfluorohexane sulfonate (PFHxS)    | 33                 | 72.7%    | 12                      | 50.0%         | 1.8434                     | 0.0073         | 11.0000        | 1.3427            | 0.0490                            | 1.3427                      |
|               |                 |                                 | 123-91-1    | 1,4-Dioxane                          | 14                 | 57.1%    | 9                       | 44.4%         | 3.6150                     | 0.3700         | 7.6200         | 2.2243            | 0.4000                            | 2.2243                      |
|               |                 |                                 | 335-67-1    | Perfluorooctanoic acid (PFOA)        | 33                 | 75.8%    | 12                      | 58.3%         | 7.2646                     | 0.0158         | 47.0000        | 5.5073            | 0.8800                            | 5.5073                      |
|               |                 |                                 | 375-22-4    | Perfluorobutanoic acid (PFBA)        | 33                 | 66.7%    | 12                      | 50.0%         | 0.5740                     | 0.0047         | 1.7000         | 0.3842            | 0.1900                            | 0.3842                      |
|               |                 |                                 | 45187-15-3  | Perfluorobutanesulfonate (PFBS)      | 33                 | 69.7%    | 12                      | 50.0%         | 1.5413                     | 0.0090         | 9.7000         | 1.0769            | 0.1700                            | 1.0769                      |
|               |                 |                                 | 45298-90-6  | Perfluorooctane sulfonic acid (PFOS) | 31                 | 58.1%    | 12                      | 41.7%         | 2.5705                     | 0.0053         | 20.0000        | 1.4949            | <0.051                            | 1.4949                      |

all concentrations in µg/L

pink shading indicates method used to determine measure of central tendency

bold indicates measure of central tendency above MN drinking water guidance

Table A-1 (continued)  
Summary Statistics Regulated PFAS and 1,4-Dioxane

| Facility Code | Facility Type   | Facility Name                                 | CAS RN      | Chemical Name                        | Total Sample Count | % Detect | Number of Sampled Wells | % Well Detect | Arithmetic Mean of Detects | Minimum Detect | Maximum Detect | Kaplan Meier Mean | Median of Detects and Non-Detects | Measure of Central Tendency |
|---------------|-----------------|-----------------------------------------------|-------------|--------------------------------------|--------------------|----------|-------------------------|---------------|----------------------------|----------------|----------------|-------------------|-----------------------------------|-----------------------------|
| SW-77         | Closed Landfill | Rock County Sanitary Landfill                 | 108427-53-8 | Perfluorohexane sulfonate (PFHxS)    | 4                  | 0.0%     | 4                       | 0.0%          |                            |                |                | 0.0000            | <0.0049                           | <0.0049                     |
|               |                 |                                               | 123-91-1    | 1,4-Dioxane                          | 10                 | 10.0%    | 10                      | 10.0%         | 0.9500                     | 0.9500         | 0.9500         | 0.9500            | <0.071                            | <0.071                      |
|               |                 |                                               | 335-67-1    | Perfluorooctanoic acid (PFOA)        | 4                  | 0.0%     | 4                       | 0.0%          |                            |                |                | 0.0000            | <0.0025                           | <0.0025                     |
|               |                 |                                               | 375-22-4    | Perfluorobutanoic acid (PFBA)        | 6                  | 66.7%    | 4                       | 50.0%         | 0.0061                     | 0.0036         | 0.0093         | 0.0053            | 0.0039                            | 0.0053                      |
|               |                 |                                               | 45187-15-3  | Perfluorobutanesulfonate (PFBS)      | 4                  | 0.0%     | 4                       | 0.0%          |                            |                |                | 0.0000            | <0.0049                           | <0.0049                     |
|               |                 |                                               | 45298-90-6  | Perfluorooctane sulfonic acid (PFOS) | 4                  | 0.0%     | 4                       | 0.0%          |                            |                |                | 0.0000            | <0.0049                           | <0.0049                     |
| SW-79         | Operating MSW   | Kandiyohi County Sanitary Landfill            | 108427-53-8 | Perfluorohexane sulfonate (PFHxS)    | 12                 | 25.0%    | 2                       | 50.0%         | 0.0379                     | 0.0228         | 0.0542         | 0.0266            | <0.0051                           | <0.0051                     |
|               |                 |                                               | 335-67-1    | Perfluorooctanoic acid (PFOA)        | 12                 | 8.3%     | 2                       | 50.0%         | 0.0030                     | 0.0030         | 0.0030         | 0.0030            | <0.0025                           | <0.0025                     |
|               |                 |                                               | 375-22-4    | Perfluorobutanoic acid (PFBA)        | 12                 | 75.0%    | 2                       | 100.0%        | 0.0182                     | 0.0038         | 0.0689         | 0.0146            | 0.0072                            | 0.0146                      |
|               |                 |                                               | 45187-15-3  | Perfluorobutanesulfonate (PFBS)      | 12                 | 25.0%    | 2                       | 50.0%         | 0.0840                     | 0.0175         | 0.1670         | 0.0341            | <0.0051                           | <0.0051                     |
|               |                 |                                               | 45298-90-6  | Perfluorooctane sulfonic acid (PFOS) | 12                 | 25.0%    | 2                       | 50.0%         | 0.0112                     | 0.0084         | 0.0147         | 0.0091            | <0.005                            | <0.005                      |
|               |                 |                                               | 108427-53-8 | Perfluorohexane sulfonate (PFHxS)    | 45                 | 28.9%    | 14                      | 50.0%         | 0.0051                     | 0.0049         | 0.0052         | 0.0050            | 0.0051                            | 0.0051                      |
| SW-8          | Closed Landfill | Johnson Bros./Lochness Park Sanitary Landfill | 123-91-1    | 1,4-Dioxane                          | 40                 | 22.5%    | 14                      | 21.4%         | 0.5737                     | 0.0630         | 1.1000         | 0.1779            | <0.03                             | <0.03                       |
|               |                 |                                               | 335-67-1    | Perfluorooctanoic acid (PFOA)        | 52                 | 36.5%    | 14                      | 57.1%         | 0.0133                     | 0.0025         | 0.0330         | 0.0083            | 0.0098                            | 0.0098                      |
|               |                 |                                               | 375-22-4    | Perfluorobutanoic acid (PFBA)        | 45                 | 77.8%    | 14                      | 85.7%         | 0.0699                     | 0.0044         | 0.3000         | 0.0624            | 0.0717                            | 0.0624                      |
|               |                 |                                               | 45187-15-3  | Perfluorobutanesulfonate (PFBS)      | 45                 | 28.9%    | 14                      | 50.0%         | 0.0051                     | 0.0049         | 0.0052         | 0.0050            | <0.0051                           | <0.0051                     |
|               |                 |                                               | 45298-90-6  | Perfluorooctane sulfonic acid (PFOS) | 52                 | 26.9%    | 14                      | 50.0%         | 0.0052                     | 0.0049         | 0.0061         | 0.0051            | 0.0061                            | 0.0061                      |
|               |                 |                                               | 108427-53-8 | Perfluorohexane sulfonate (PFHxS)    | 13                 | 0.0%     | 8                       | 0.0%          |                            |                |                | 0.0000            | <0.006                            | <0.004                      |
| SW-82         | Closed Landfill | Mille Lacs Sanitary Landfill                  | 123-91-1    | 1,4-Dioxane                          | 76                 | 21.1%    | 21                      | 33.3%         | 1.7226                     | 0.0620         | 3.7000         | 0.4116            | <0.22                             | <0.22                       |
|               |                 |                                               | 335-67-1    | Perfluorooctanoic acid (PFOA)        | 13                 | 15.4%    | 8                       | 25.0%         | 0.0079                     | 0.0028         | 0.0130         | 0.0036            | <0.006                            | <0.006                      |
|               |                 |                                               | 375-22-4    | Perfluorobutanoic acid (PFBA)        | 13                 | 69.2%    | 8                       | 75.0%         | 0.0101                     | 0.0030         | 0.0185         | 0.0080            | 0.0080                            | 0.008                       |
|               |                 |                                               | 45187-15-3  | Perfluorobutanesulfonate (PFBS)      | 13                 | 0.0%     | 8                       | 0.0%          |                            |                |                | 0.0000            | <0.008                            | <0.005                      |
|               |                 |                                               | 45298-90-6  | Perfluorooctane sulfonic acid (PFOS) | 13                 | 0.0%     | 8                       | 0.0%          |                            |                |                | 0.0000            | <0.005                            | <0.005                      |
|               |                 |                                               | 108427-53-8 | Perfluorohexane sulfonate (PFHxS)    | 4                  | 0.0%     | 4                       | 0.0%          |                            |                |                | 0.0000            | <0.005                            | <0.0049                     |
| SW-83         | Closed Landfill | Redwood County Sanitary Landfill              | 123-91-1    | 1,4-Dioxane                          | 8                  | 25.0%    | 7                       | 14.3%         | 0.7850                     | 0.6100         | 0.9600         | 0.6538            | <0.071                            | <0.071                      |
|               |                 |                                               | 335-67-1    | Perfluorooctanoic acid (PFOA)        | 5                  | 40.0%    | 4                       | 25.0%         | 0.0086                     | 0.0077         | 0.0095         | 0.0081            | <0.0025                           | <0.0025                     |
|               |                 |                                               | 375-22-4    | Perfluorobutanoic acid (PFBA)        | 6                  | 66.7%    | 4                       | 50.0%         | 0.0086                     | 0.0057         | 0.0122         | 0.0076            | 0.0069                            | 0.0076                      |
|               |                 |                                               | 45187-15-3  | Perfluorobutanesulfonate (PFBS)      | 4                  | 0.0%     | 4                       | 0.0%          |                            |                |                | 0.0000            | <0.005                            | <0.0049                     |
|               |                 |                                               | 45298-90-6  | Perfluorooctane sulfonic acid (PFOS) | 4                  | 0.0%     | 4                       | 0.0%          |                            |                |                | 0.0000            | <0.005                            | <0.0049                     |
|               |                 |                                               | 108427-53-8 | Perfluorohexane sulfonate (PFHxS)    | 7                  | 14.3%    | 6                       | 16.7%         | 0.0120                     | 0.0120         | 0.0120         | 0.0120            | <0.006                            | <0.006                      |
| SW-85         | Closed Landfill | Albert Lea Sanitary Landfill                  | 123-91-1    | 1,4-Dioxane                          | 33                 | 63.6%    | 15                      | 60.0%         | 5.7595                     | 0.2500         | 20.1200        | 3.7561            | 0.5200                            | <b>3.7561</b>               |
|               |                 |                                               | 335-67-1    | Perfluorooctanoic acid (PFOA)        | 7                  | 14.3%    | 6                       | 16.7%         | 0.0330                     | 0.0330         | 0.0330         | 0.0330            | <0.006                            | <0.006                      |
|               |                 |                                               | 375-22-4    | Perfluorobutanoic acid (PFBA)        | 7                  | 85.7%    | 6                       | 100.0%        | 0.0243                     | 0.0110         | 0.0430         | 0.0224            | 0.0180                            | 0.0224                      |
|               |                 |                                               | 45187-15-3  | Perfluorobutanesulfonate (PFBS)      | 7                  | 14.3%    | 6                       | 16.7%         | 0.0120                     | 0.0120         | 0.0120         | 0.0120            | <0.008                            | <0.008                      |
|               |                 |                                               | 45298-90-6  | Perfluorooctane sulfonic acid (PFOS) | 7                  | 0.0%     | 6                       | 0.0%          |                            |                |                | 0.0000            | <0.005                            | <0.005                      |
|               |                 |                                               | 108427-53-8 | Perfluorohexane sulfonate (PFHxS)    | 9                  | 22.2%    | 7                       | 14.3%         | 0.0542                     | 0.0399         | 0.0684         | 0.0431            | <0.013                            | <0.013                      |
| SW-91         | Closed Landfill | Sun Prairie Sanitary Landfill                 | 123-91-1    | 1,4-Dioxane                          | 8                  | 25.0%    | 6                       | 16.7%         | 1.4650                     | 1.2500         | 1.6800         | 1.3038            | <0.071                            | <0.071                      |
|               |                 |                                               | 335-67-1    | Perfluorooctanoic acid (PFOA)        | 9                  | 33.3%    | 7                       | 14.3%         | 0.0690                     | 0.0606         | 0.0750         | 0.0634            | <0.012                            | <0.012                      |
|               |                 |                                               | 375-22-4    | Perfluorobutanoic acid (PFBA)        | 9                  | 33.3%    | 7                       | 14.3%         | 0.0347                     | 0.0306         | 0.0380         | 0.0320            | <0.008                            | <0.008                      |
|               |                 |                                               | 45187-15-3  | Perfluorobutanesulfonate (PFBS)      | 9                  | 33.3%    | 7                       | 14.3%         | 0.0960                     | 0.0660         | 0.1160         | 0.0760            | <0.009                            | <0.009                      |
|               |                 |                                               | 45298-90-6  | Perfluorooctane sulfonic acid (PFOS) | 9                  | 22.2%    | 7                       | 14.3%         | 0.0197                     | 0.0081         | 0.0312         | 0.0107            | <0.007                            | <0.007                      |
|               |                 |                                               | 108427-53-8 | Perfluorohexane sulfonate (PFHxS)    | 36                 | 11.1%    | 21                      | 14.3%         | 0.0106                     | 0.0053         | 0.0140         | 0.0062            | <0.006                            | <0.006                      |
| SW-94         | Closed Landfill | Anoka Municipal Regional Landfill             | 123-91-1    | 1,4-Dioxane                          | 170                | 82.9%    | 44                      | 75.0%         | 7.5943                     | 0.0620         | 49.0000        | 6.3094            | 4.6000                            | <b>6.3094</b>               |
|               |                 |                                               | 335-67-1    | Perfluorooctanoic acid (PFOA)        | 40                 | 62.5%    | 21                      | 76.2%         | 0.0591                     | 0.0220         | 0.1600         | 0.0531            | 0.0585                            | <b>0.0531</b>               |
|               |                 |                                               | 375-22-4    | Perfluorobutanoic acid (PFBA)        | 36                 | 88.9%    | 21                      | 85.7%         | 0.1458                     | 0.0170         | 0.3500         | 0.1408            | 0.1370                            | 0.1408                      |
|               |                 |                                               | 45187-15-3  | Perfluorobutanesulfonate (PFBS)      | 36                 | 13.9%    | 21                      | 23.8%         | 0.0065                     | 0.0050         | 0.0080         | 0.0053            | <0.008                            | <0.008                      |
|               |                 |                                               | 45298-90-6  | Perfluorooctane sulfonic acid (PFOS) | 40                 | 7.5%     | 21                      | 14.3%         | 0.0089                     | 0.0068         | 0.0130         | 0.0071            | <0.007                            | <0.007                      |
|               |                 |                                               | 108427-53-8 | Perfluorohexane sulfonate (PFHxS)    | 5                  | 0.0%     | 5                       | 0.0%          |                            |                |                | 0.0000            | <0.013                            | <0.013                      |
| SW-99         | Closed Landfill | Becker County Sanitary Landfill               | 123-91-1    | 1,4-Dioxane                          | 167                | 7.8%     | 49                      | 20.4%         | 0.1853                     | 0.0470         | 0.6600         | 0.0721            | <0.22                             | <0.22                       |
|               |                 |                                               | 335-67-1    | Perfluorooctanoic acid (PFOA)        | 5                  | 0.0%     | 5                       | 0.0%          |                            |                |                | 0.0000            | <0.012                            | <0.012                      |
|               |                 |                                               | 375-22-4    | Perfluorobutanoic acid (PFBA)        | 5                  | 60.0%    | 5                       | 60.0%         | 0.0093                     | 0.0080         | 0.0110         | 0.0088            | 0.0080                            | 0.0088                      |
|               |                 |                                               | 45187-15-3  | Perfluorobutanesulfonate (PFBS)      | 5                  | 0.0%     | 5                       | 0.0%          |                            |                |                | 0.0000            | <0.009                            | <0.009                      |
|               |                 |                                               | 45298-90-6  | Perfluorooctane sulfonic acid (PFOS) | 5                  | 0.0%     | 5                       | 0.0%          |                            |                |                | 0.0000            | <0.007                            | <0.007                      |
|               |                 |                                               | 123-91-1    | 1,4-Dioxane                          | 11                 | 9.1%     | 6                       | 16.7%         | 0.3300                     | 0.3300         | 0.3300         | 0.3300            | <0.071                            | <0.071                      |
| SW-108        | Closed Landfill | Benson Sanitary Landfill                      | 335-67-1    | Perfluorooctanoic acid (PFOA)        | 2                  | 100.0%   | 2                       | 100.0%        | 0.0123                     | 0.0033         | 0.0212         | 0.0123            | 0.0123                            | 0.0123                      |
|               |                 |                                               | 375-22-4    | Perfluorobutanoic acid (PFBA)        | 2                  | 100.0%   | 2                       | 100.0%        | 0.0145                     | 0.0031         | 0.0258         | 0.0145            | 0.0145                            | 0.0145                      |

all concentrations in µg/L

pink shading indicates method used to determine measure of central tendency

bold indicates measure of central tendency above MN drinking water guidance

Table A-1 (continued)  
Summary Statistics Regulated PFAS and 1,4-Dioxane

| Facility Code | Facility Type     | Facility Name                         | CAS RN   | Chemical Name | Total Sample Count | % Detect | Number of Sampled Wells | % Well Detect | Arithmetic Mean of Detects | Minimum Detect | Maximum Detect | Kaplan Meier Mean | Median of Detects and Non-Detects | Measure of Central Tendency |
|---------------|-------------------|---------------------------------------|----------|---------------|--------------------|----------|-------------------------|---------------|----------------------------|----------------|----------------|-------------------|-----------------------------------|-----------------------------|
| SW-116        | Closed Landfill   | Sauk Centre Sanitary Landfill         | 123-91-1 | 1,4-Dioxane   | 34                 | 26.5%    | 11                      | 36.4%         | 0.6411                     | 0.1100         | 1.6000         | 0.2506            | <0.071                            | <0.071                      |
| SW-122        | Closed Landfill   | Mahnomen Sanitary Landfill            | 123-91-1 | 1,4-Dioxane   | 12                 | 0.0%     | 6                       | 0.0%          |                            |                |                | 0.0000            | <0.22                             | <0.031                      |
| SW-128        | Closed Landfill   | Hudson Sanitary Landfill              | 123-91-1 | 1,4-Dioxane   | 23                 | 39.1%    | 12                      | 25.0%         | 3.6889                     | 1.1000         | 11.0000        | 2.1130            | <0.22                             | <0.22                       |
| SW-130        | Closed Landfill   | Pickett Sanitary Landfill             | 123-91-1 | 1,4-Dioxane   | 47                 | 12.8%    | 26                      | 15.4%         | 0.5627                     | 0.0960         | 1.1000         | 0.1556            | <0.22                             | <0.22                       |
| SW-140        | Closed Landfill   | Lake County Sanitary Landfill         | 123-91-1 | 1,4-Dioxane   | 11                 | 0.0%     | 11                      | 0.0%          |                            |                |                | 0.0000            | <0.22                             | <0.22                       |
| SW-146        | Closed Landfill   | Leech Lake Sanitary Landfill          | 123-91-1 | 1,4-Dioxane   | 8                  | 37.5%    | 6                       | 16.7%         | 1.7667                     | 1.7000         | 1.8000         | 1.7250            | <0.36                             | <0.36                       |
| SW-150        | Closed Landfill   | Hickory Grove Sanitary Landfill       | 123-91-1 | 1,4-Dioxane   | 16                 | 37.5%    | 7                       | 71.4%         | 8.8750                     | 0.2500         | 15.0000        | 3.4844            | <0.22                             | <0.22                       |
| SW-163        | Closed Landfill   | Brookston Sanitary Landfill           | 123-91-1 | 1,4-Dioxane   | 7                  | 14.3%    | 7                       | 14.3%         | 0.7500                     | 0.7500         | 0.7500         | 0.7500            | <0.22                             | <0.22                       |
| SW-164        | Closed Landfill   | Floodwood Sanitary Landfill           | 123-91-1 | 1,4-Dioxane   | 9                  | 0.0%     | 9                       | 0.0%          |                            |                |                | 0.0000            | <0.22                             | <0.22                       |
| SW-169        | Closed Landfill   | Longville Remer Landfill              | 123-91-1 | 1,4-Dioxane   | 8                  | 0.0%     | 8                       | 0.0%          |                            |                |                | 0.0000            | <0.22                             | <0.22                       |
| SW-171        | Closed Landfill   | Lake Of The Woods Sanitary Landfill   | 123-91-1 | 1,4-Dioxane   | 19                 | 26.3%    | 10                      | 40.0%         | 1.8250                     | 0.0950         | 5.9000         | 0.5503            | <0.22                             | <0.22                       |
| SW-172        | Closed Landfill   | Paynesville Sanitary Landfill         | 123-91-1 | 1,4-Dioxane   | 33                 | 33.3%    | 18                      | 27.8%         | 2.2100                     | 0.4400         | 3.9900         | 1.0300            | <0.071                            | <0.071                      |
| SW-177        | Closed Landfill   | Vermillion Modified Sanitary Landfill | 123-91-1 | 1,4-Dioxane   | 10                 | 0.0%     | 5                       | 0.0%          |                            |                |                | 0.0000            | <0.46                             | <0.36                       |
| SW-225        | Closed Landfill   | Northome Sanitary Landfill            | 123-91-1 | 1,4-Dioxane   | 6                  | 0.0%     | 6                       | 0.0%          |                            |                |                | 0.0000            | <0.36                             | <0.36                       |
| SW-236        | Closed Landfill   | Northwest Angle Modified Sanitary LF  | 123-91-1 | 1,4-Dioxane   | 3                  | 0.0%     | 3                       | 0.0%          |                            |                |                | 0.0000            | <0.22                             | <0.22                       |
| SW-243        | Closed Landfill   | Fifty Lakes Modified Landfill         | 123-91-1 | 1,4-Dioxane   | 6                  | 0.0%     | 6                       | 0.0%          |                            |                |                | 0.0000            | <0.22                             | <0.016                      |
| SW-294        | Closed Landfill   | Cook County Sanitary Landfill         | 123-91-1 | 1,4-Dioxane   | 19                 | 0.0%     | 10                      | 0.0%          |                            |                |                | 0.0000            | <0.46                             | <0.22                       |
| SW-311        | Other Solid Waste | Becker County Demolition Landfill     | 123-91-1 | 1,4-Dioxane   | 6                  | 0.0%     | 3                       | 0.0%          |                            |                |                | 0.0000            | <0.22                             | <0.22                       |
| SW-38         | Closed Landfill   | Hoyt Lakes Sanitary Landfill          | 123-91-1 | 1,4-Dioxane   | 7                  | 0.0%     | 5                       | 0.0%          |                            |                |                | 0.0000            | <0.36                             | <0.36                       |
| SW-39         | Closed Landfill   | Long Prairie Sanitary Landfill        | 123-91-1 | 1,4-Dioxane   | 30                 | 20.0%    | 11                      | 18.2%         | 0.6900                     | 0.1700         | 1.4000         | 0.2740            | <0.22                             | <0.22                       |
| SW-575        | Closed Landfill   | Land Investors Landfill               | 123-91-1 | 1,4-Dioxane   | 10                 | 30.0%    | 4                       | 25.0%         | 0.6167                     | 0.4500         | 0.8100         | 0.5000            | <0.22                             | <0.22                       |
| SW-66         | Closed Landfill   | Stevens County Sanitary Landfill      | 123-91-1 | 1,4-Dioxane   | 39                 | 38.5%    | 11                      | 36.4%         | 0.5880                     | 0.2000         | 1.7500         | 0.3492            | <0.071                            | <0.071                      |
| SW-69         | Closed Landfill   | Faribault County Sanitary Landfill    | 123-91-1 | 1,4-Dioxane   | 9                  | 33.3%    | 7                       | 14.3%         | 21.5700                    | 14.5700        | 32.1000        | 16.9033           | <0.071                            | <0.071                      |
| SW-78         | Closed Landfill   | Killian Sanitary Landfill             | 123-91-1 | 1,4-Dioxane   | 30                 | 16.7%    | 13                      | 15.4%         | 5.2660                     | 0.6300         | 9.0000         | 1.4027            | <0.22                             | <0.22                       |
| SW-81         | Closed Landfill   | Watsonwan County Sanitary Landfill    | 123-91-1 | 1,4-Dioxane   | 3                  | 0.0%     | 3                       | 0.0%          |                            |                |                | 0.0000            | <0.071                            | <0.071                      |
| SW-86         | Closed Landfill   | Battle Lake Sanitary Landfill         | 123-91-1 | 1,4-Dioxane   | 30                 | 16.7%    | 13                      | 23.1%         | 0.4188                     | 0.0640         | 0.9200         | 0.1231            | <0.22                             | <0.22                       |
| SW-96         | Closed Landfill   | Big Stone County Sanitary Landfill    | 123-91-1 | 1,4-Dioxane   | 12                 | 41.7%    | 10                      | 30.0%         | 0.5360                     | 0.3200         | 0.6900         | 0.4100            | <0.071                            | <0.071                      |
| SW-97         | Closed Landfill   | East Mesaba Sanitary Landfill         | 123-91-1 | 1,4-Dioxane   | 27                 | 18.5%    | 13                      | 23.1%         | 1.1380                     | 0.2900         | 2.3000         | 0.4470            | <0.36                             | <0.36                       |

all concentrations in µg/L

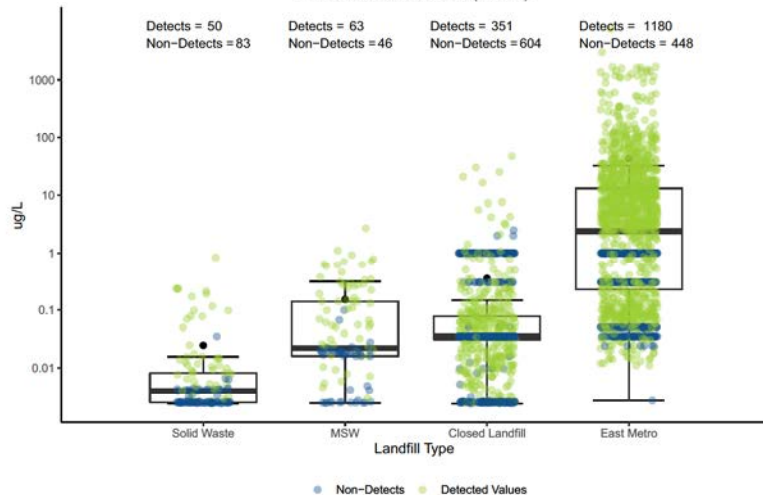
pink shading indicates method used to determine measure of central tendency

bold indicates measure of central tendency above MN drinking water guidance

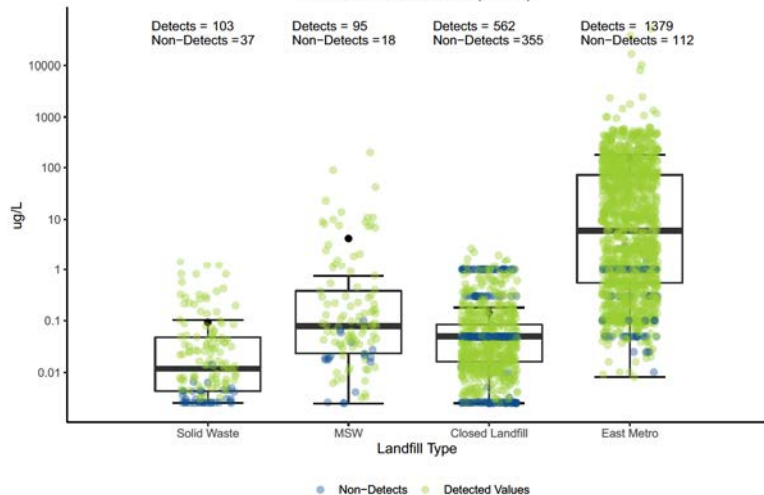
## **Appendix B**

### **Box-and-Whiskers Plots of Raw Data**

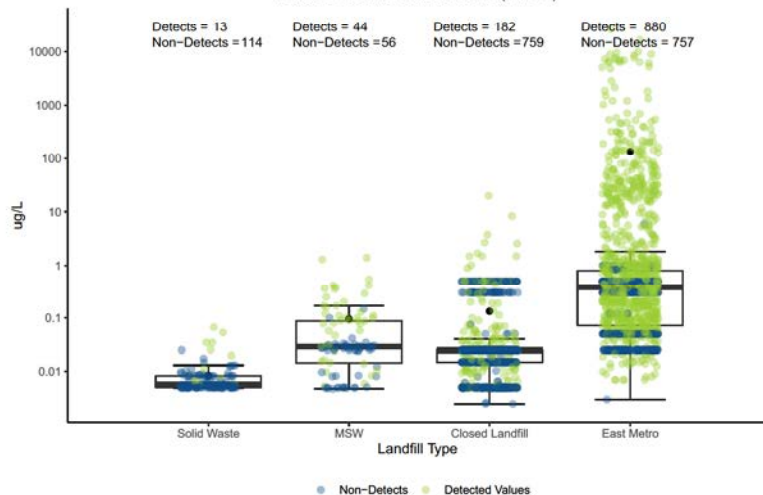
Perfluorooctanoic acid (PFOA)



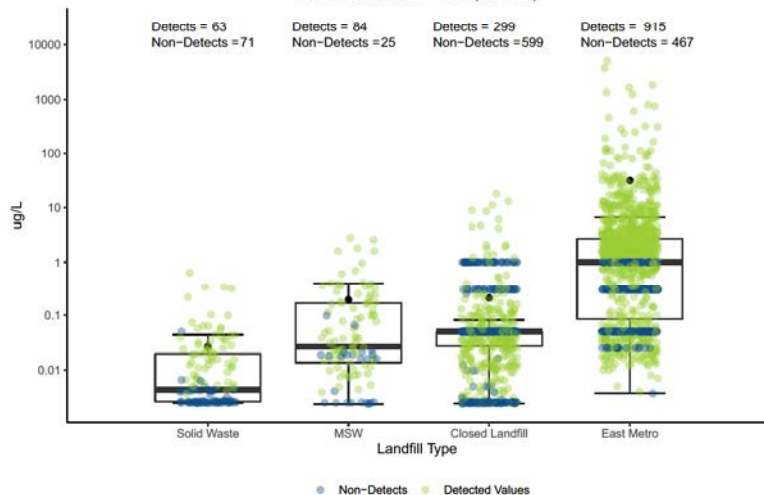
Perfluorobutanoic acid (PFBA)



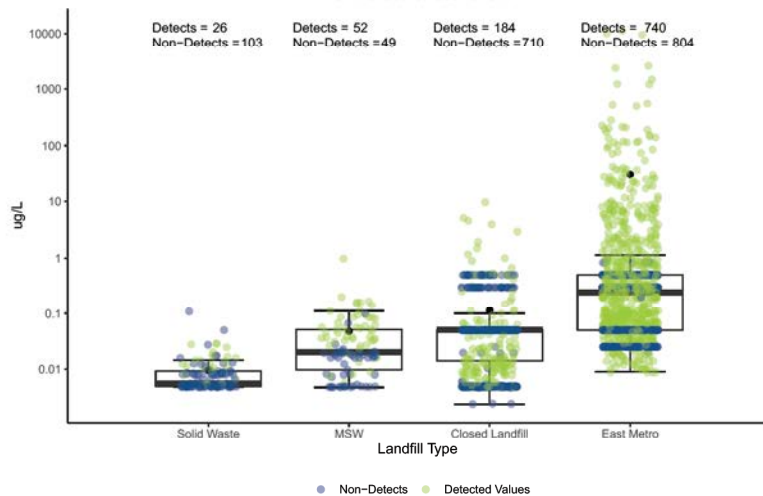
Perfluorooctane sulfonic acid (PFOS)



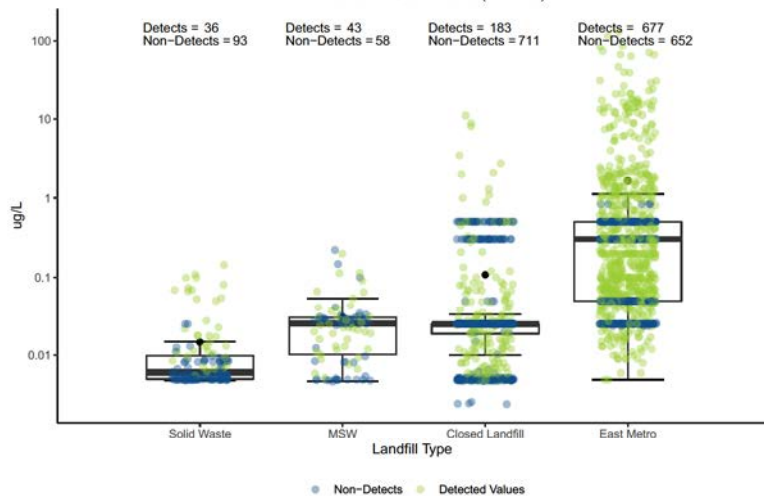
Perfluorohexanoic acid (PFHxA)



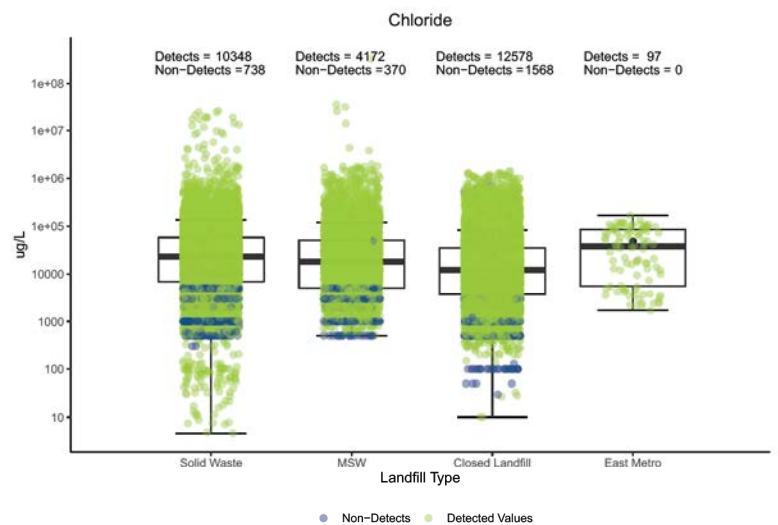
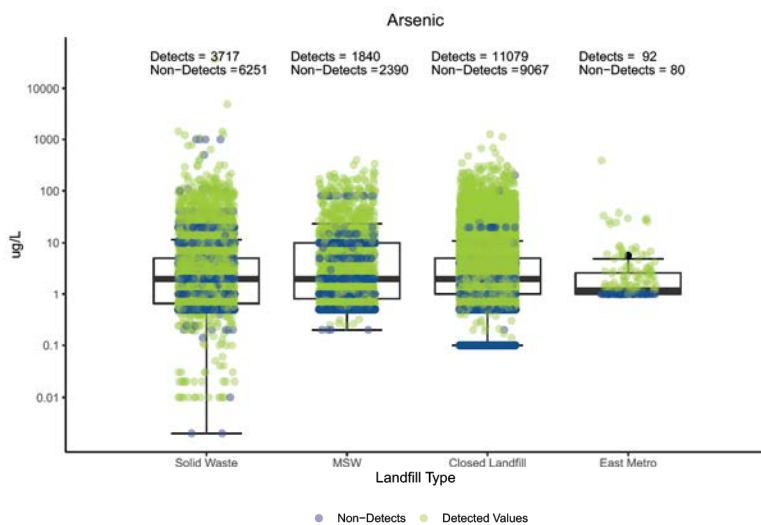
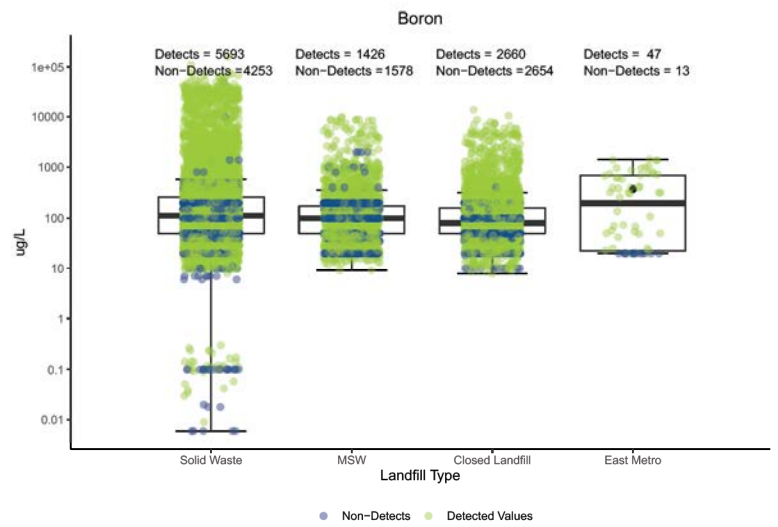
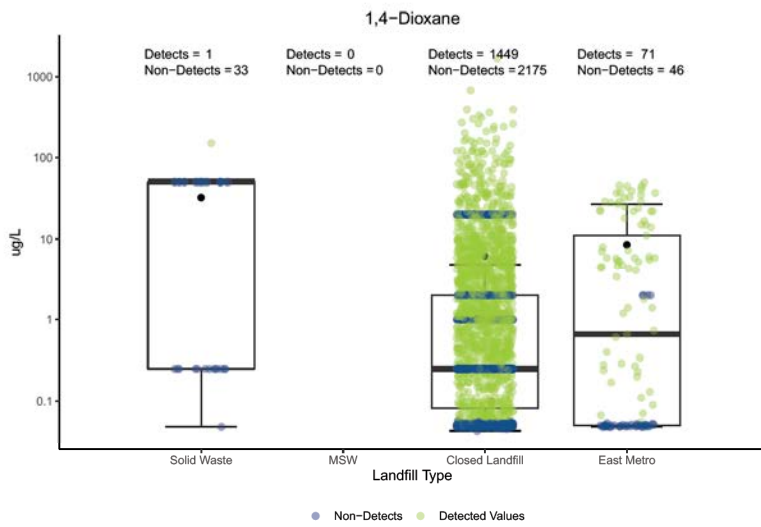
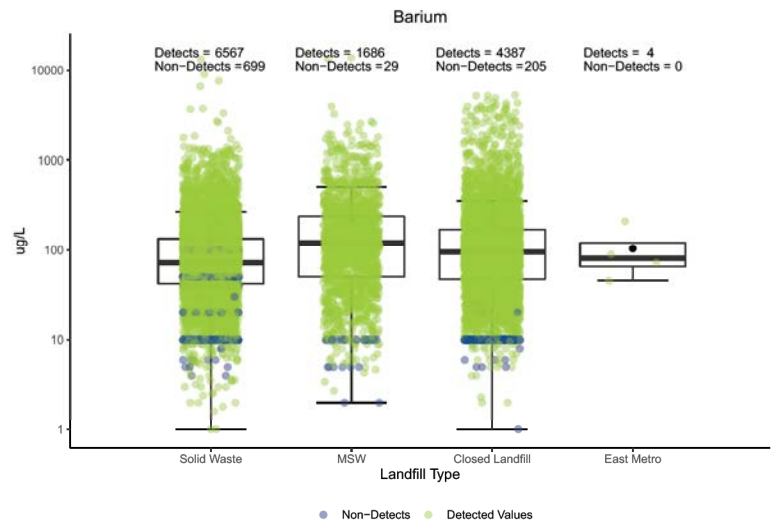
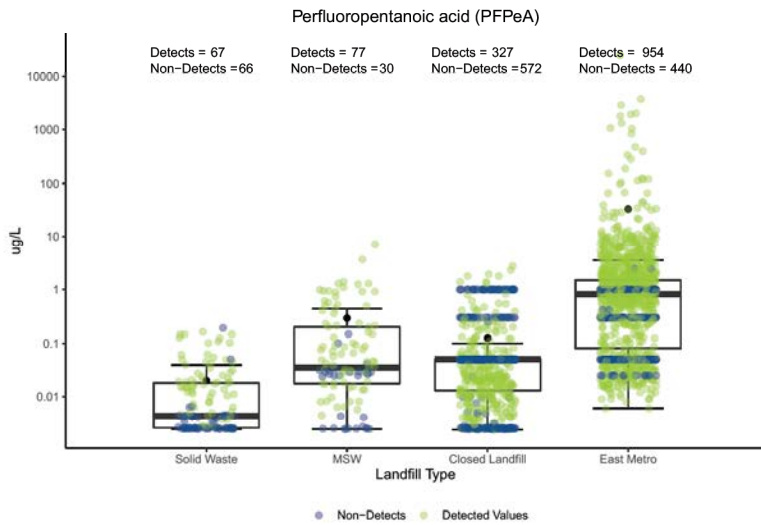
Perfluorobutanesulfonate



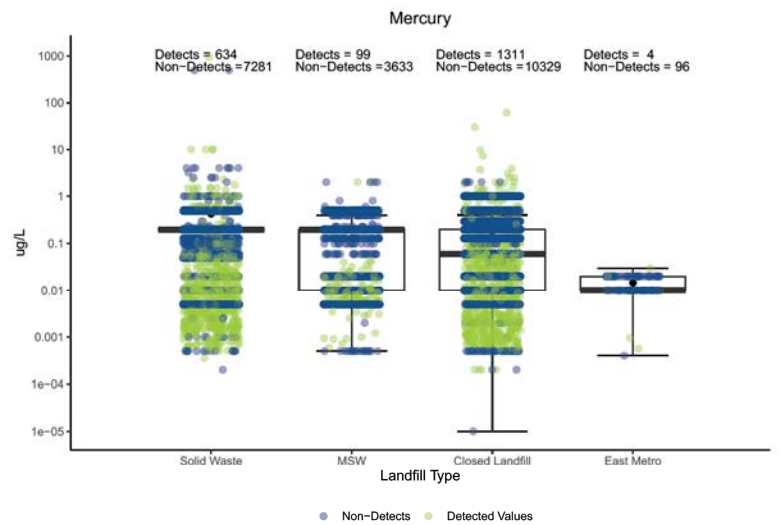
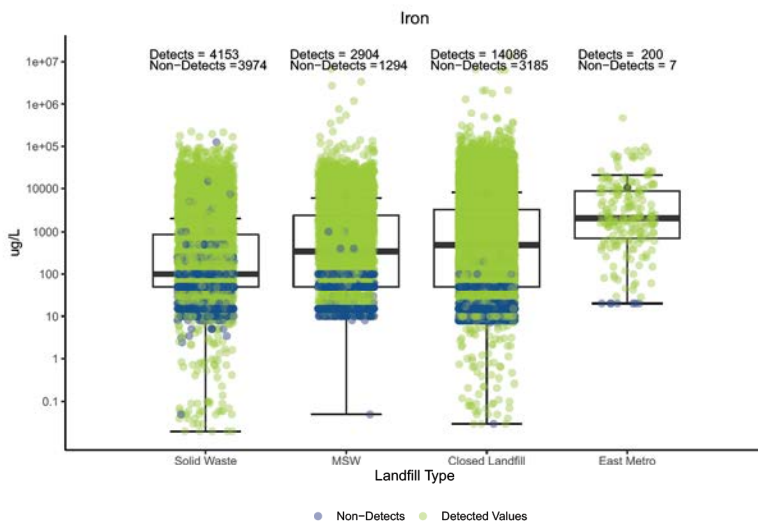
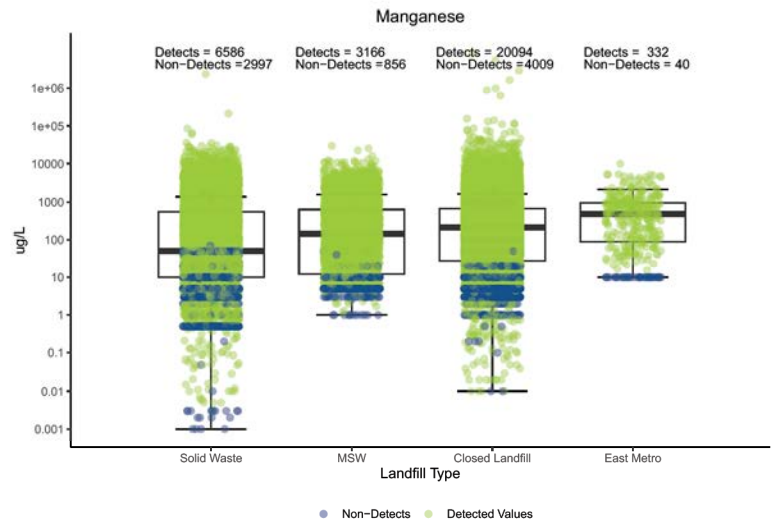
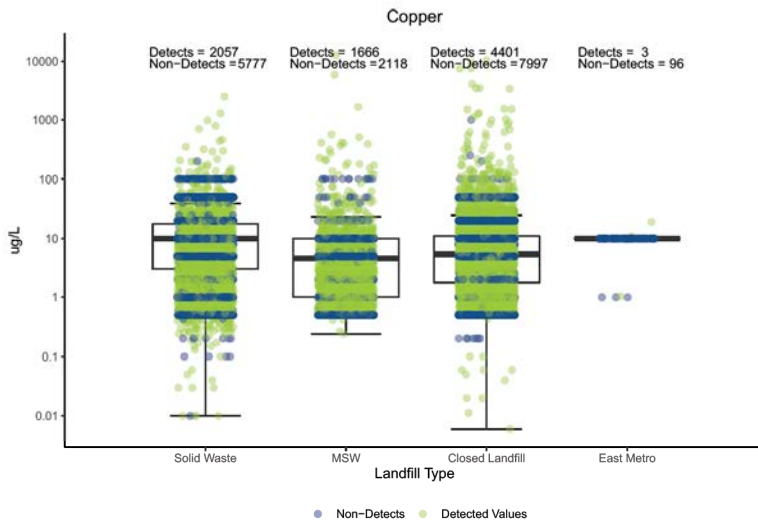
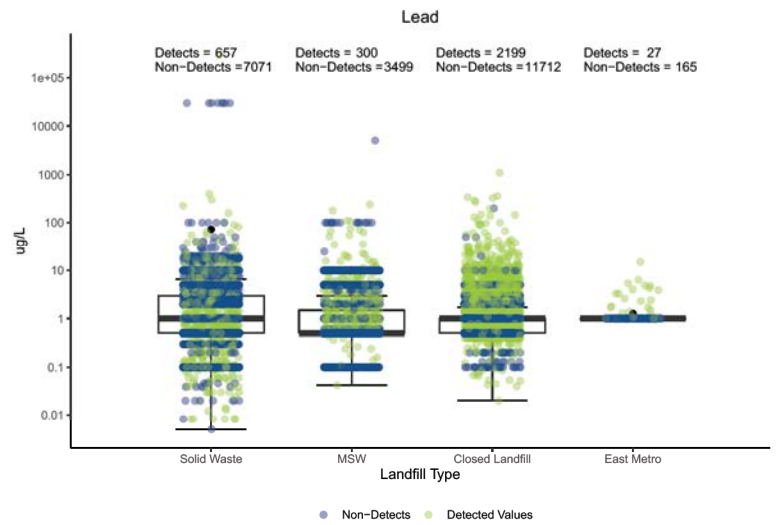
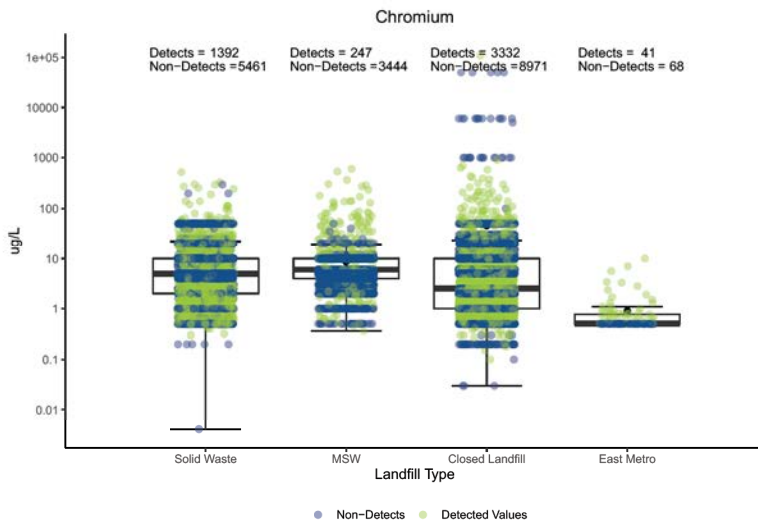
Perfluorohexane sulfonate (PFHxS)

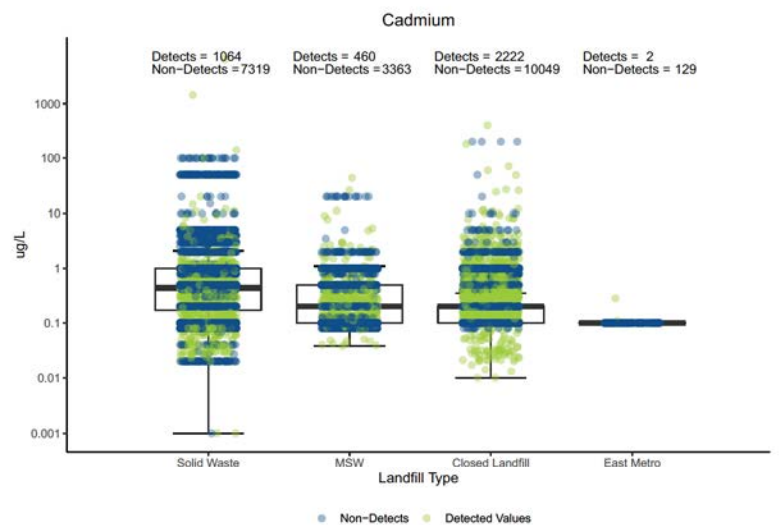
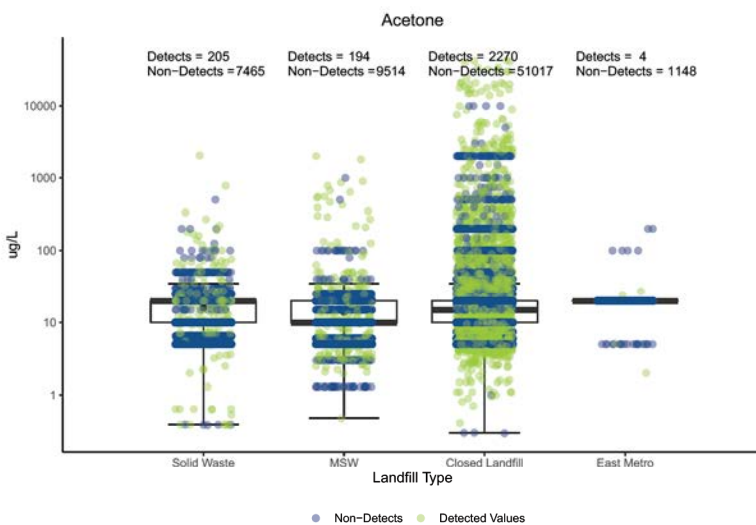
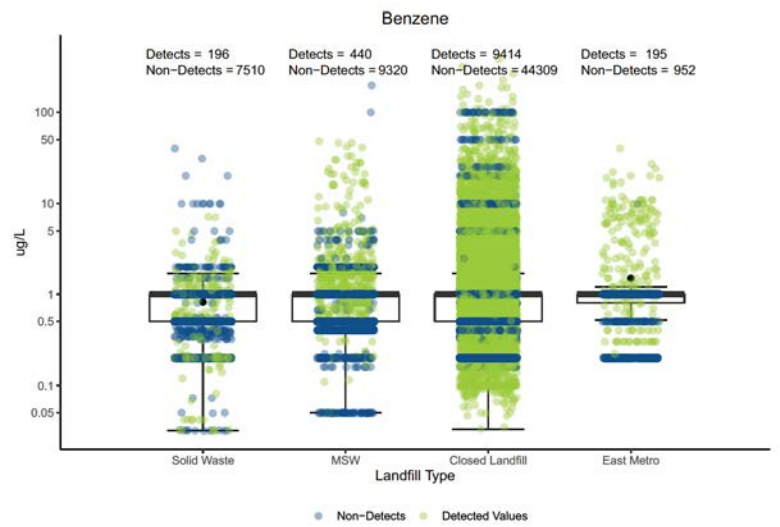
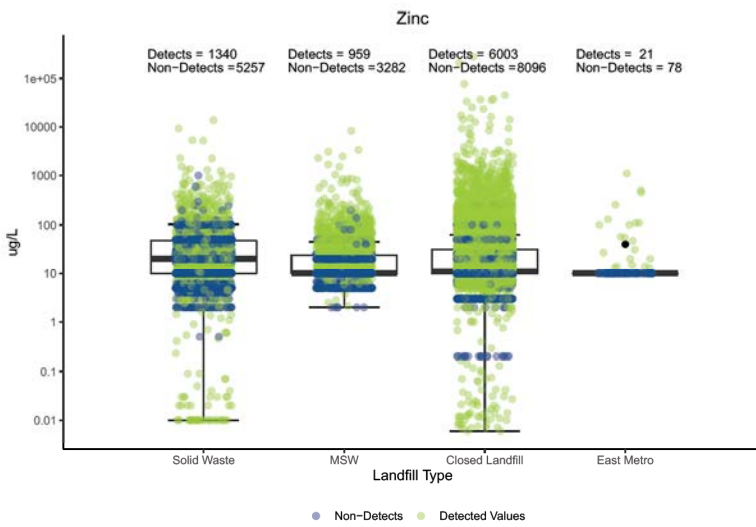
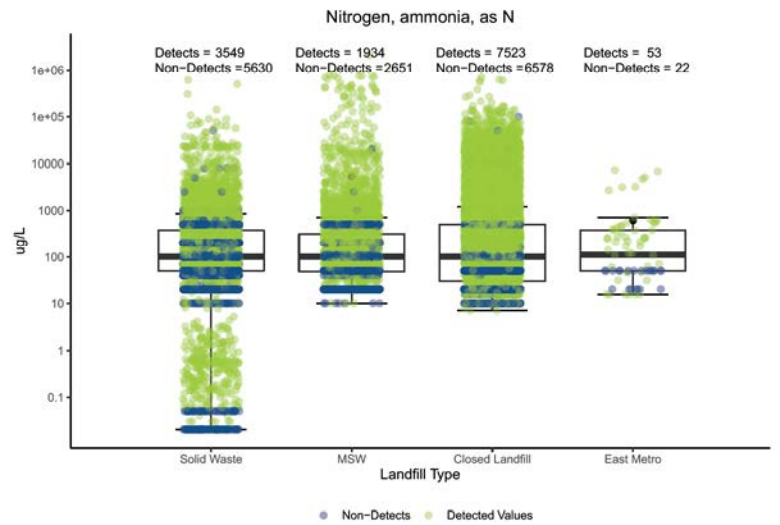
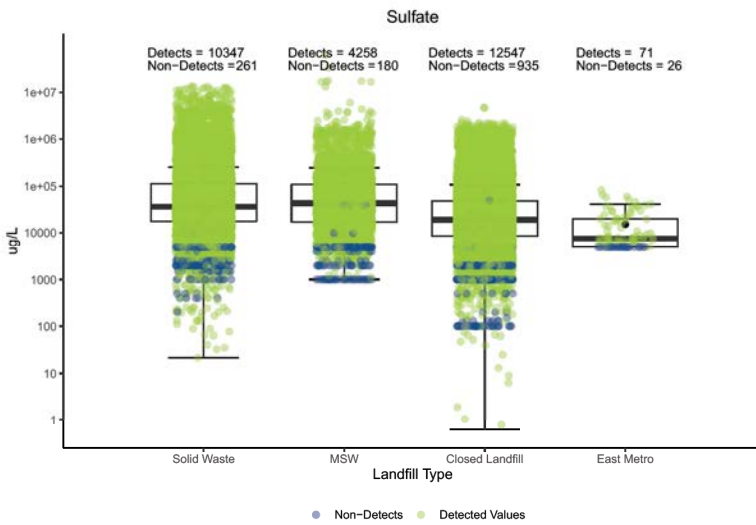




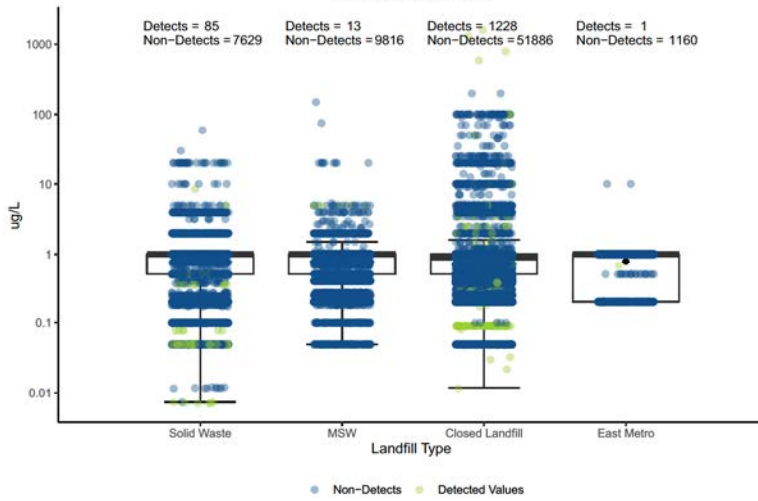




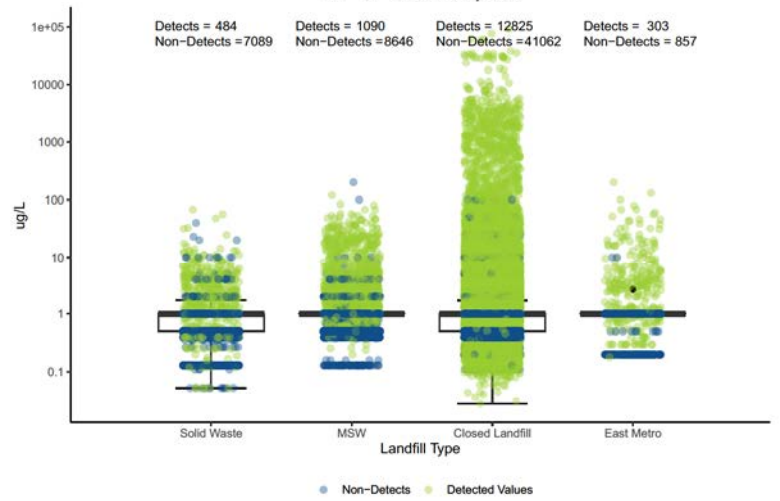




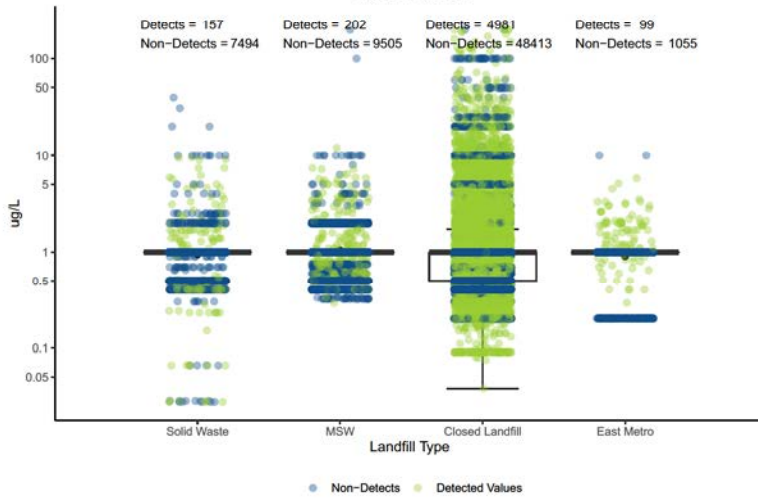
Carbon tetrachloride



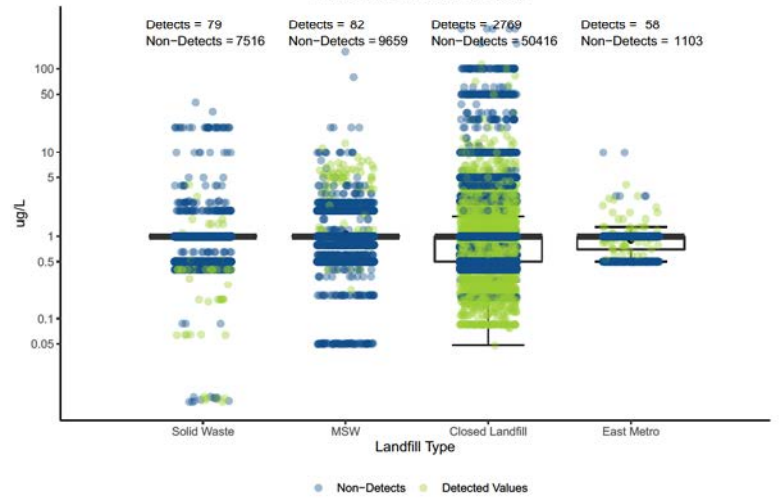
cis-1,2-Dichloroethylene



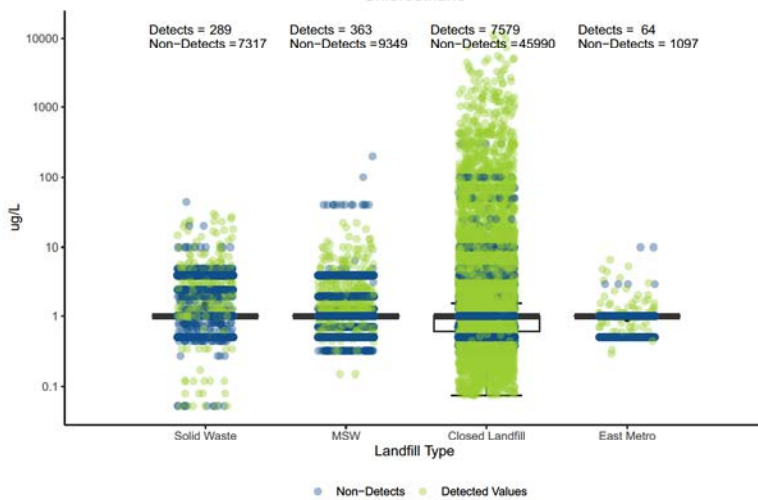
Chlorobenzene



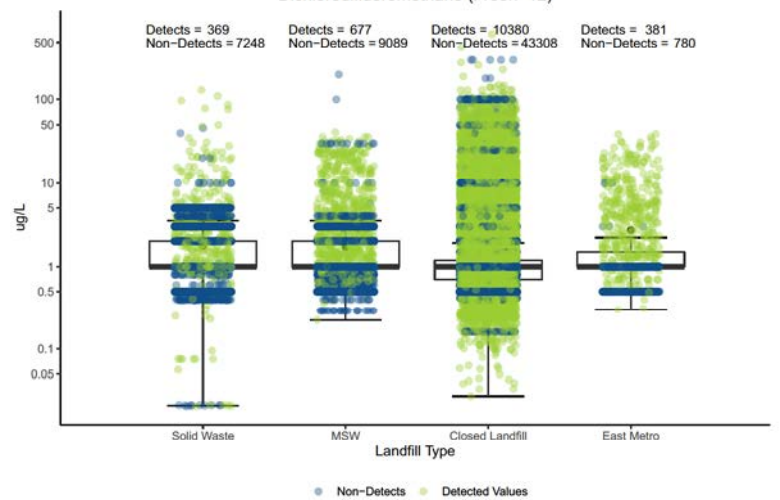
Cumene (isopropyl benzene)



Chloroethane

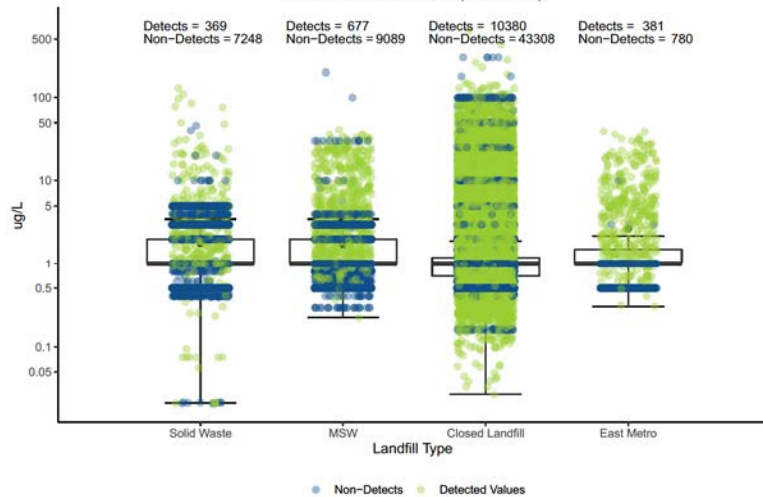


Dichlorodifluoromethane (Freon-12)

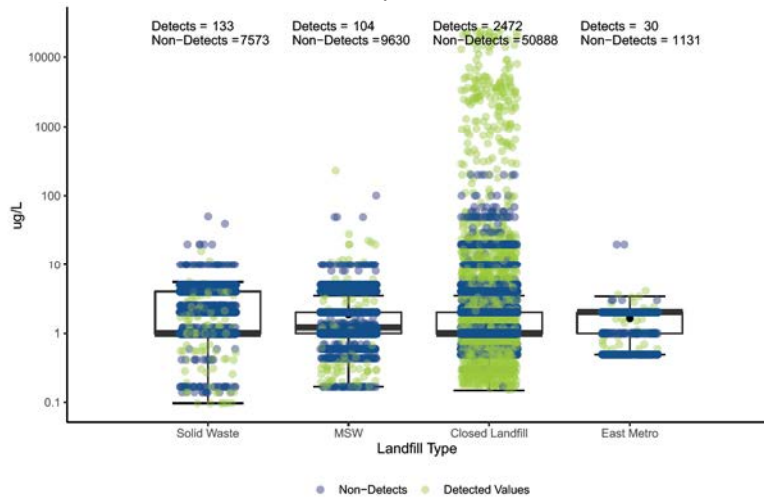




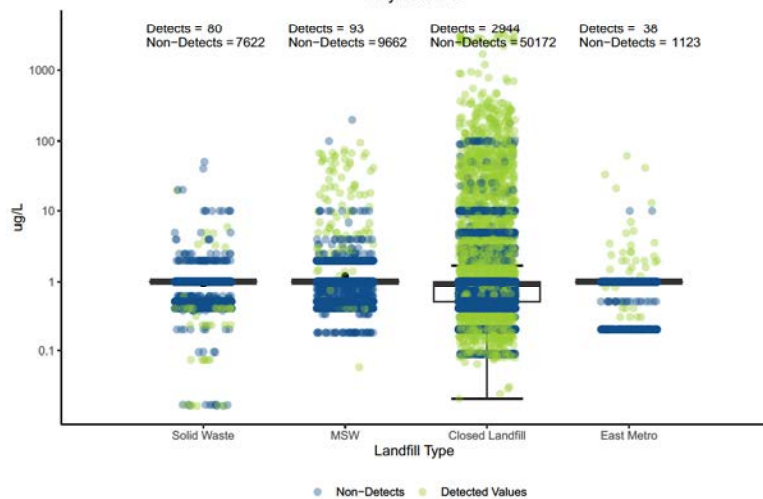
Dichlorofluoromethane (Freon-21)



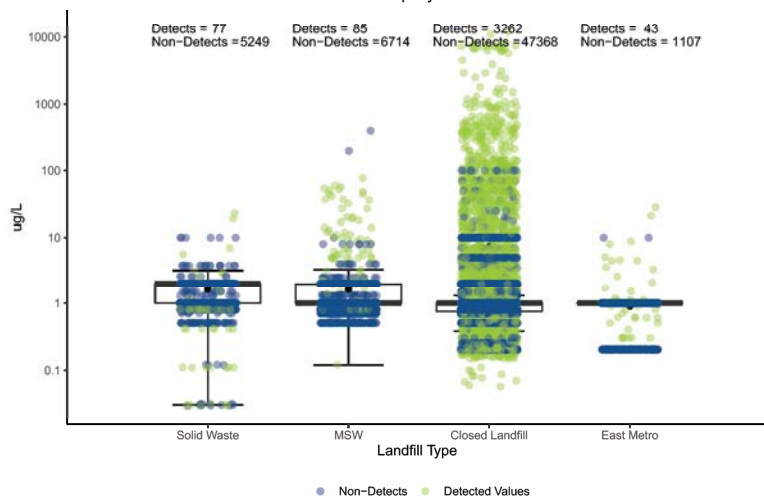
Methylene chloride



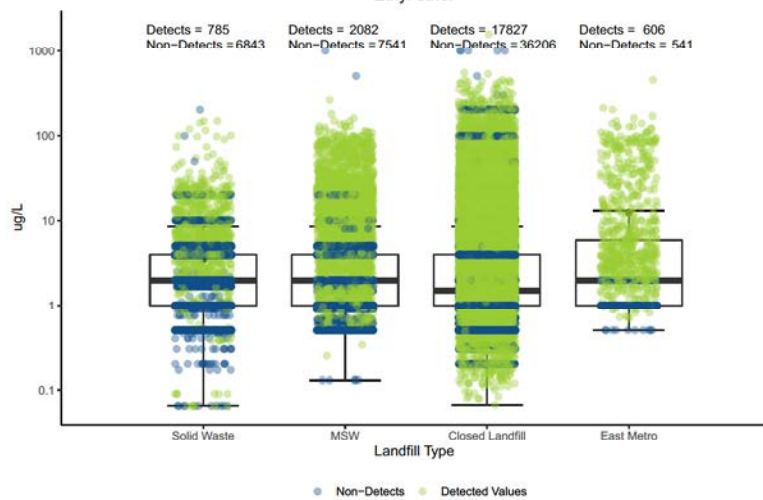
Ethylbenzene



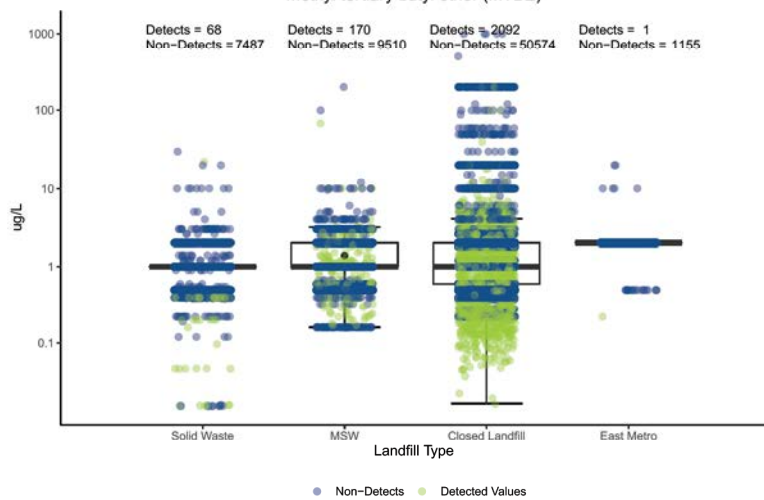
m & p Xylene

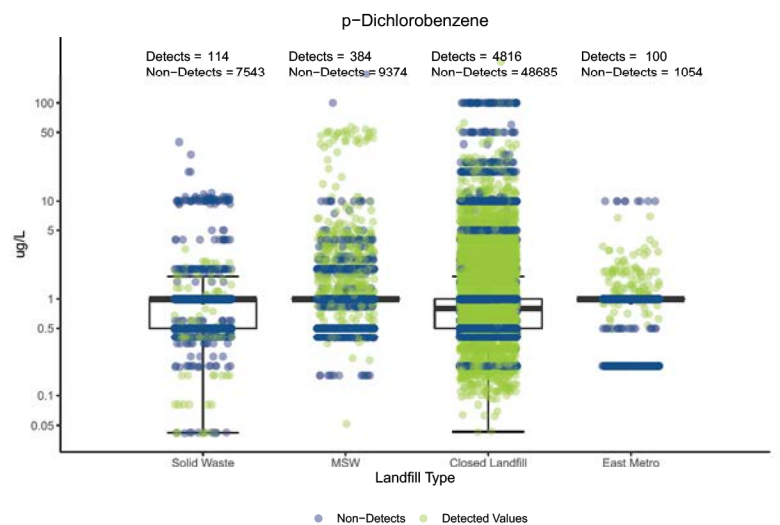
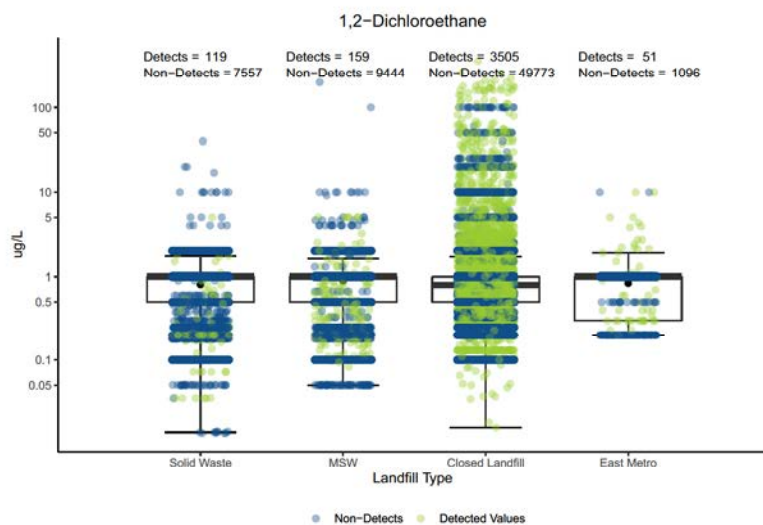
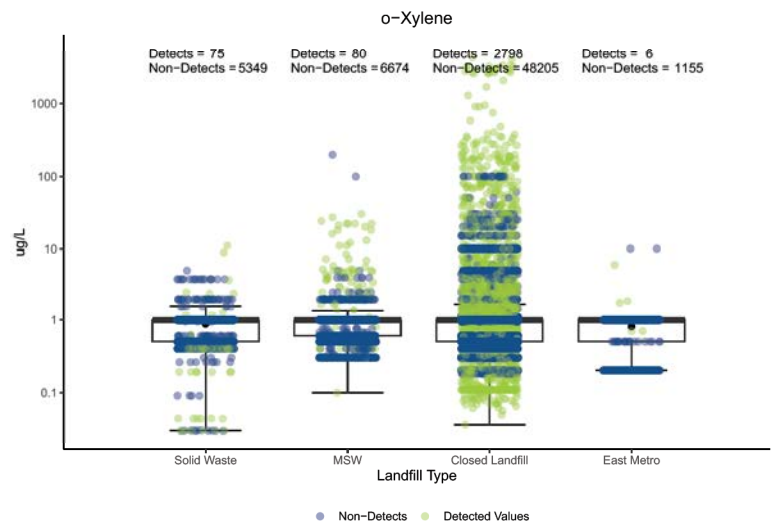
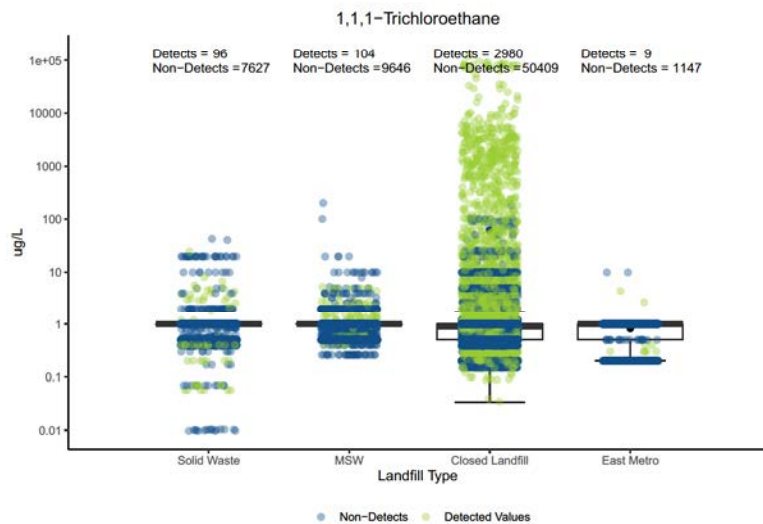
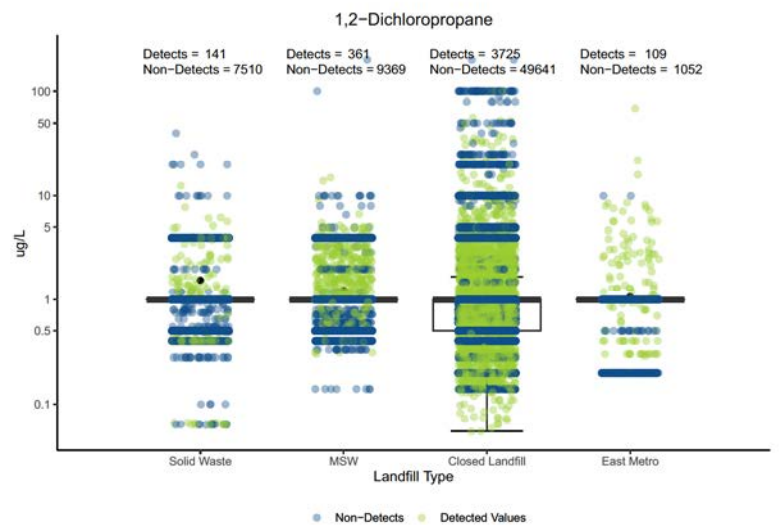
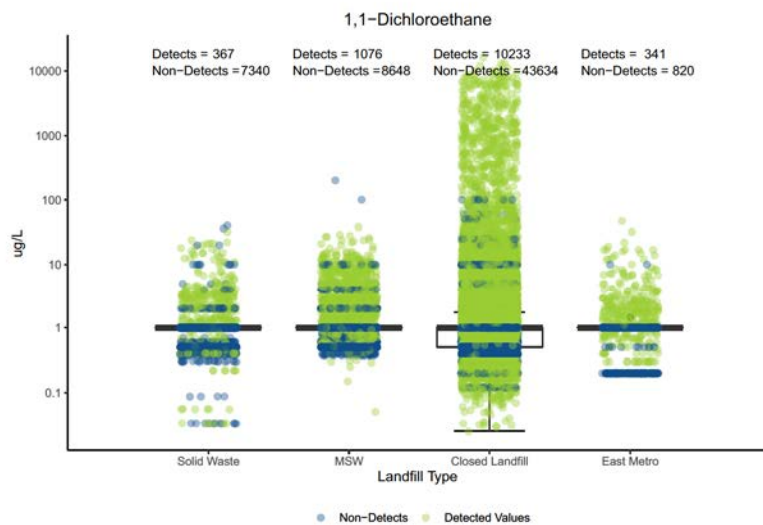


Ethyl ether

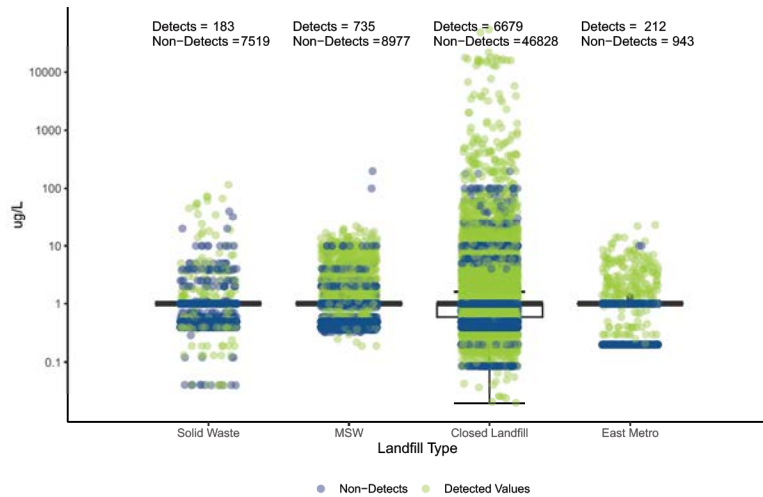


Methyl tertiary butyl ether (MTBE)

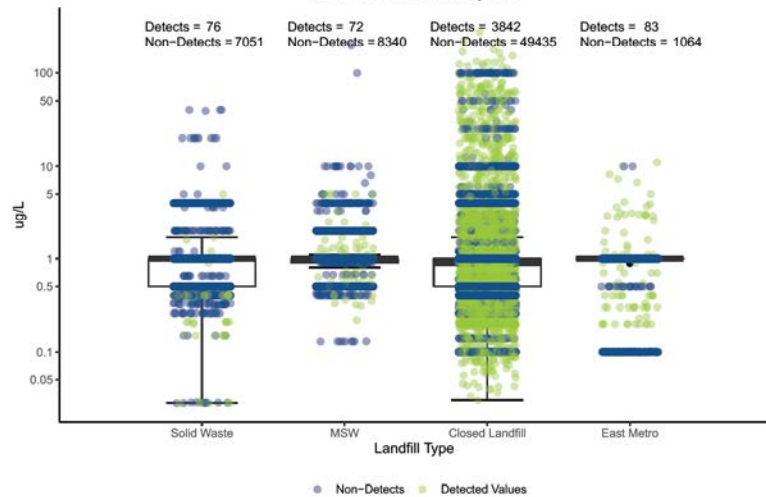




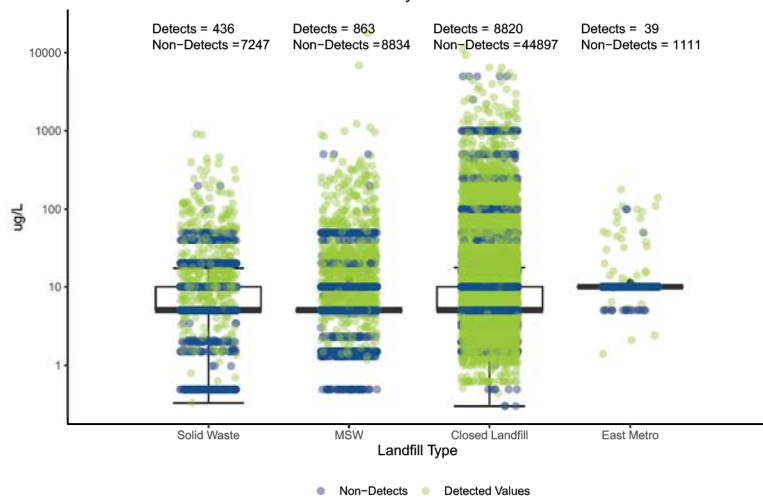
Tetrachloroethylene



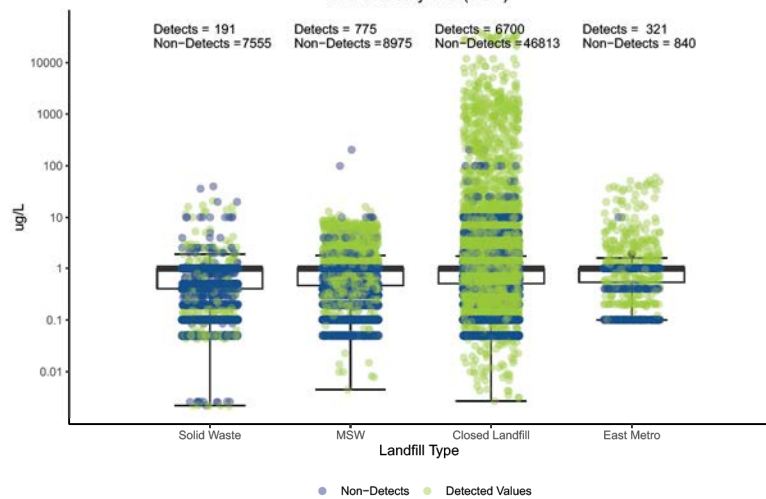
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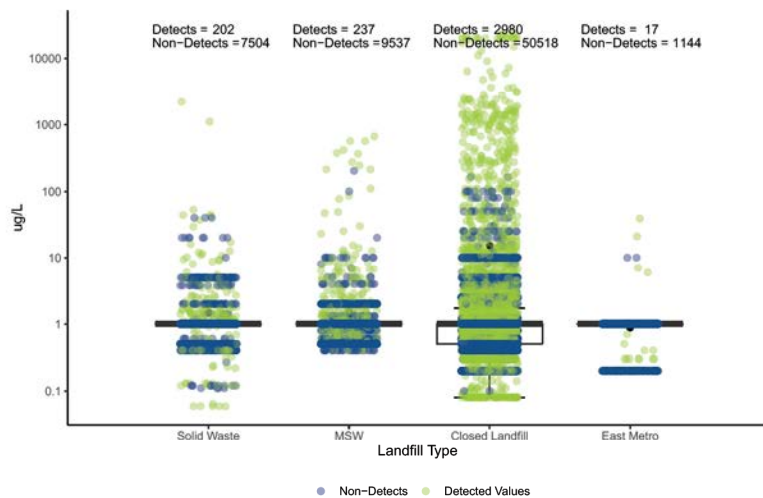
Tetrahydrofuran



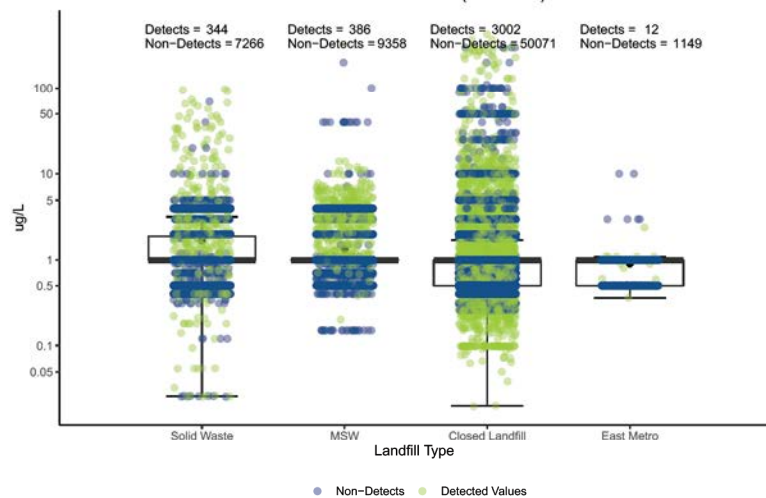
Trichloroethylene (TCE)



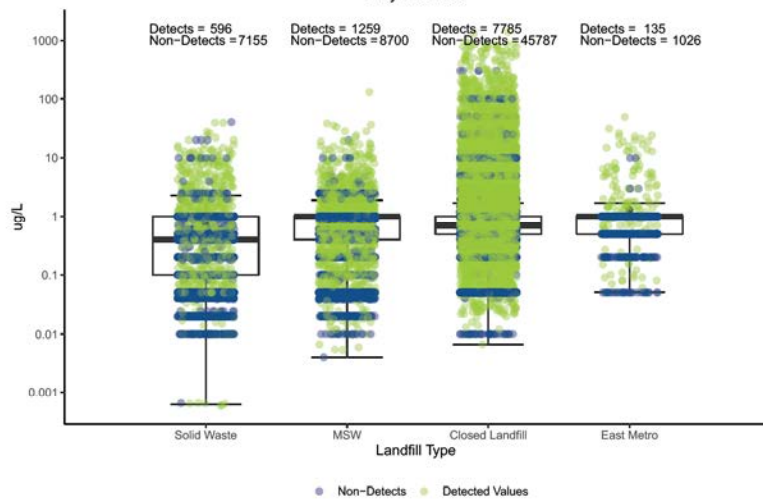
Toluene



Trichlorofluoromethane (Freon-11)



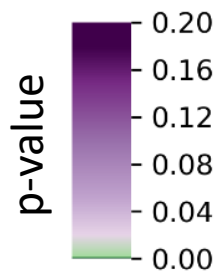
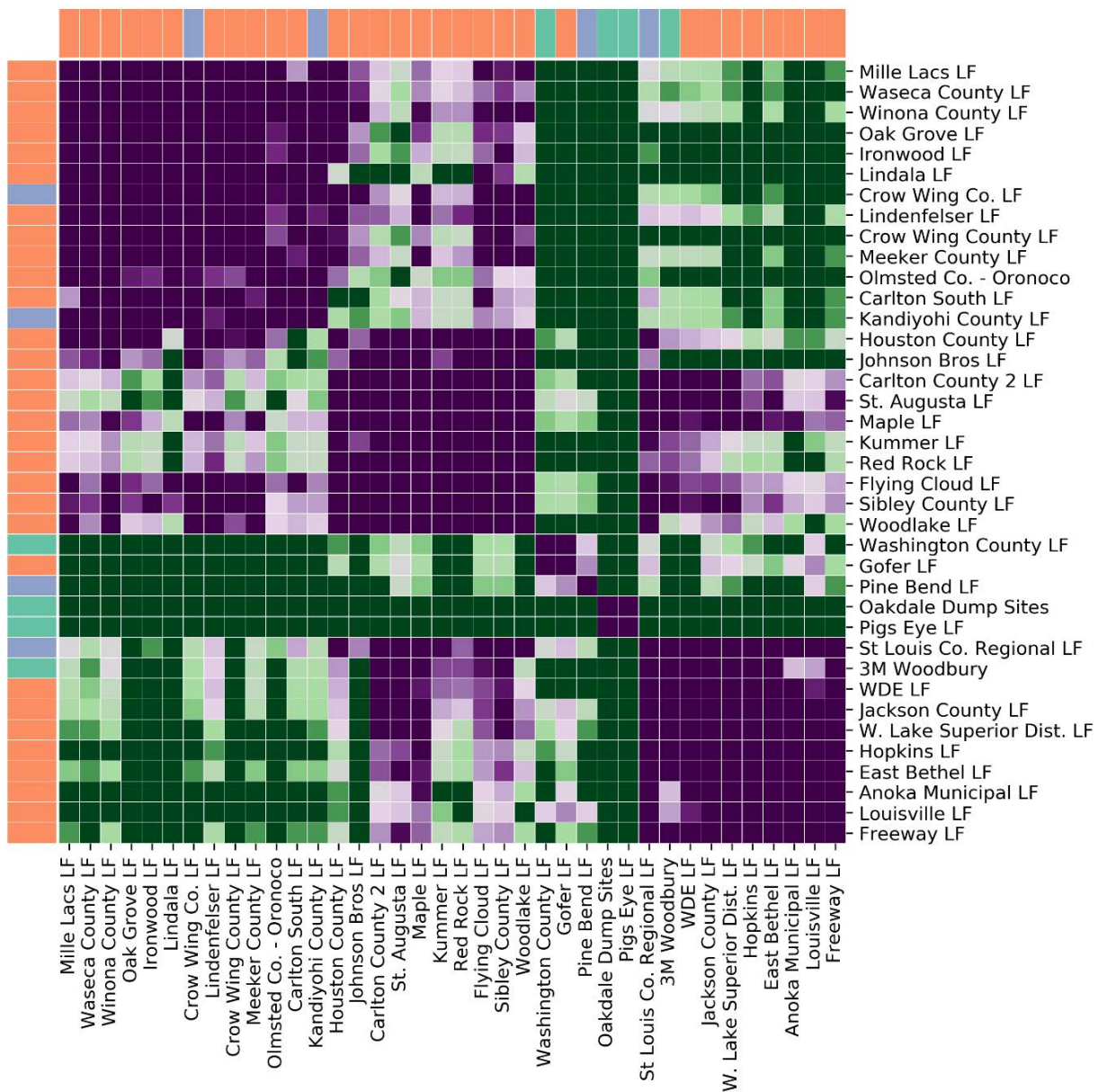
# Vinyl chloride





## **Appendix C**

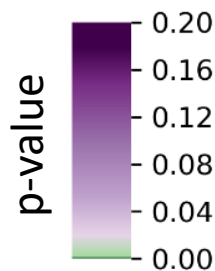
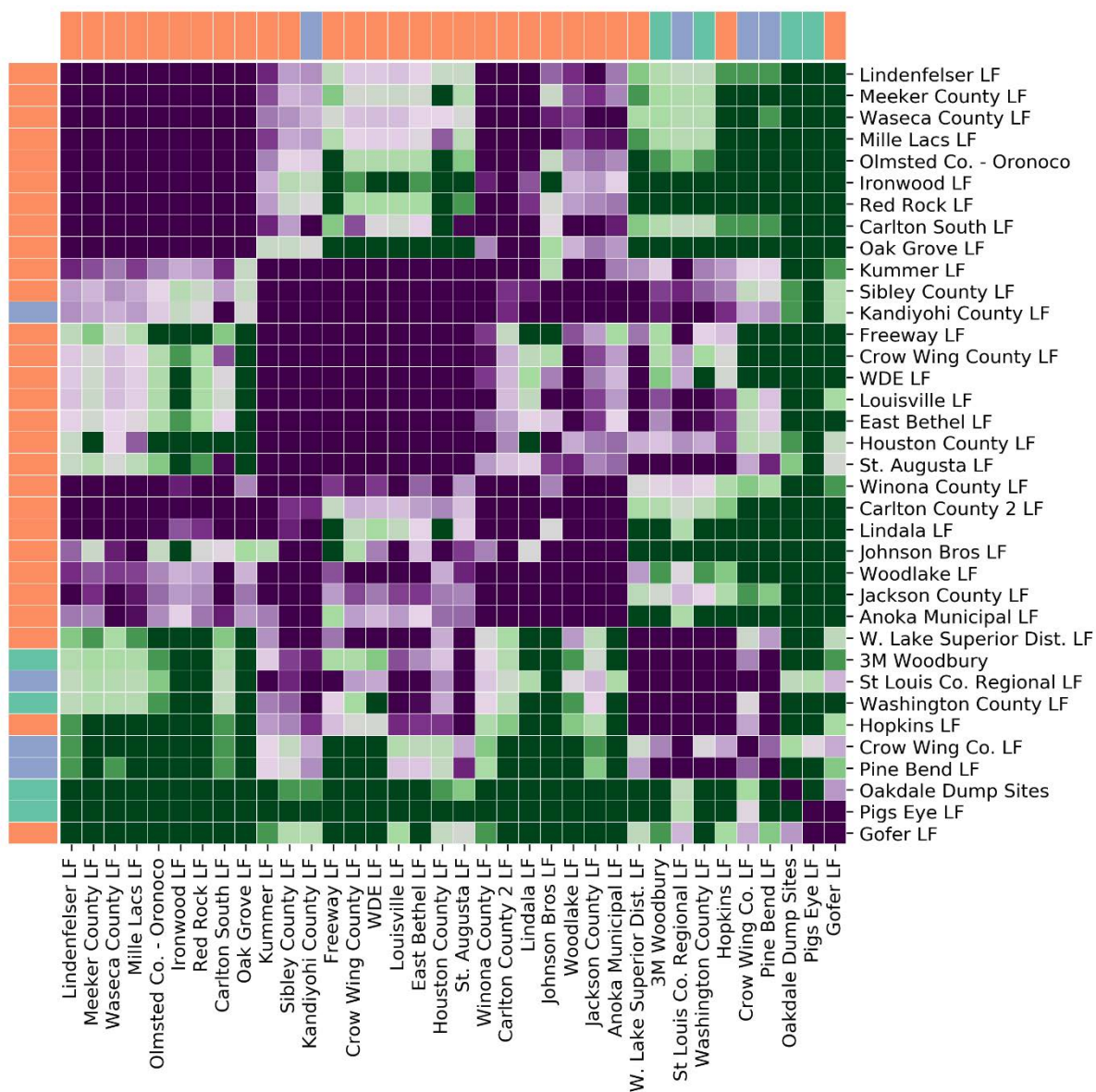
### **Wilcoxon Test Results**



p-values < 0.01 (green) are statistically significant

Wilcoxon Test p-values  
PFOA

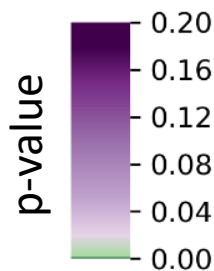
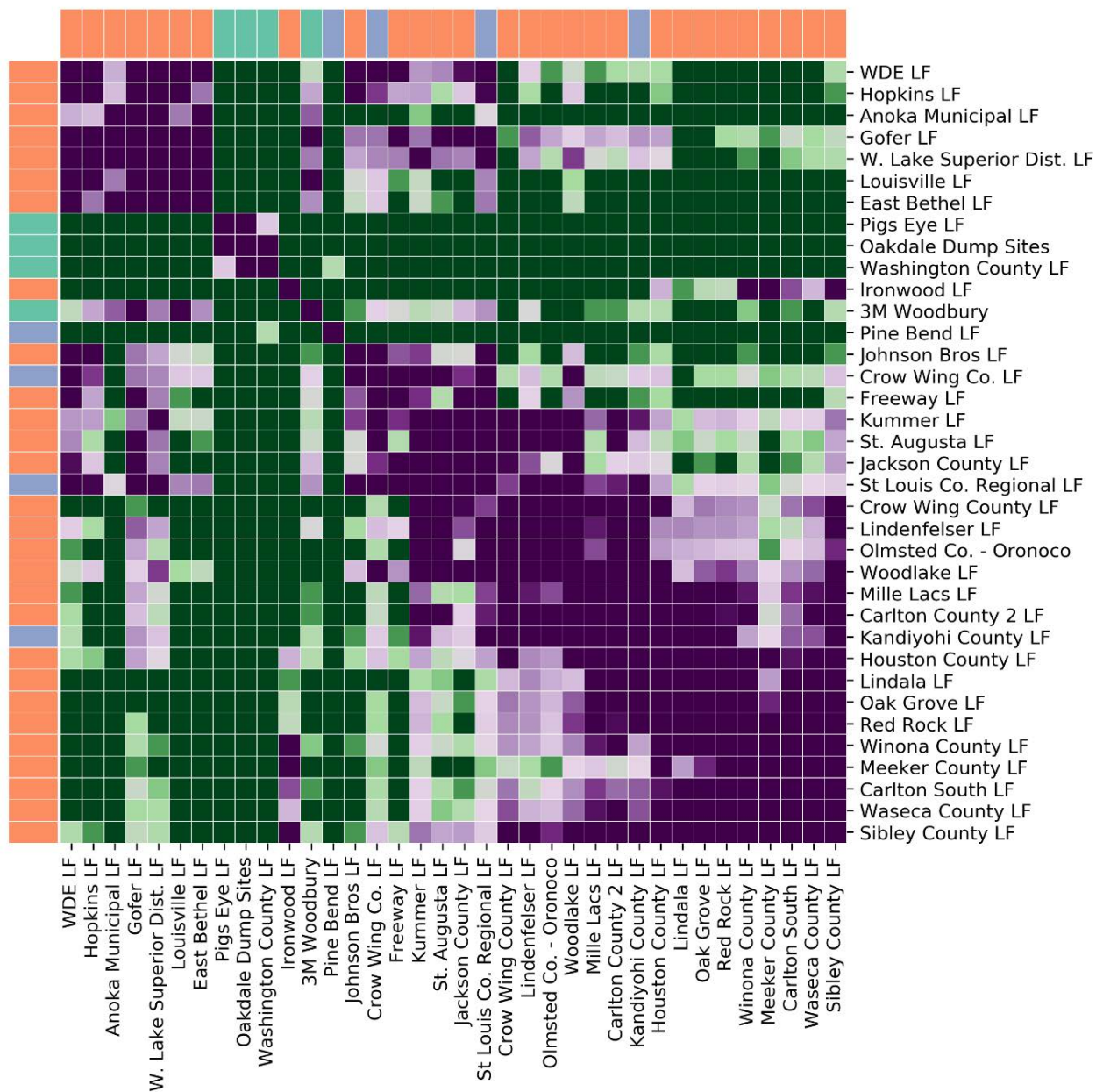
FIGURE C1



p-values < 0.01 (green) are statistically significant

Wilcoxon Test p-values  
PFOS

FIGURE C2

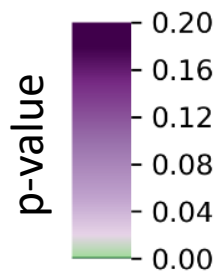


p-values < 0.01 (green) are statistically significant

Wilcoxon Test p-values  
PFBA

FIGURE C3

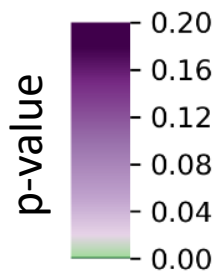
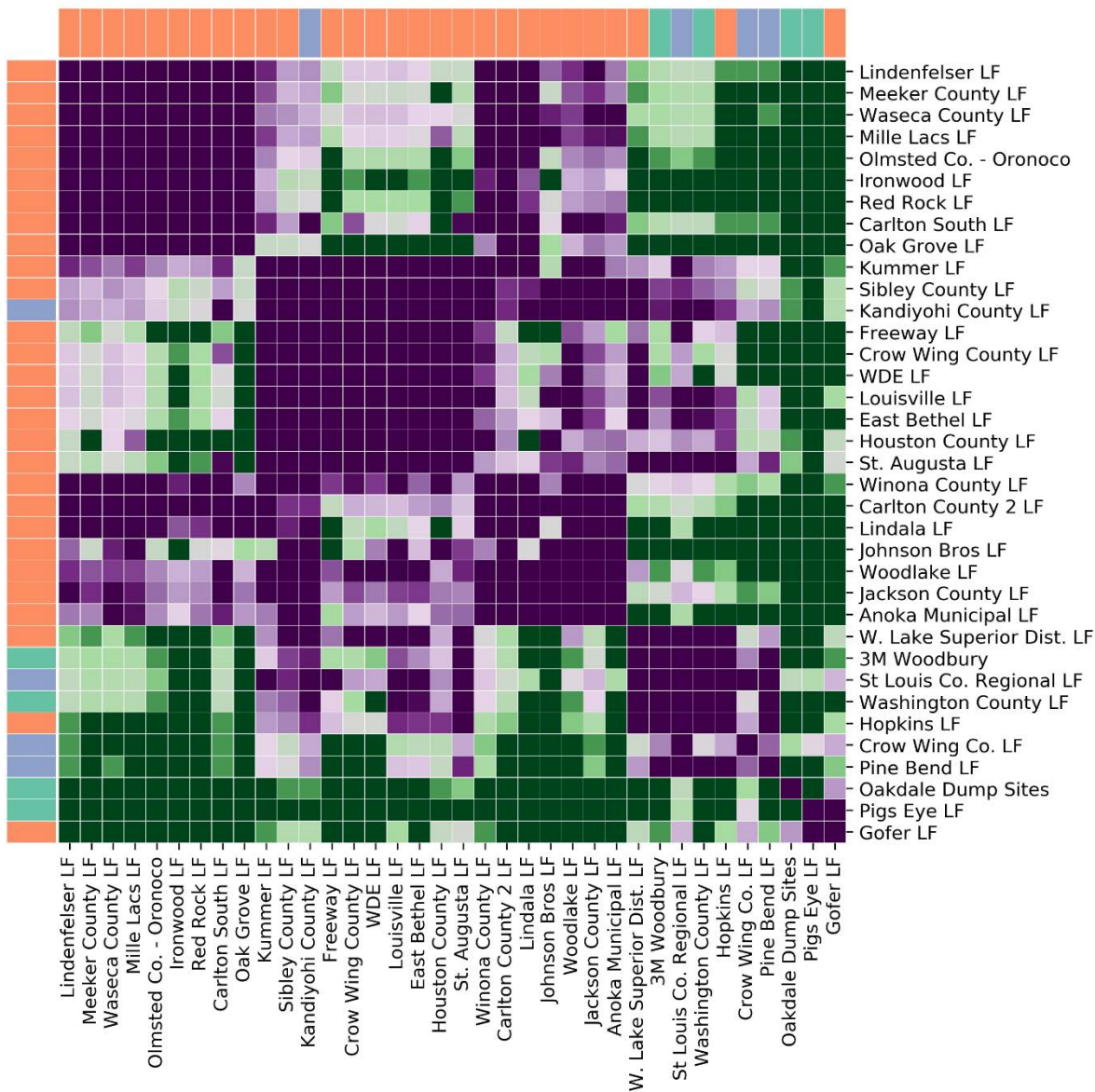




p-values < 0.01 (green) are statistically significant

Wilcoxon Test p-values  
PFHsX

FIGURE C4

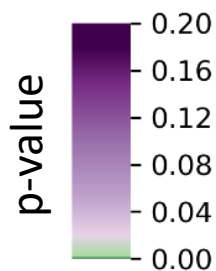
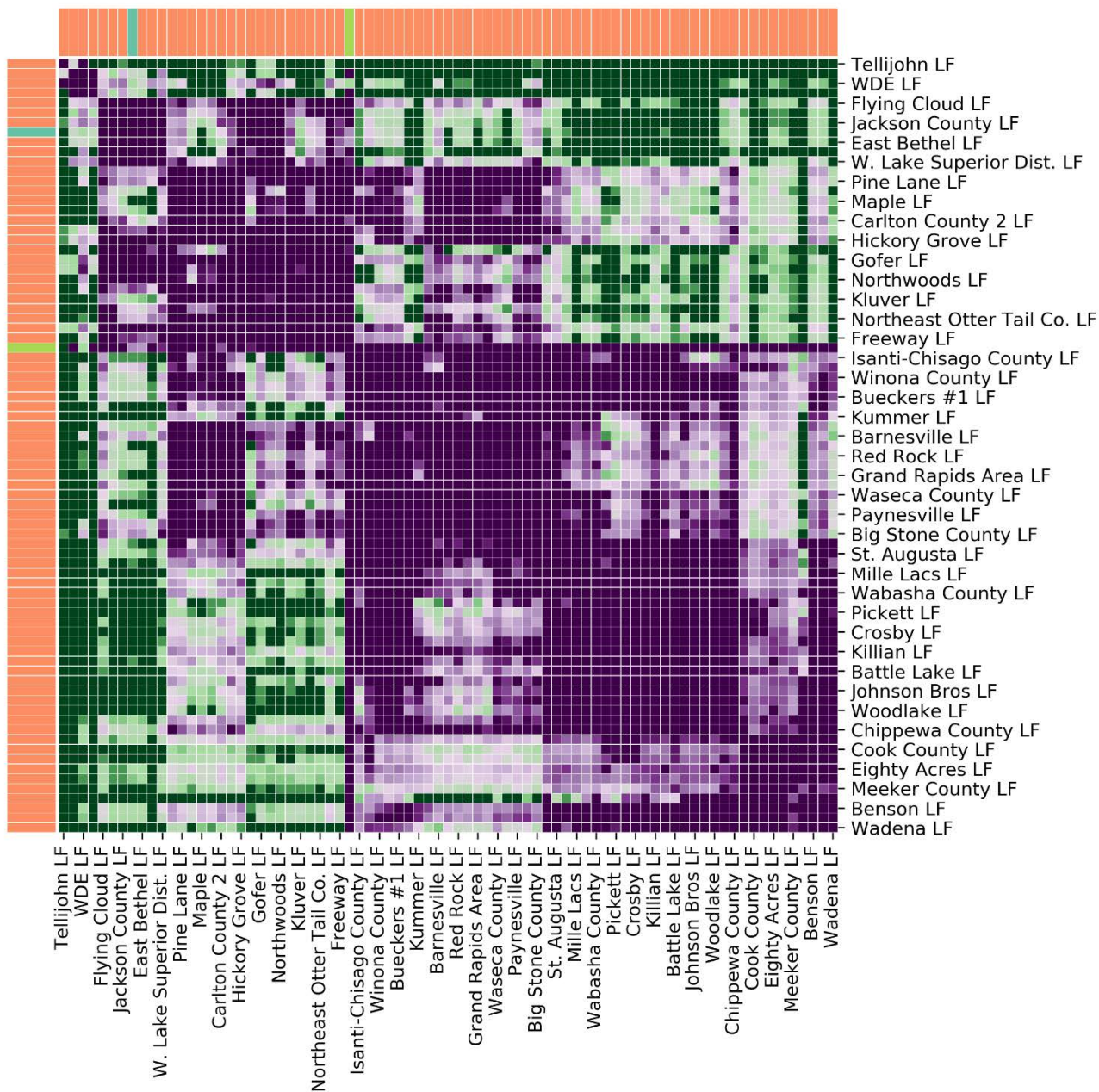


p-values < 0.01 (green) are statistically significant

Wilcoxon Test p-values  
PFBS

FIGURE C5





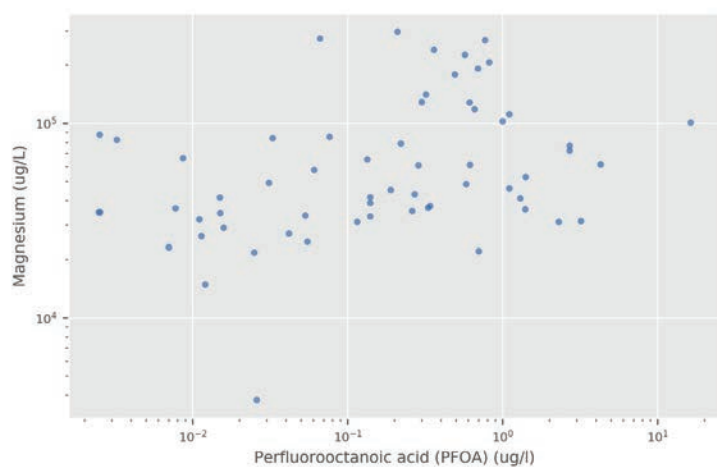
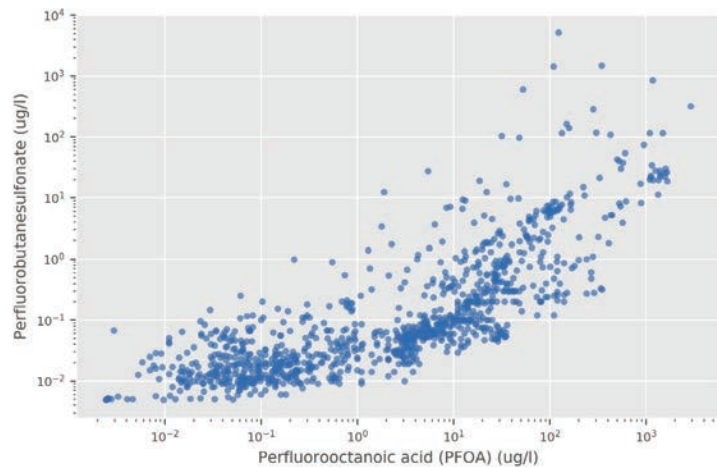
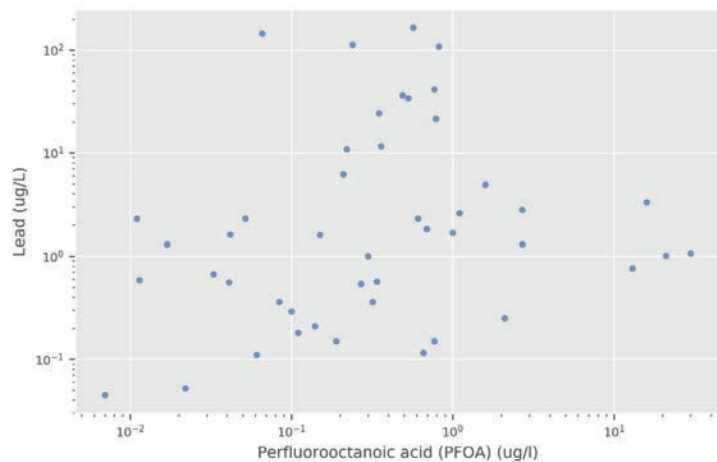
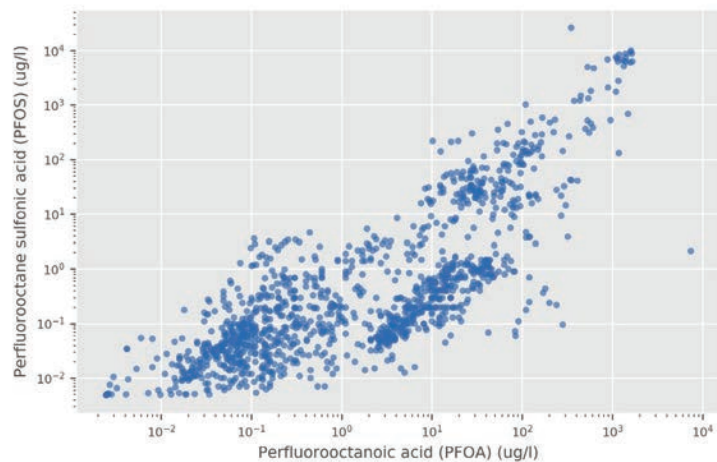
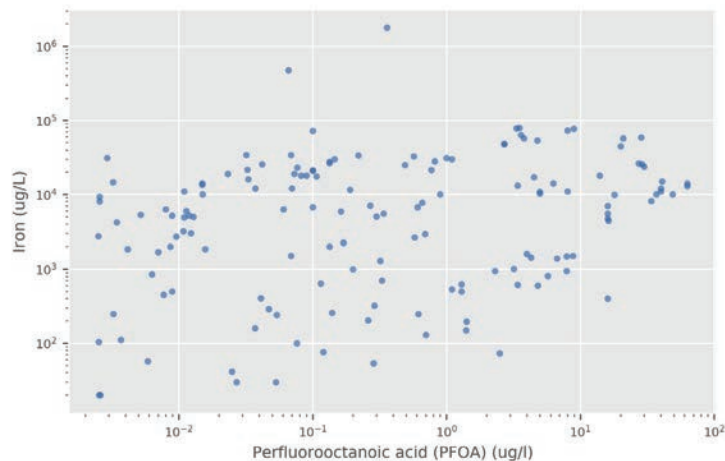
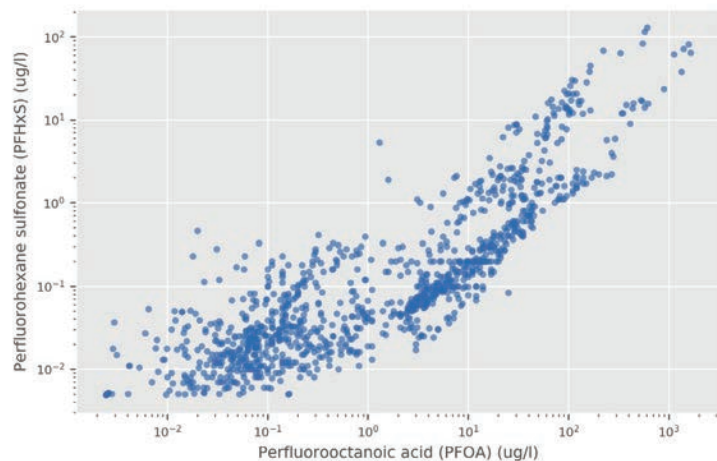
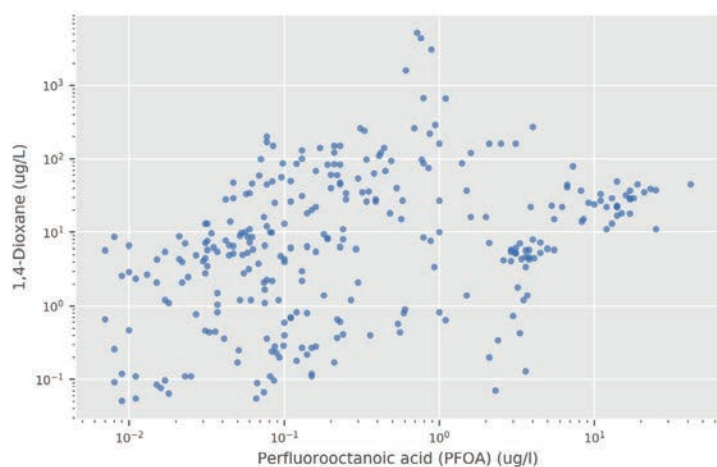
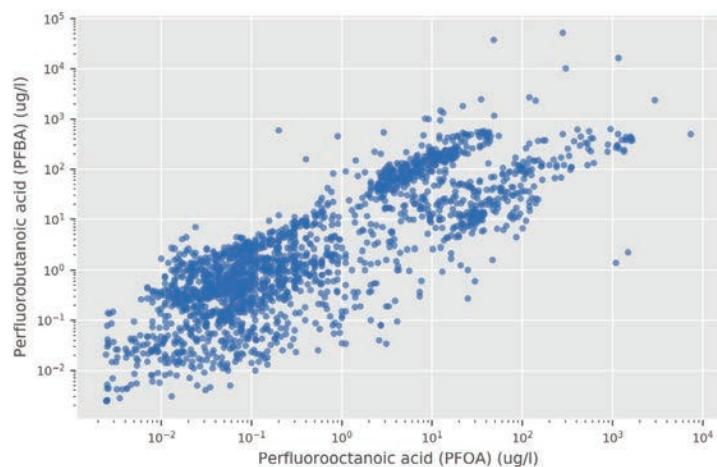
p-values < 0.01 (green) are statistically significant

Wilcoxon Test p-values  
1,4-Dioxane

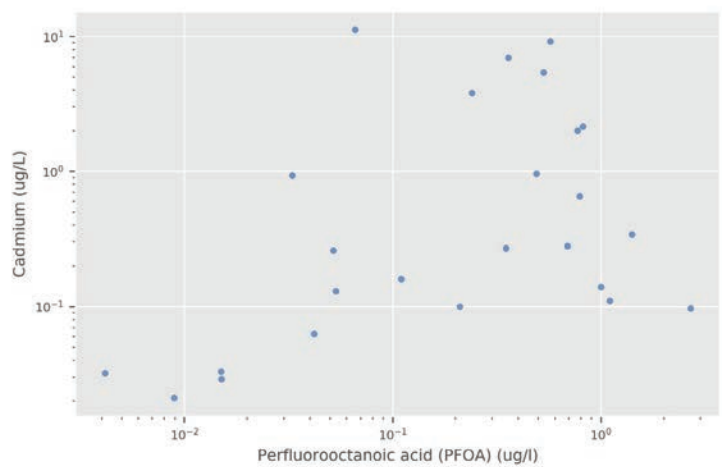
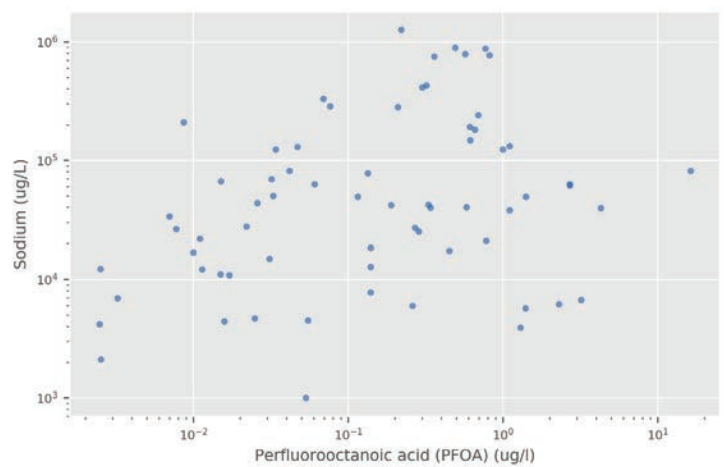
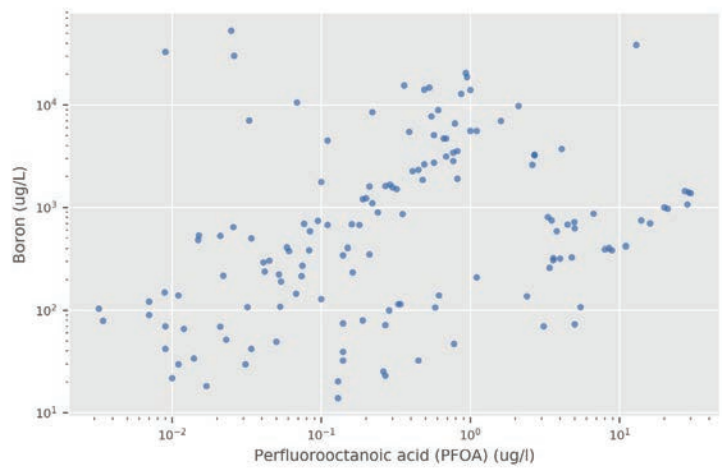
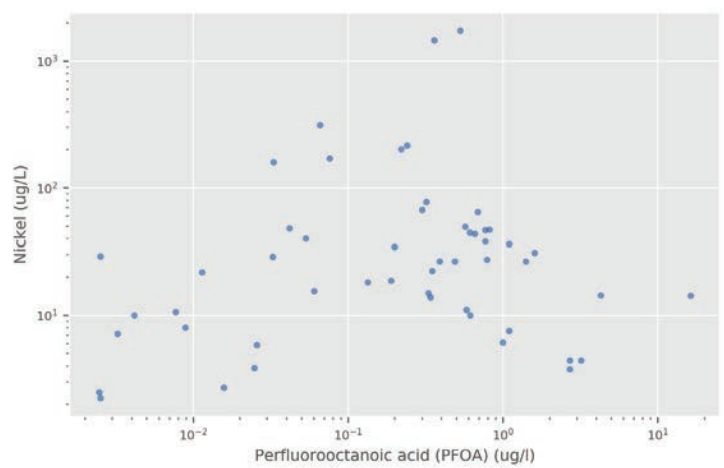
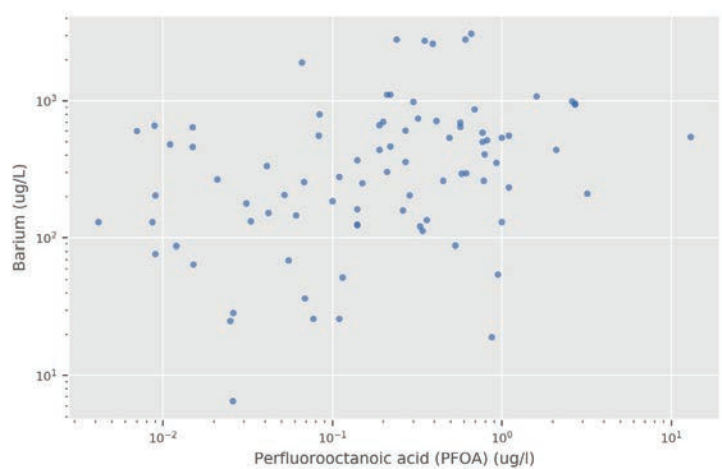
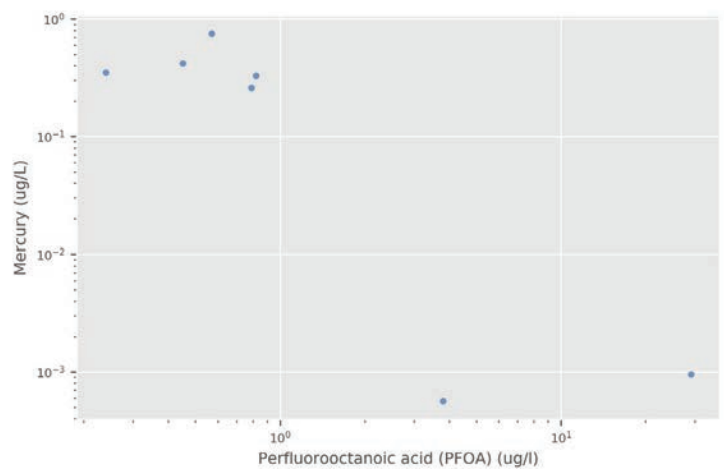
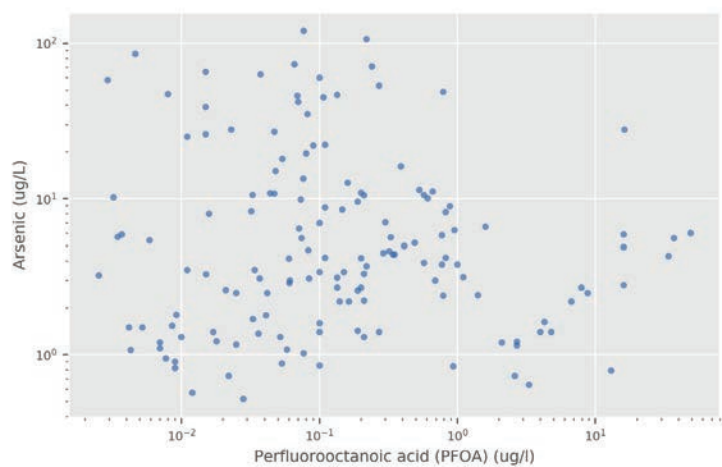
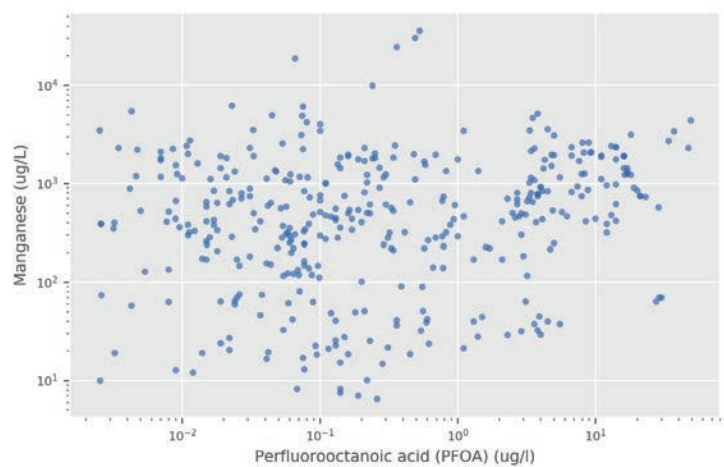
FIGURE C6

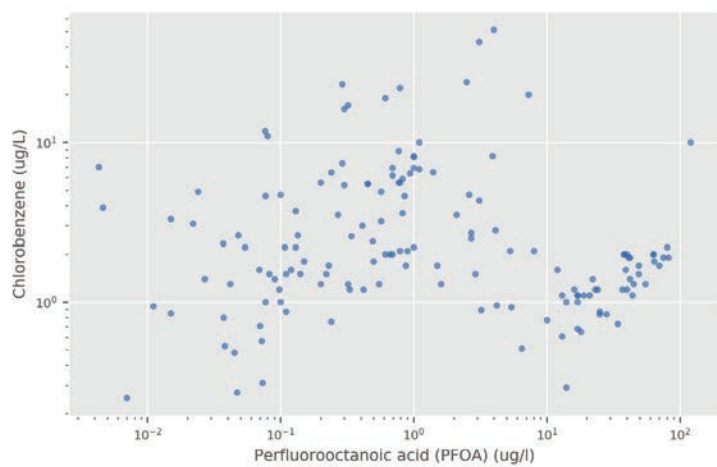
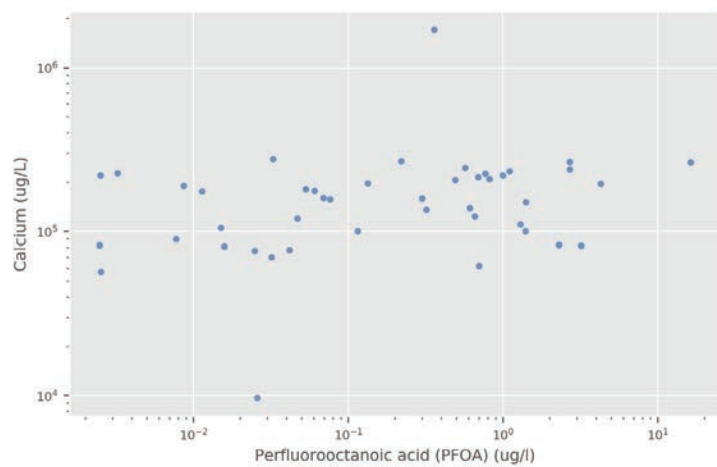
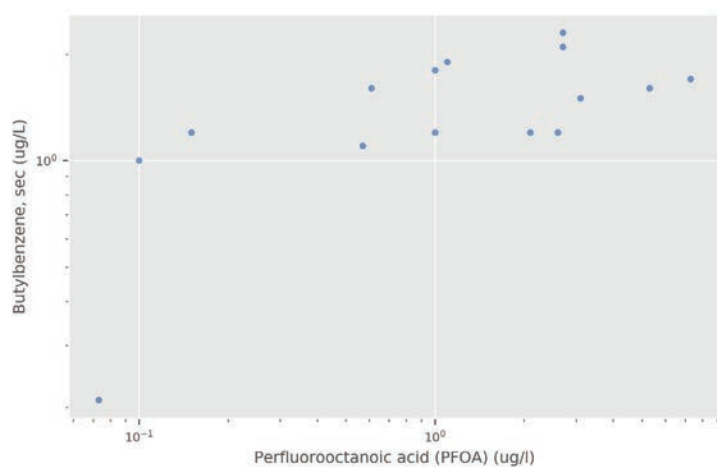
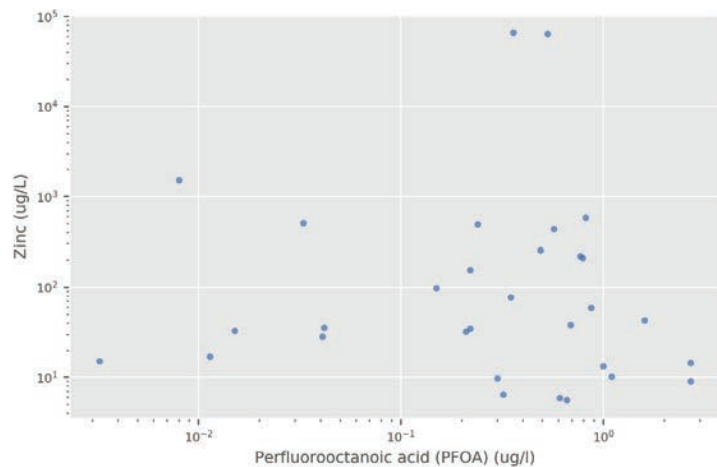
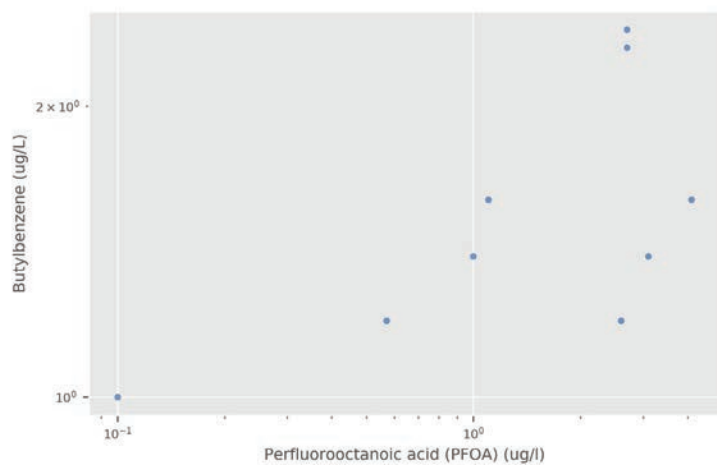
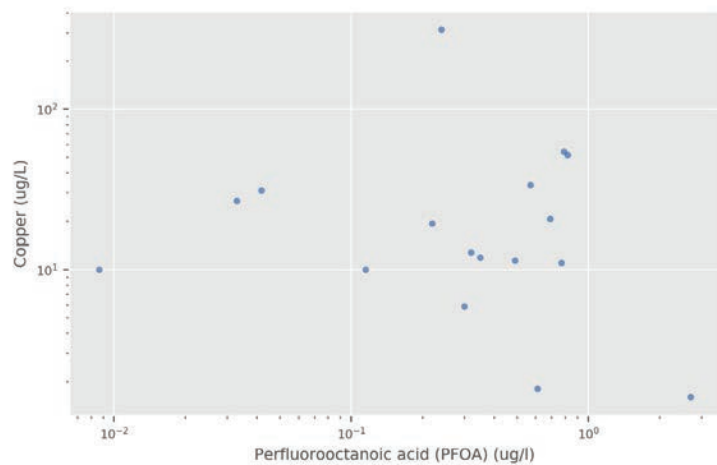
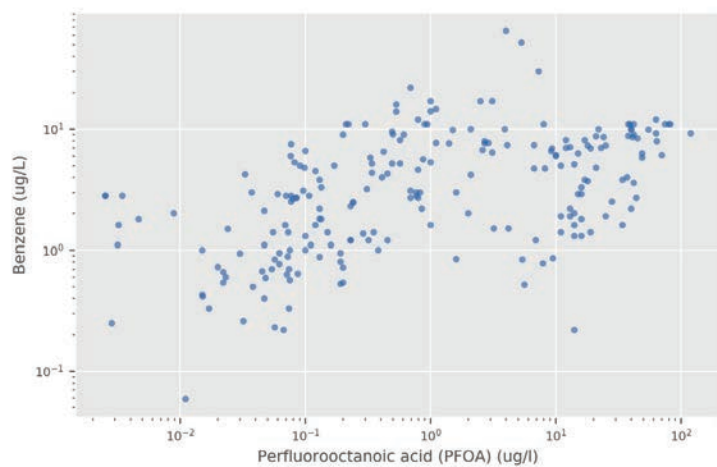
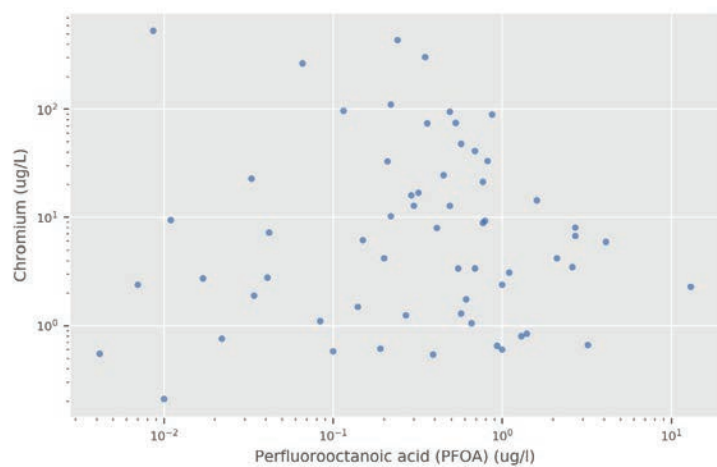
## **Appendix D**

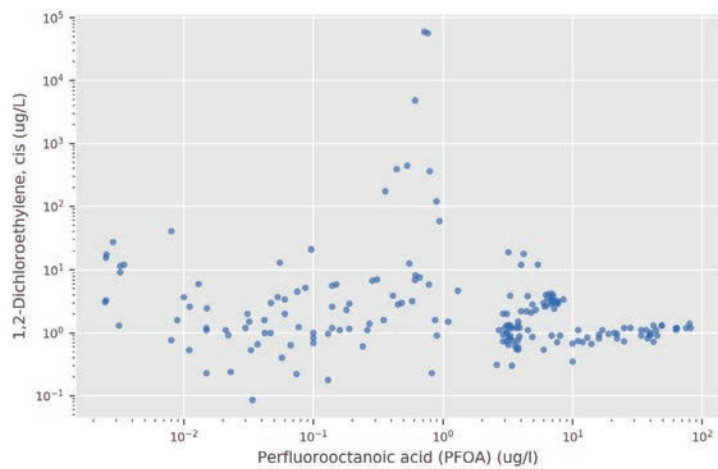
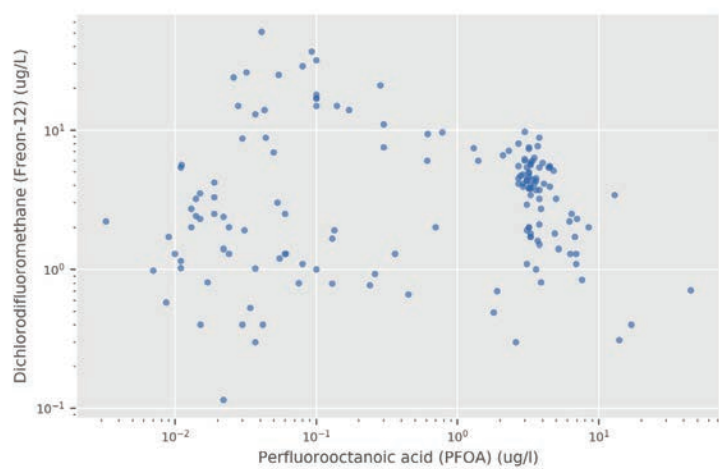
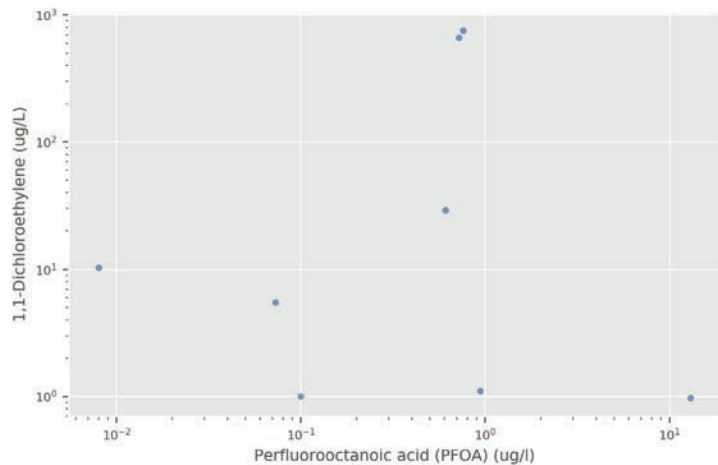
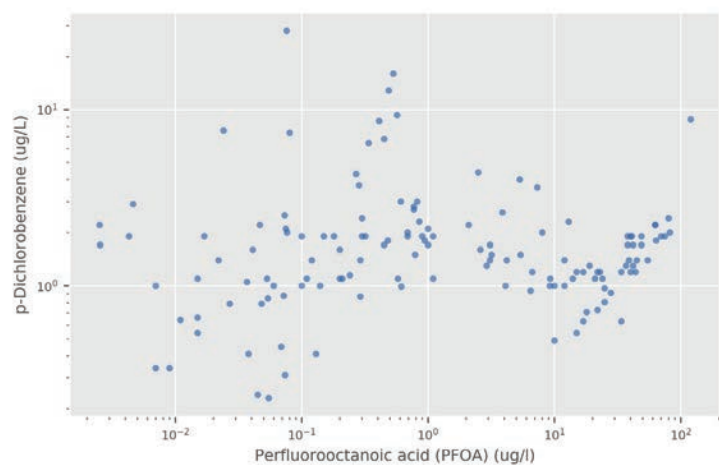
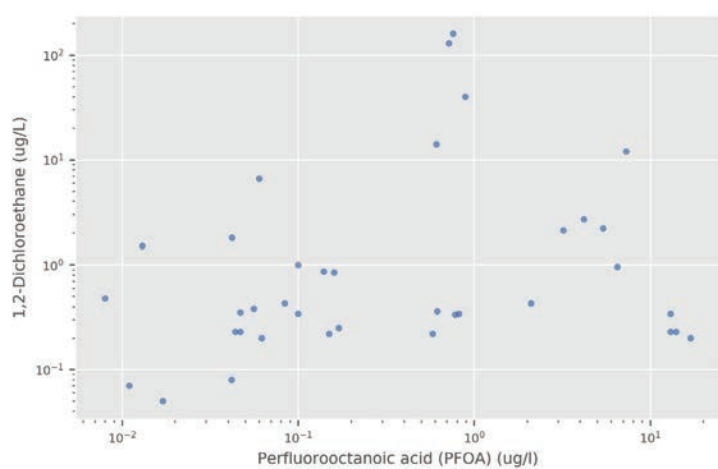
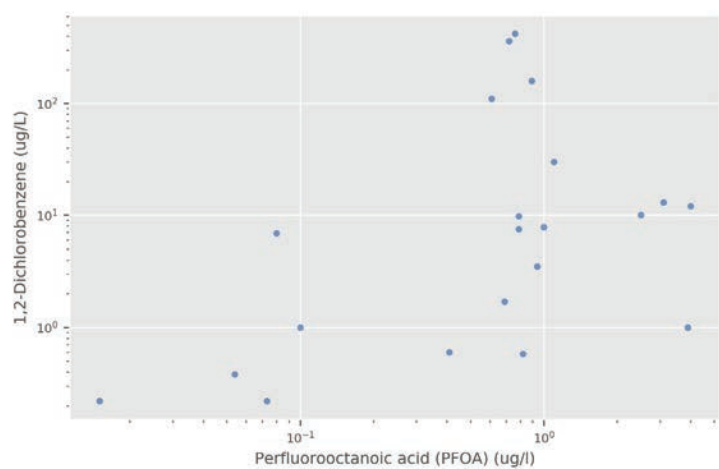
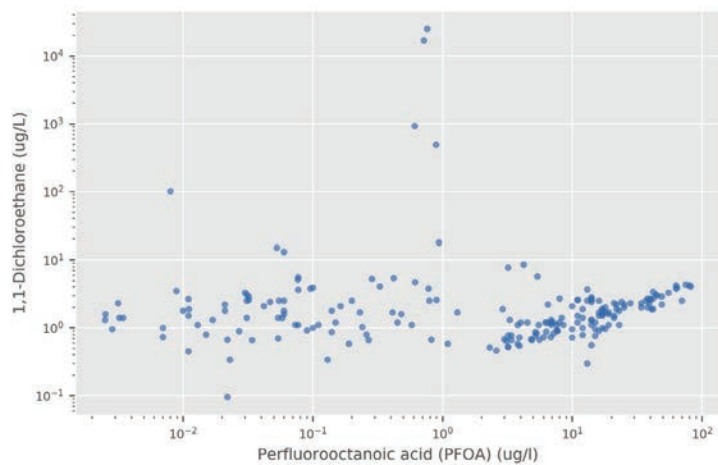
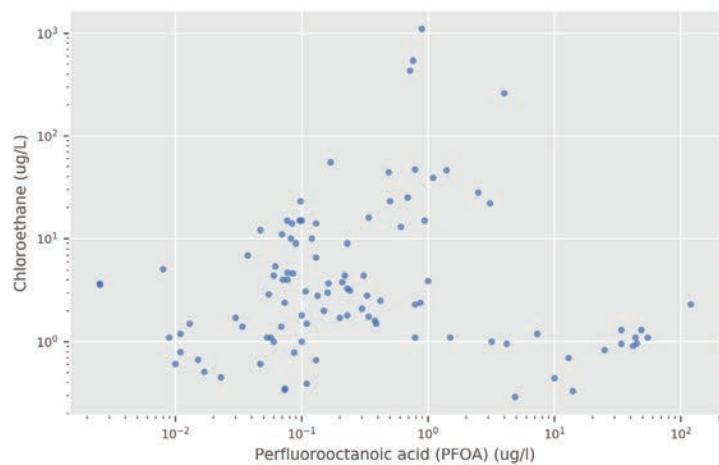
### **Scatter Plots Illustrating Relationships Between PFAS, 1-4-Dioxane, and Other Constituents**



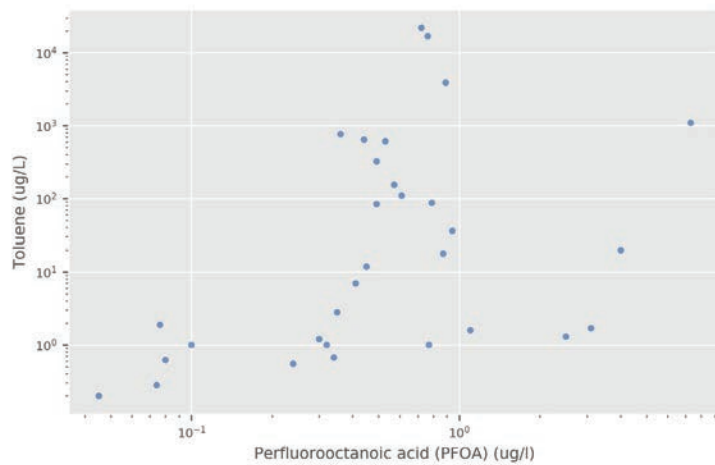
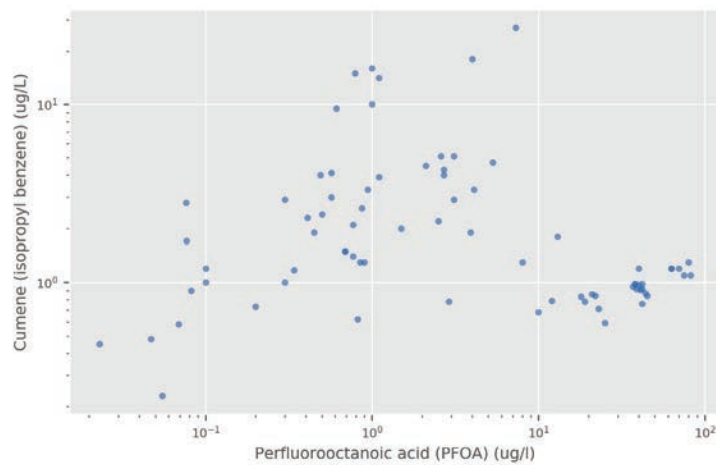
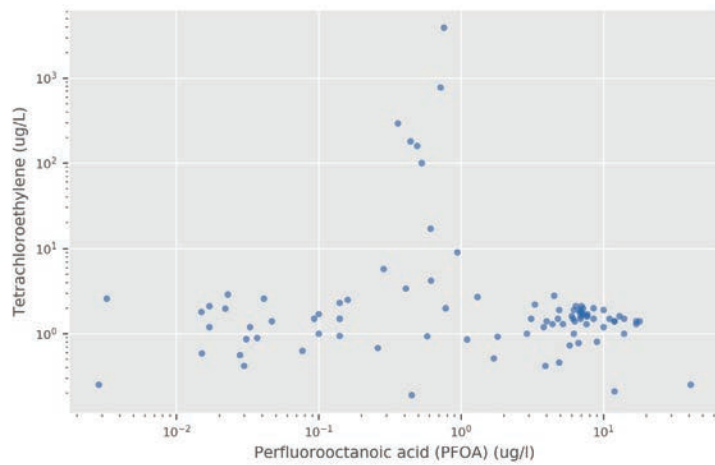
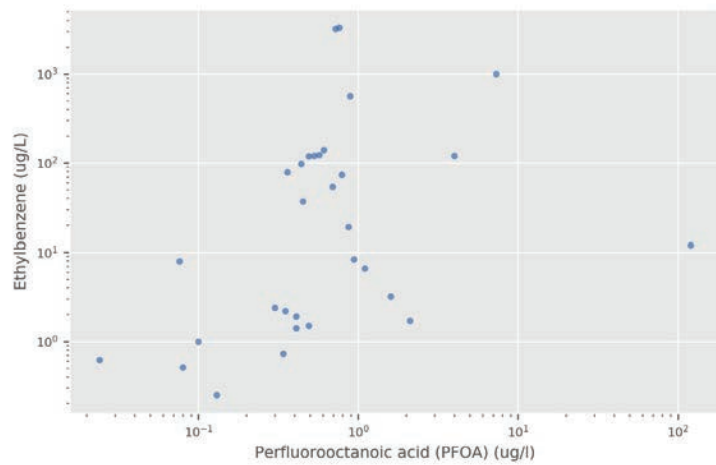
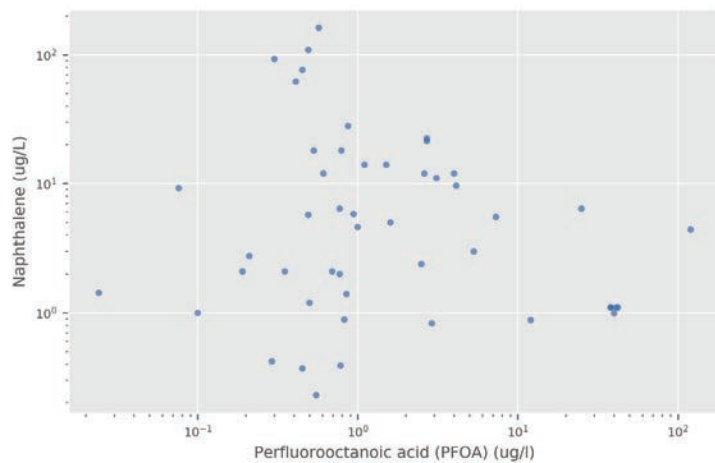
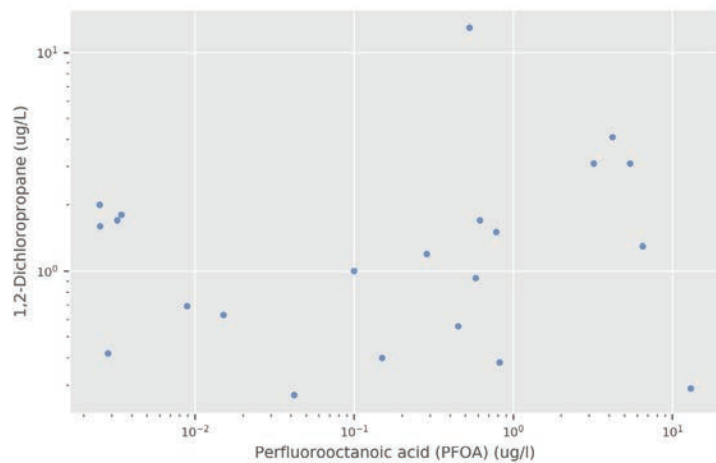
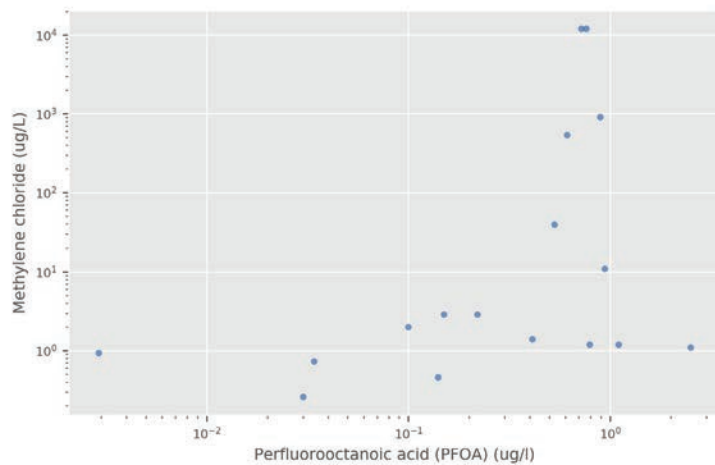
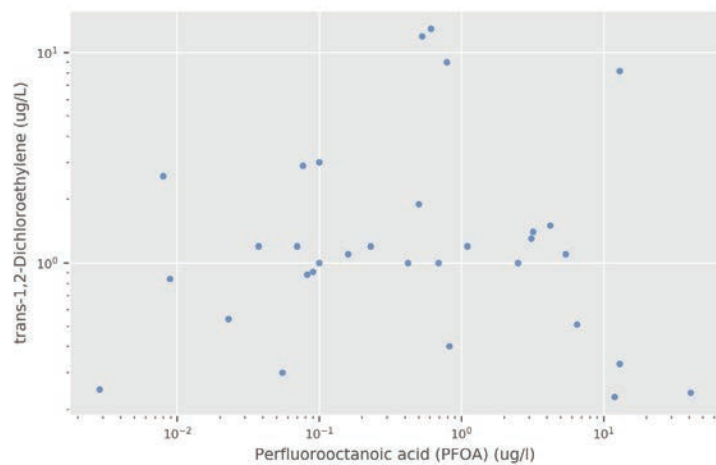


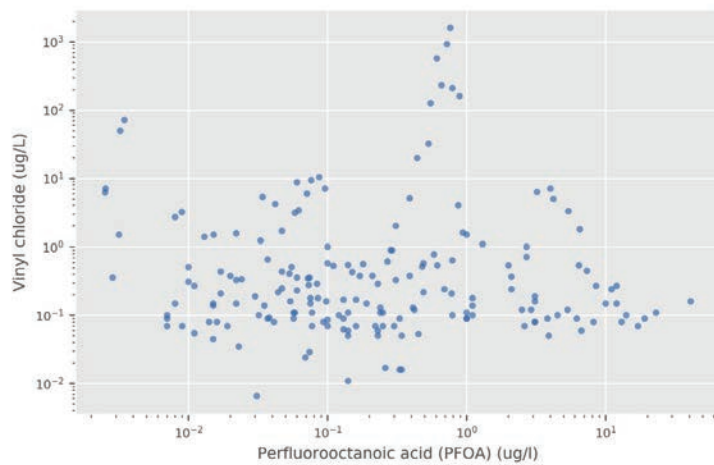
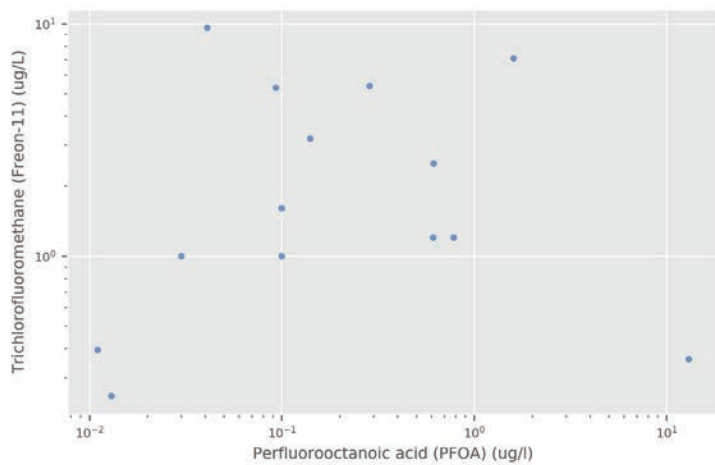
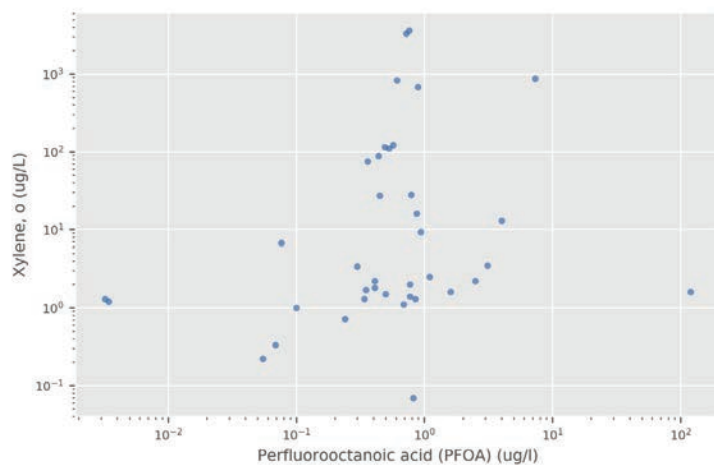
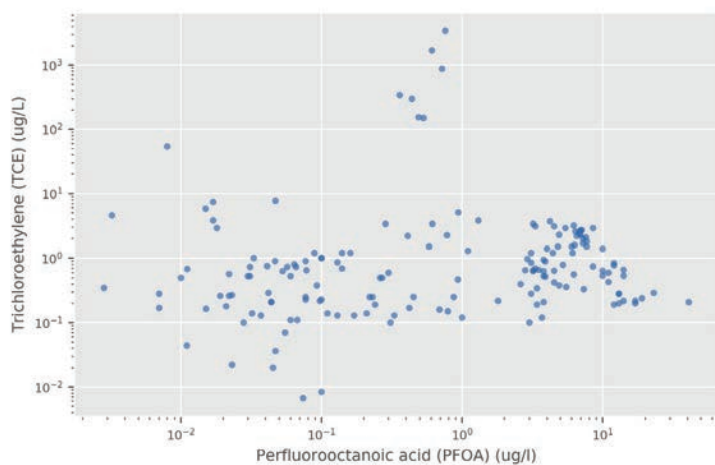
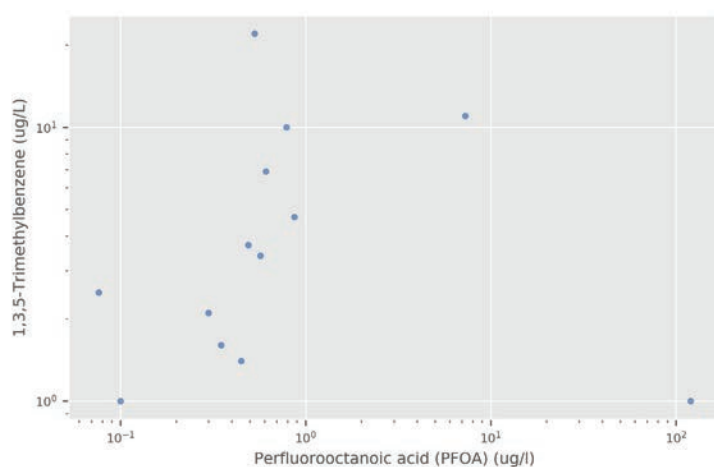
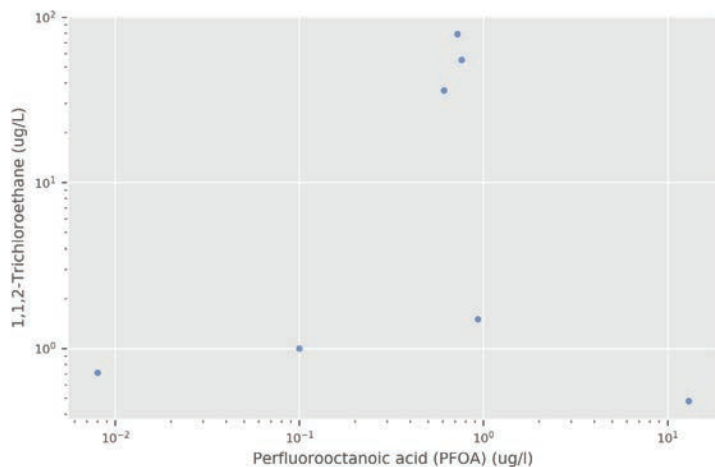
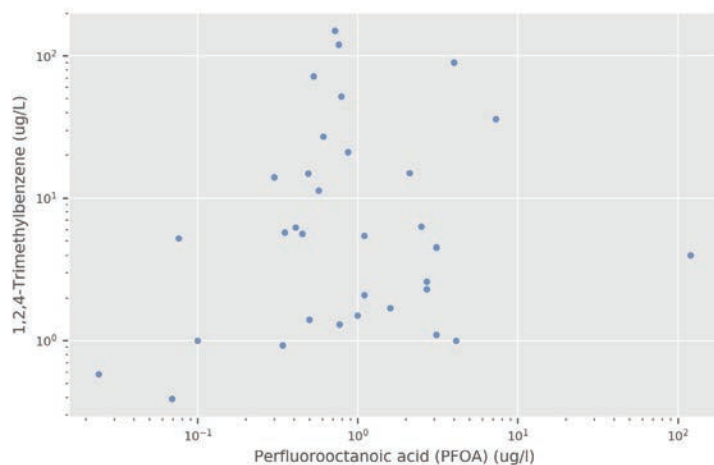
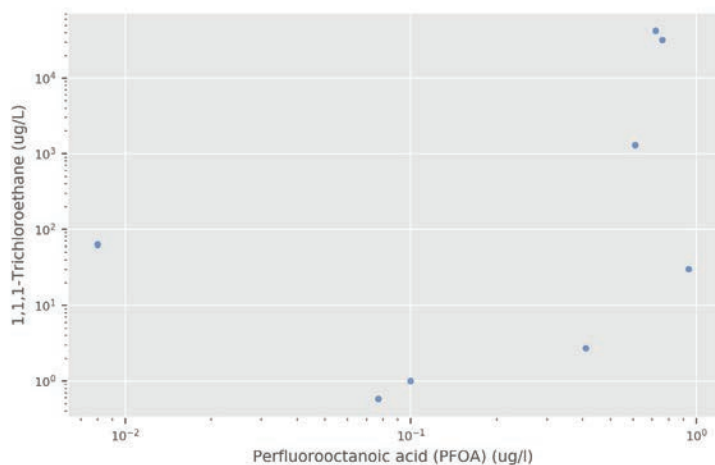


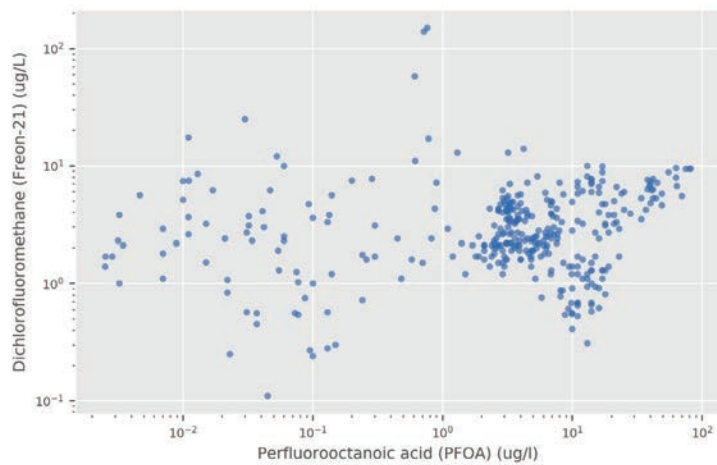
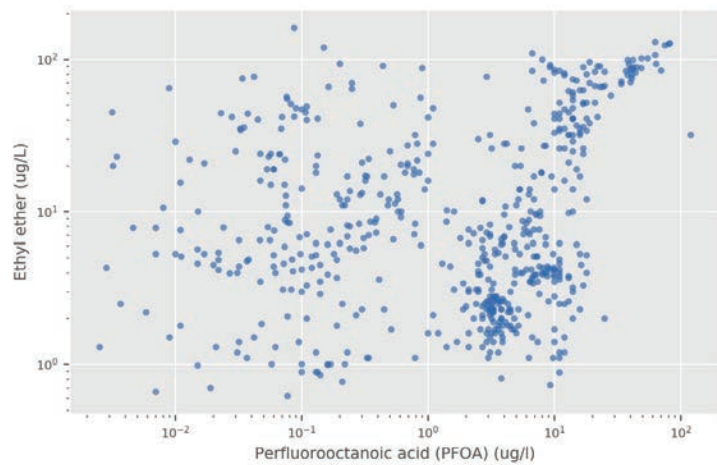
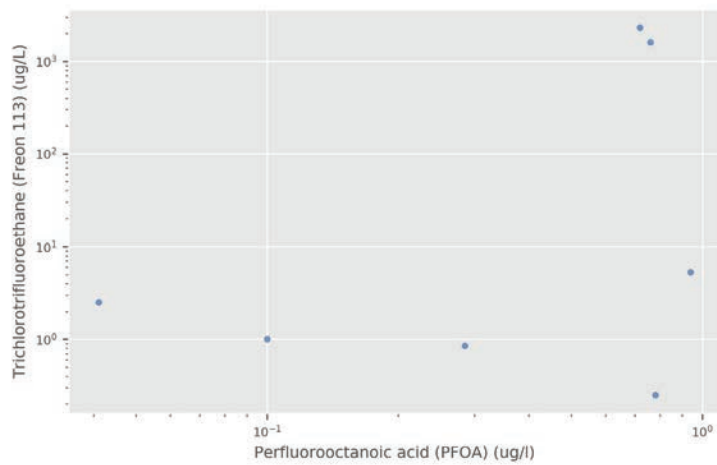
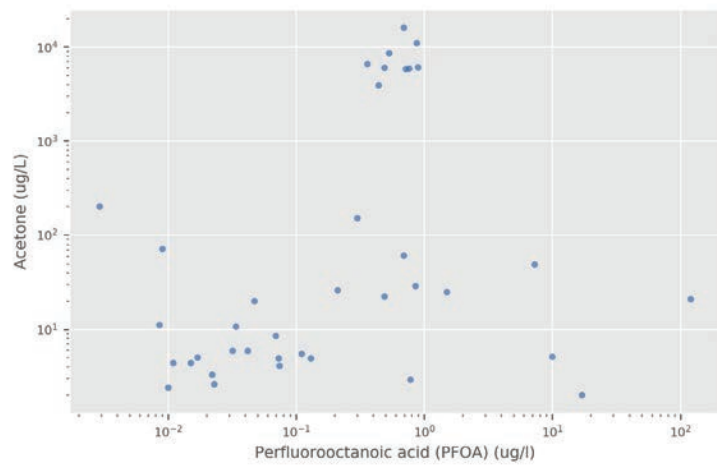
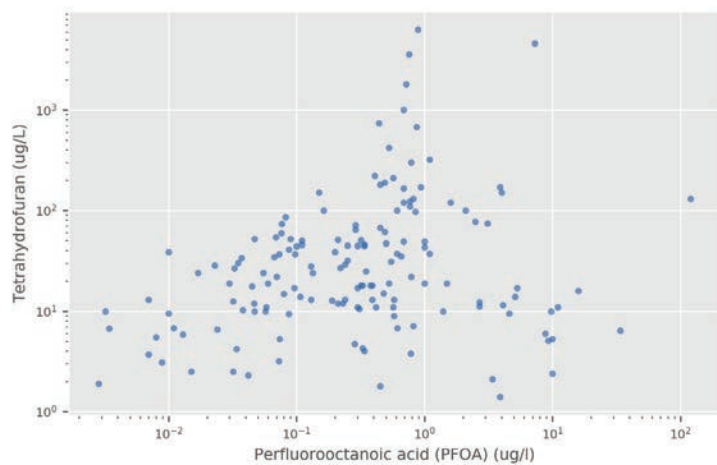
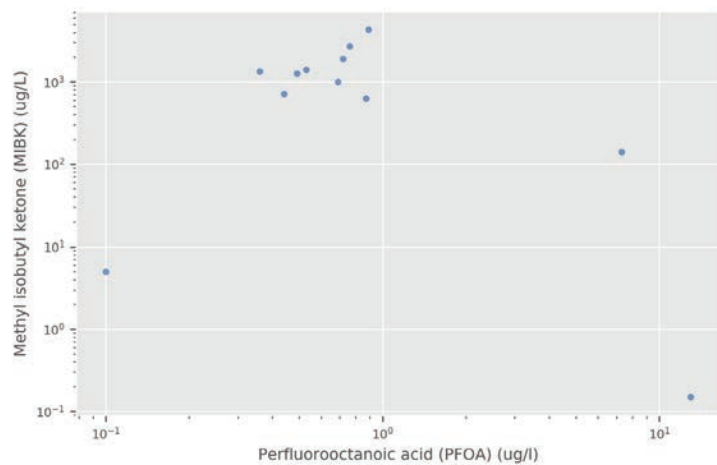
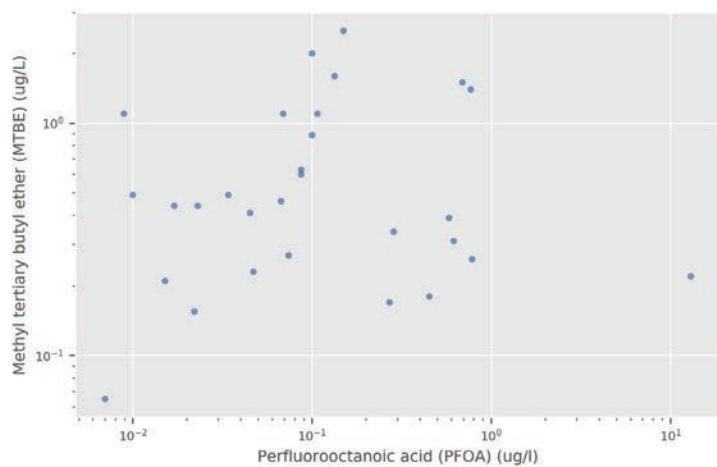
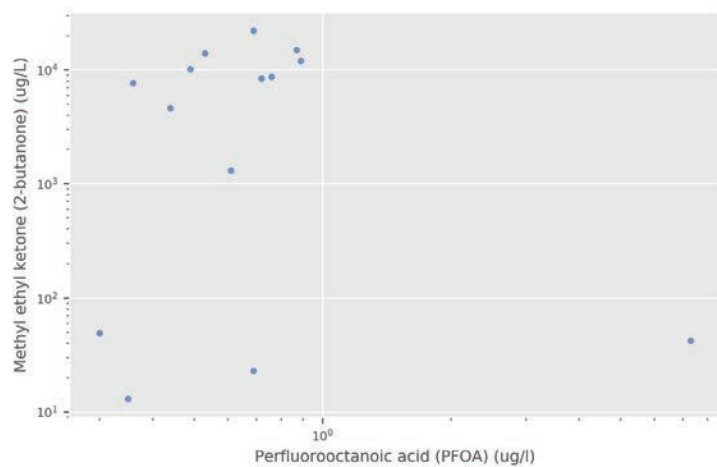


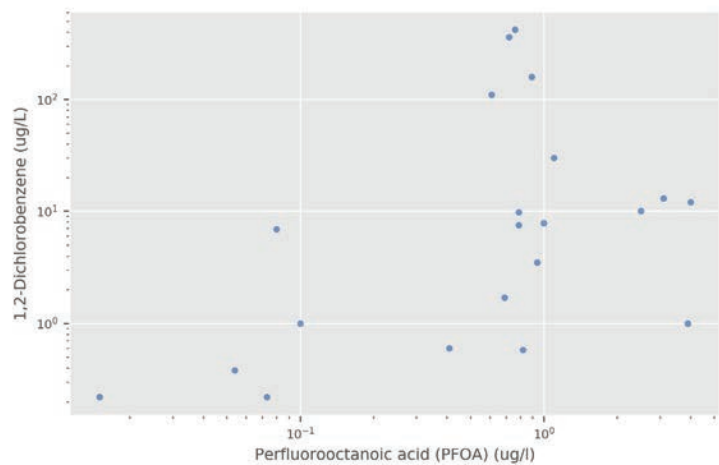
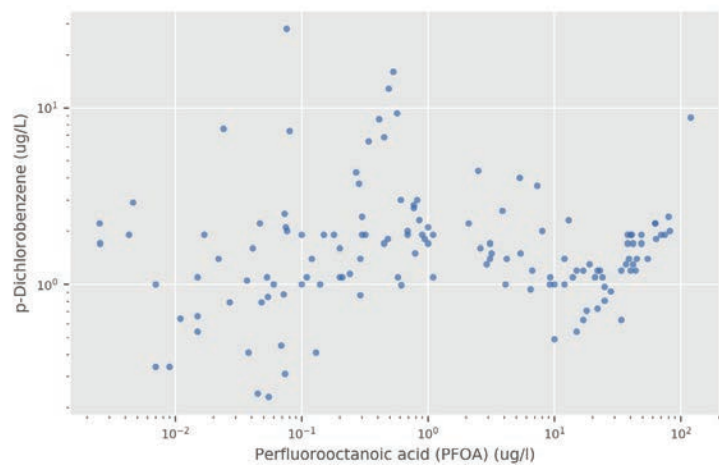


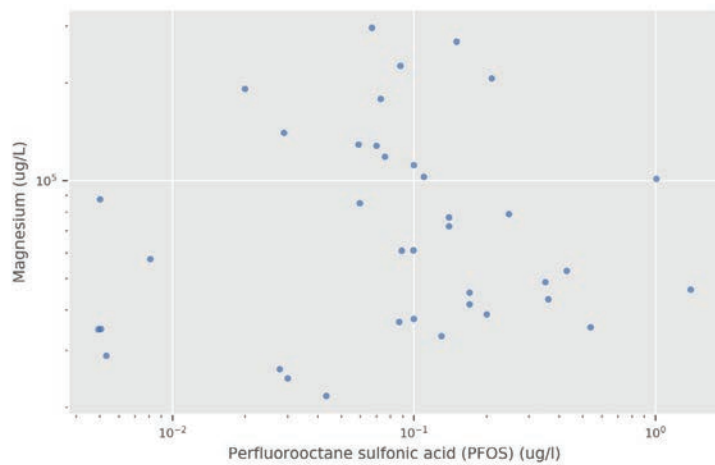
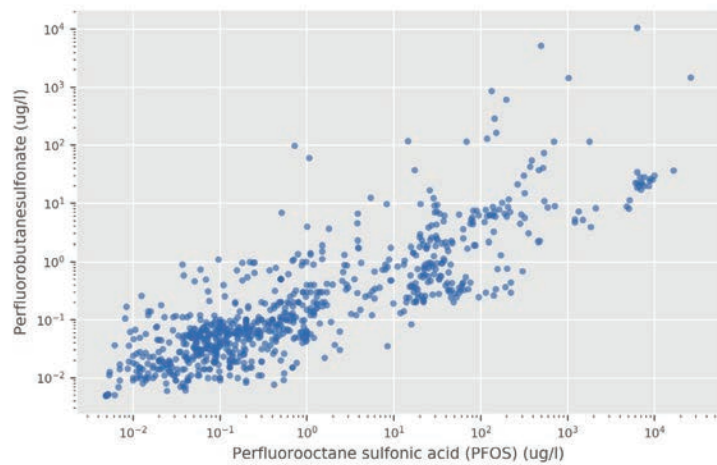
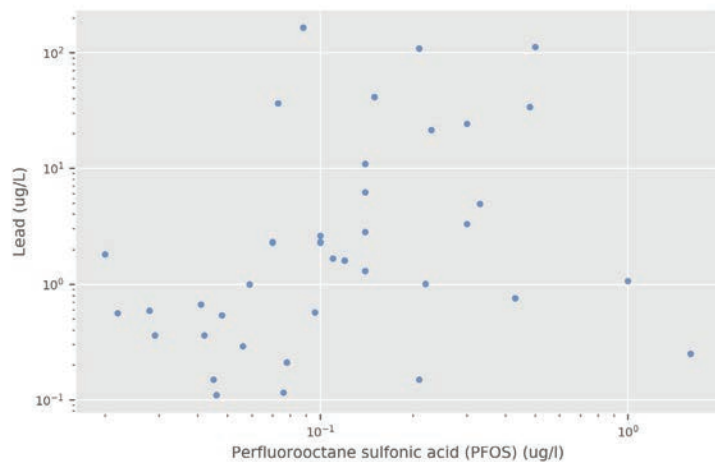
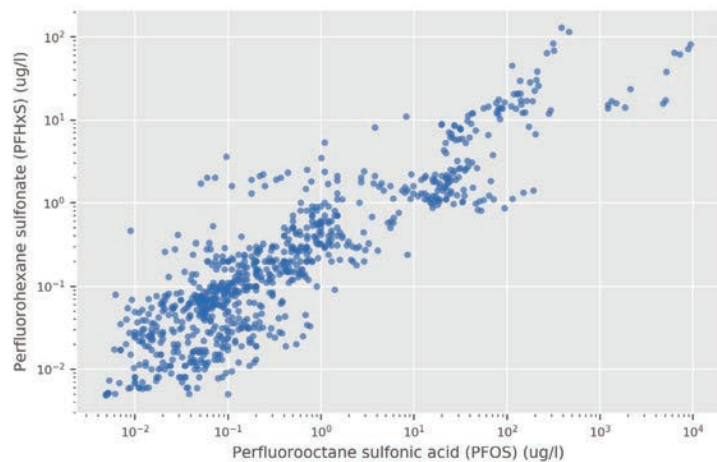
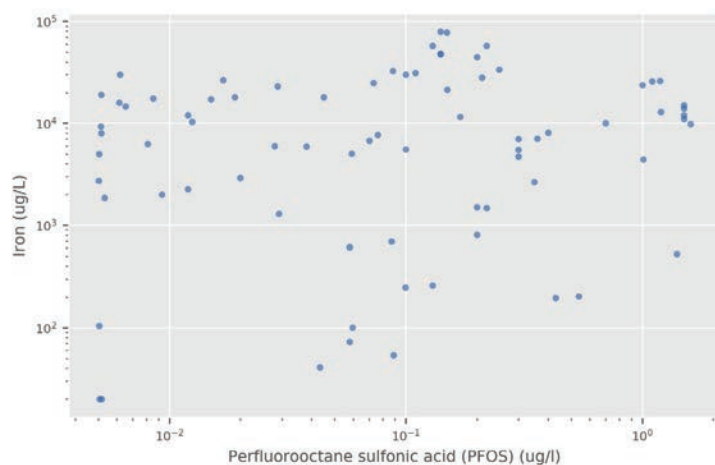
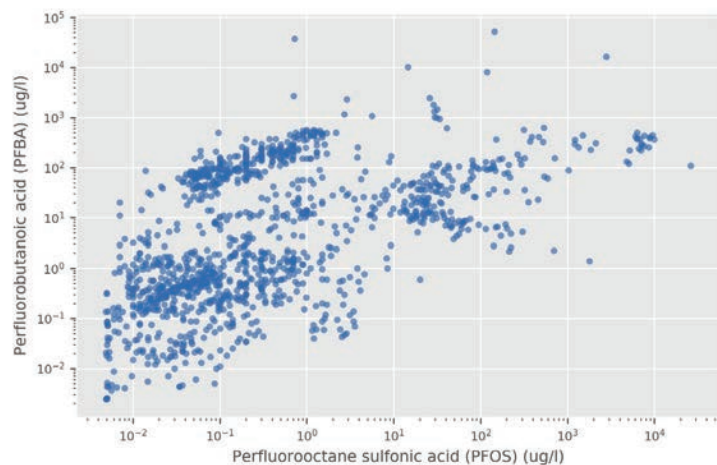
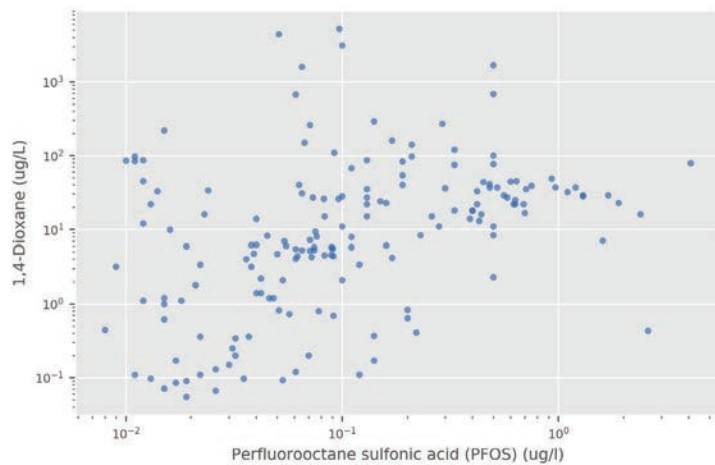
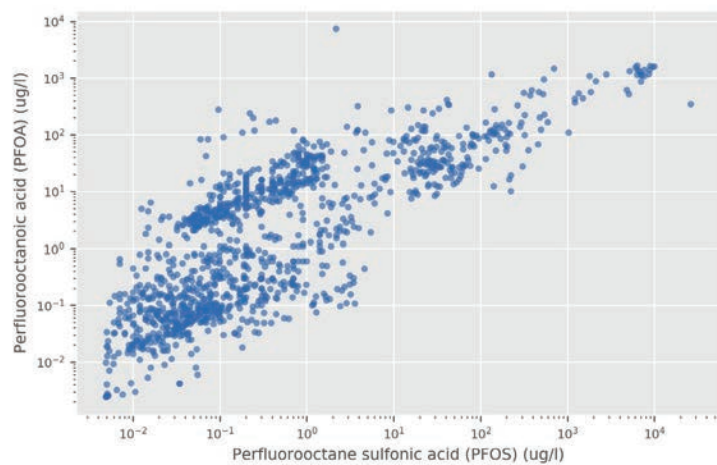




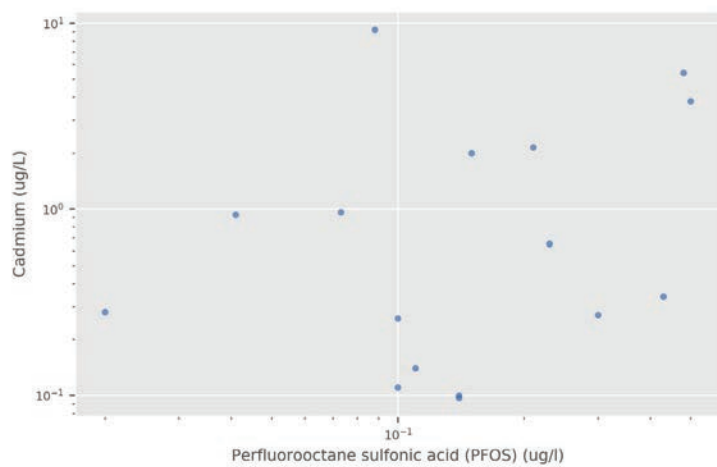
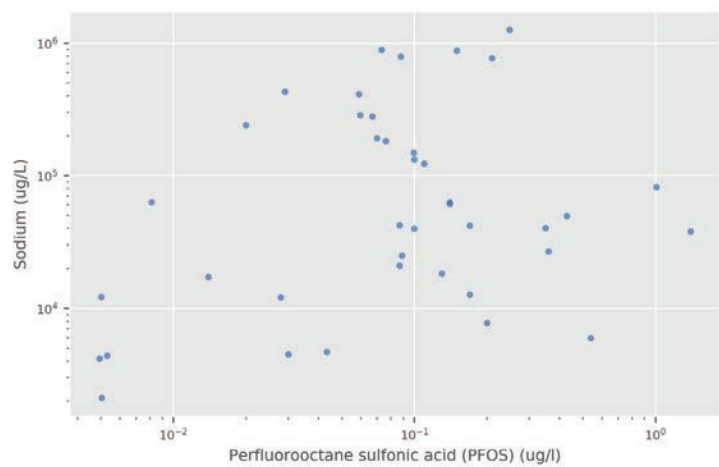
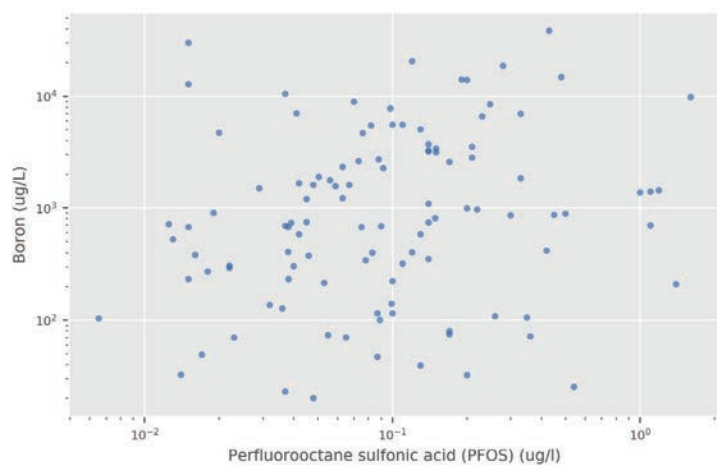
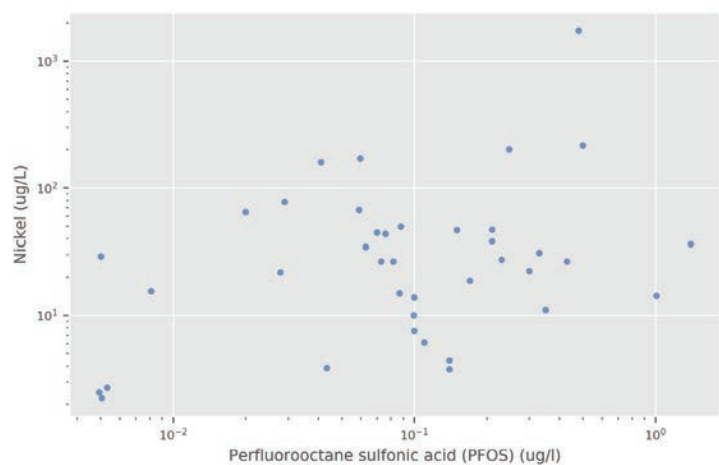
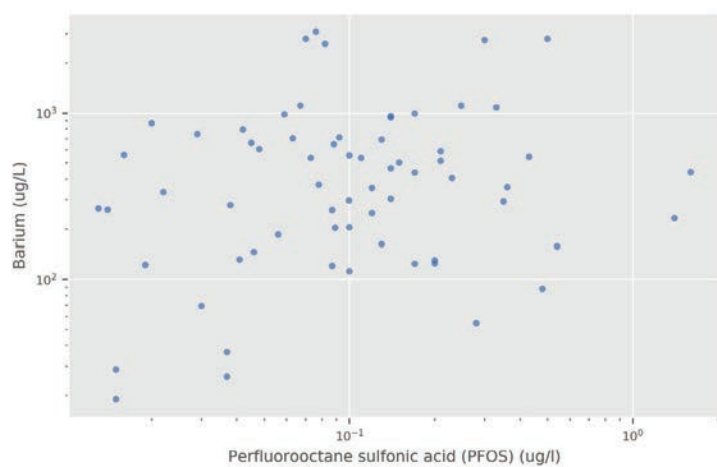
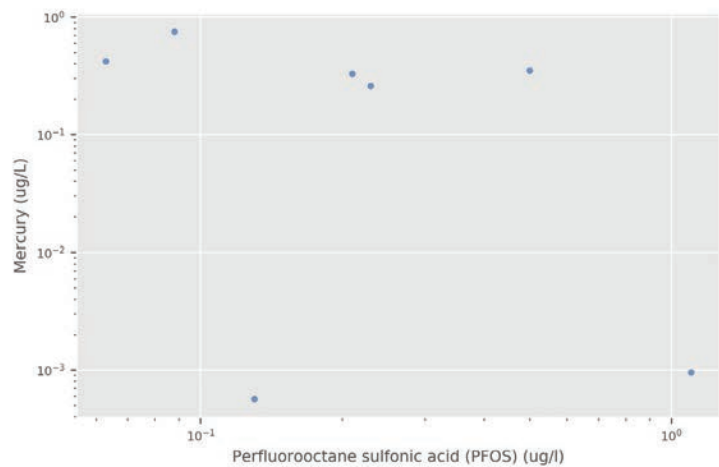
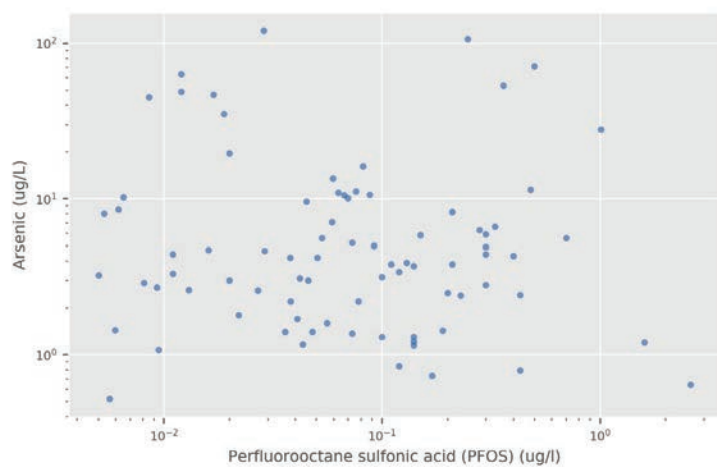
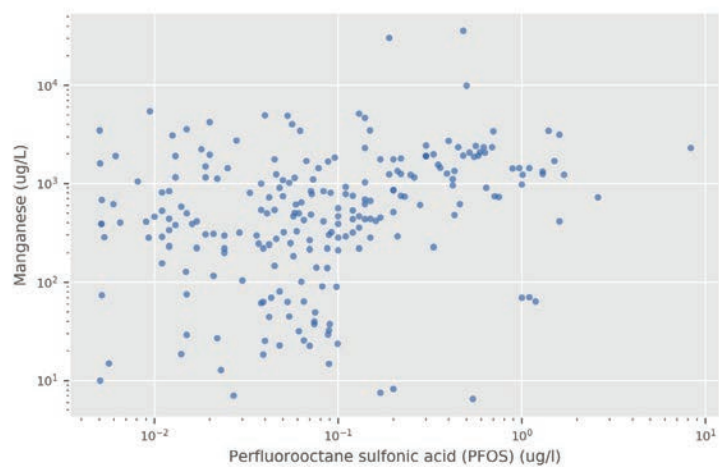




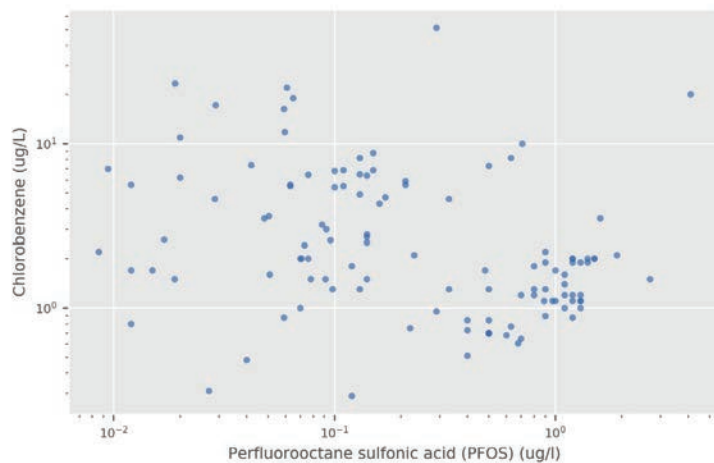
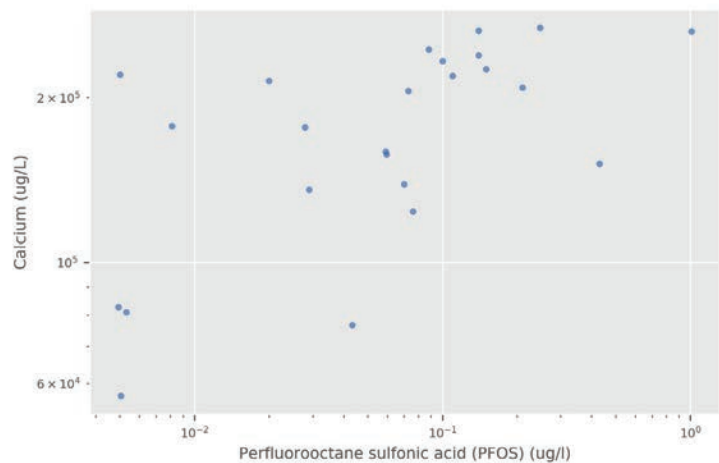
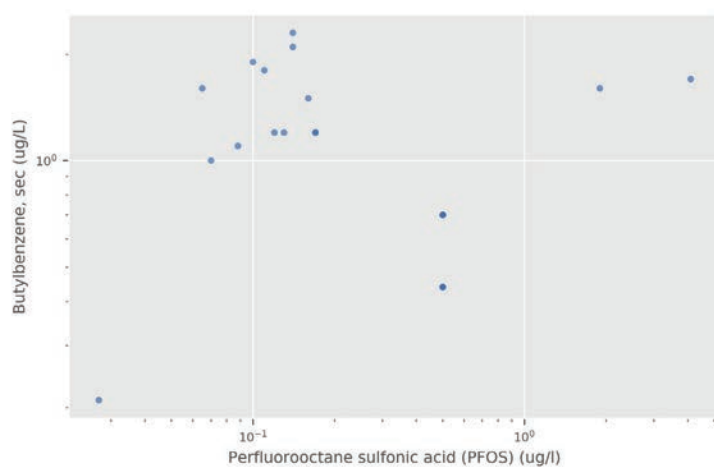
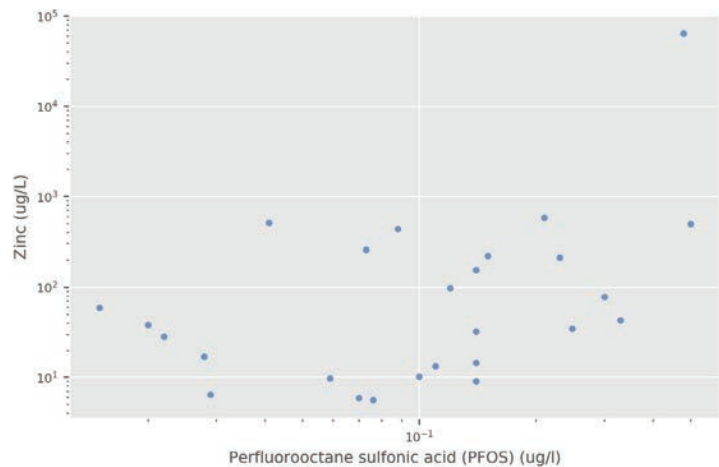
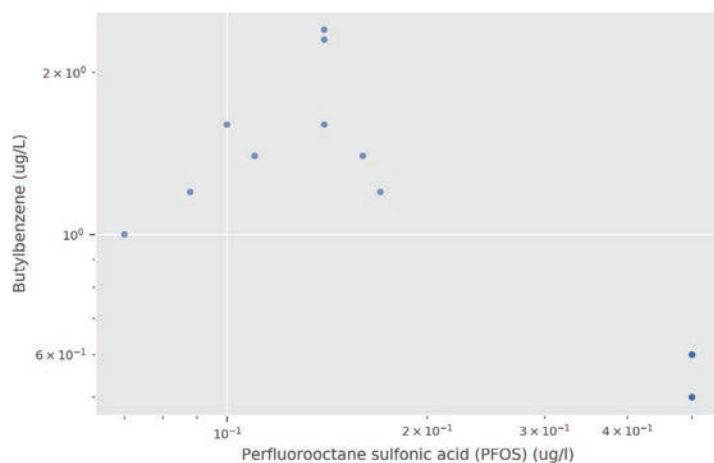
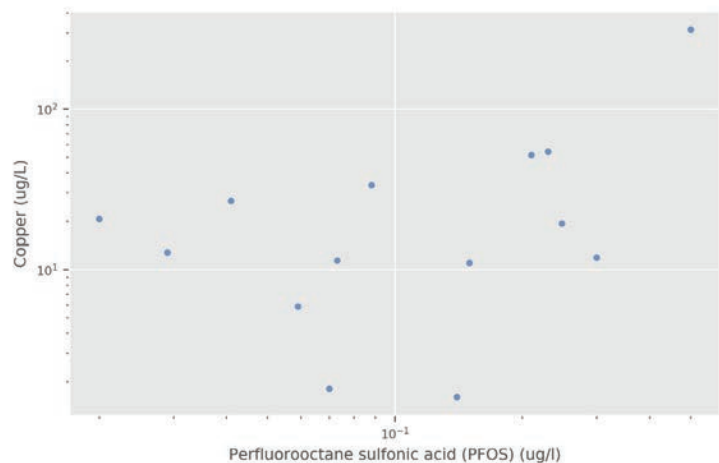
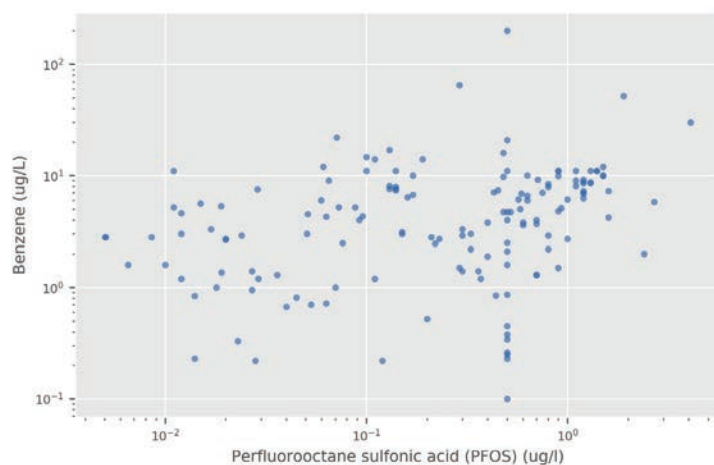
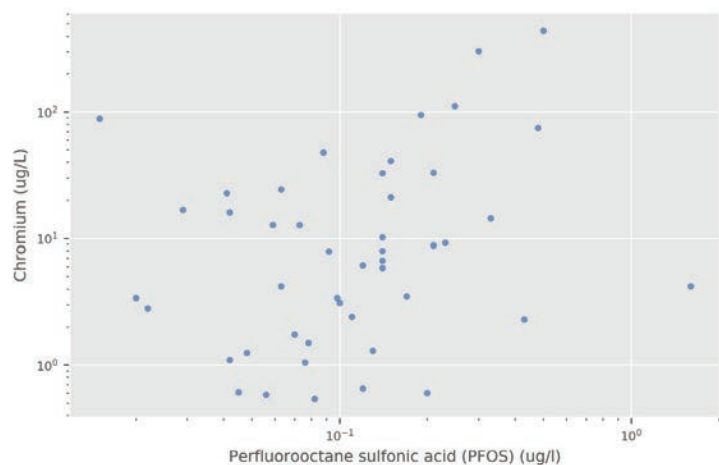


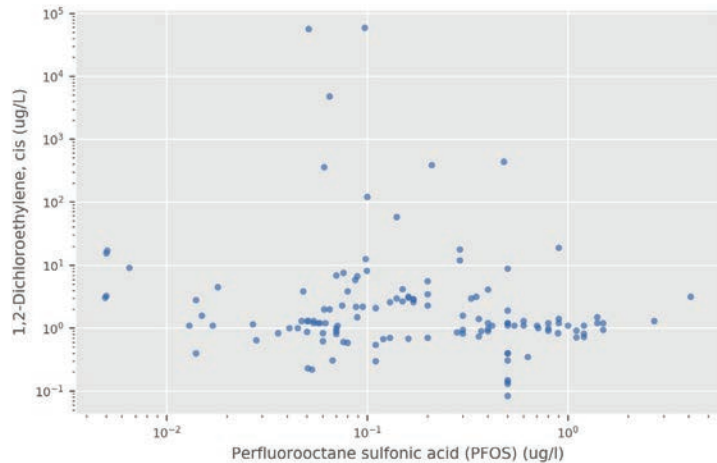
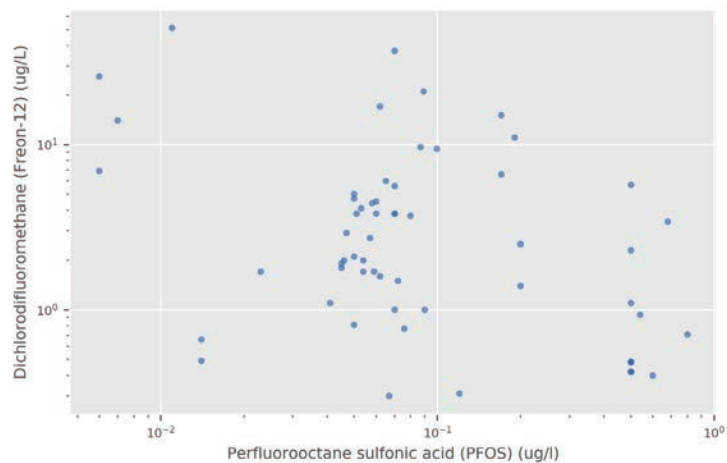
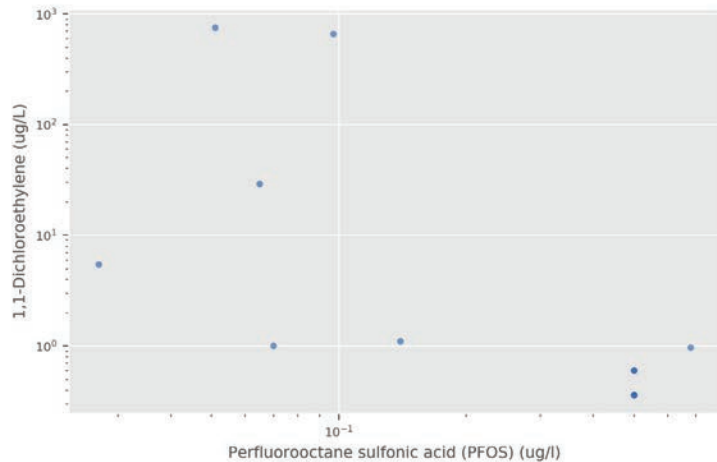
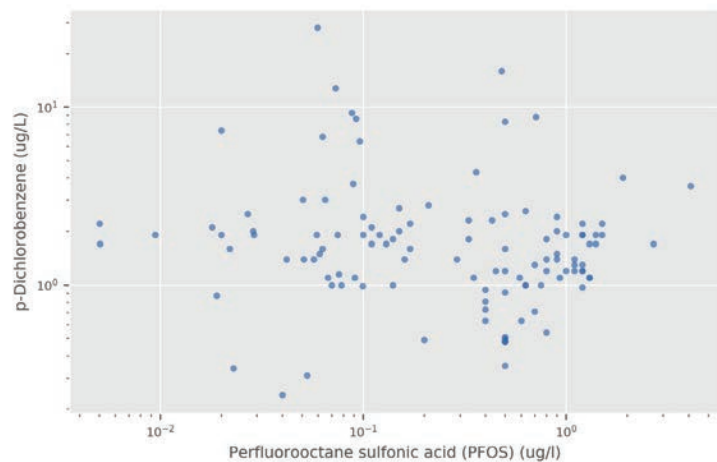
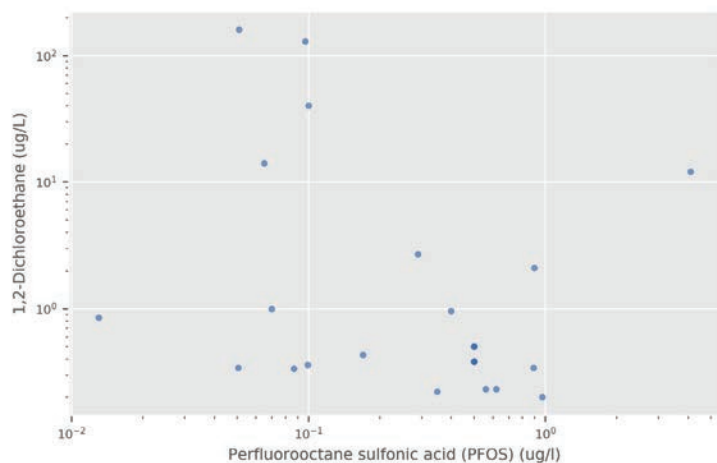
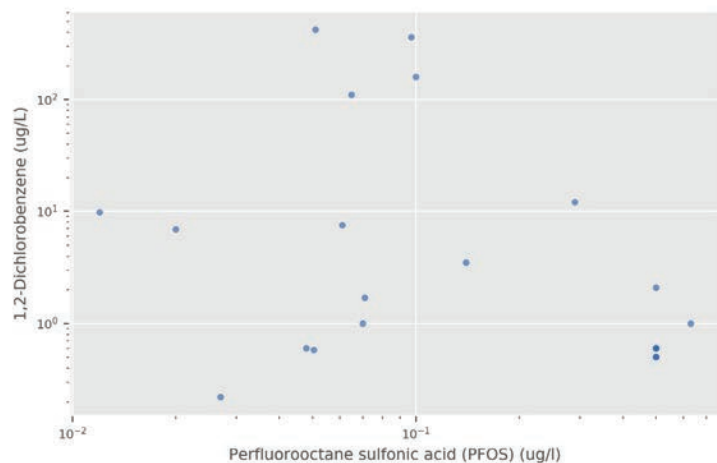
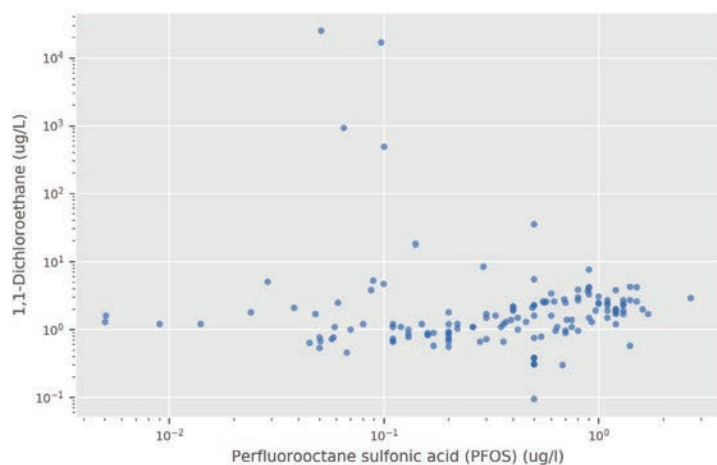
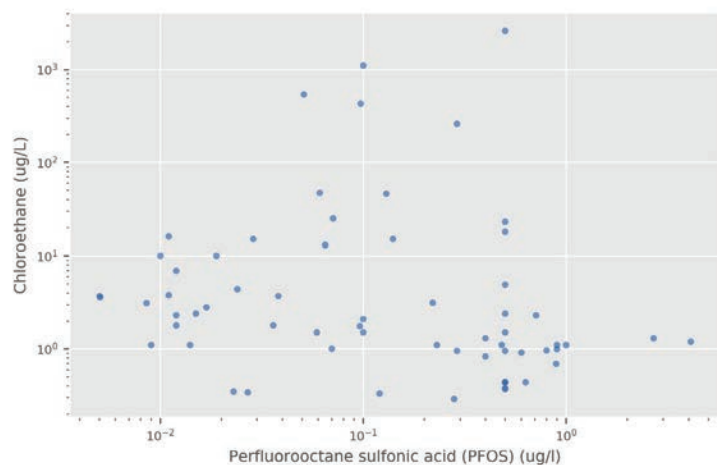


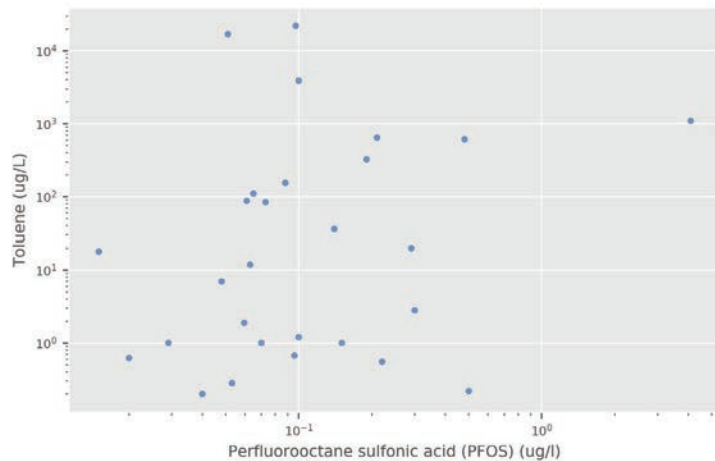
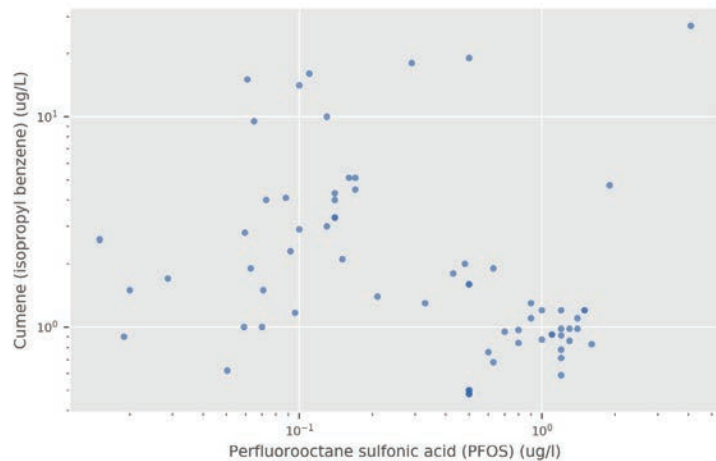
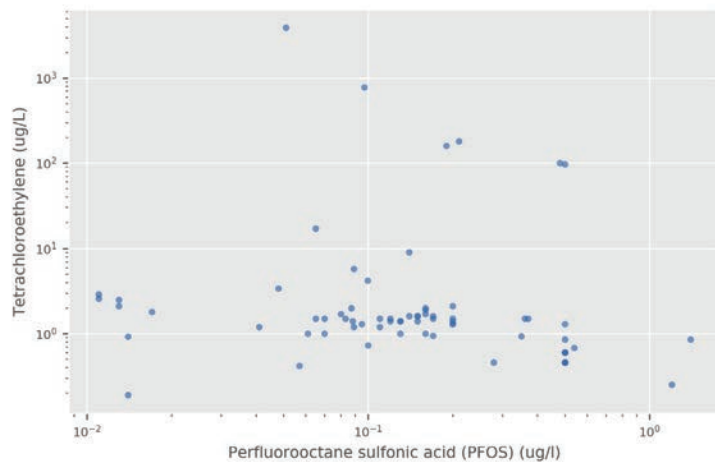
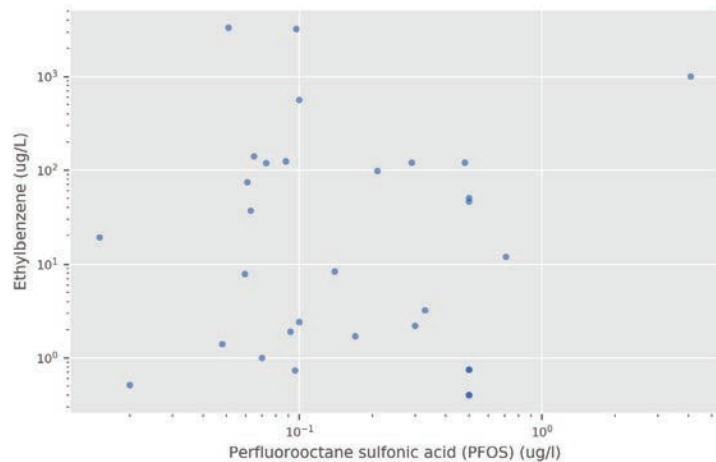
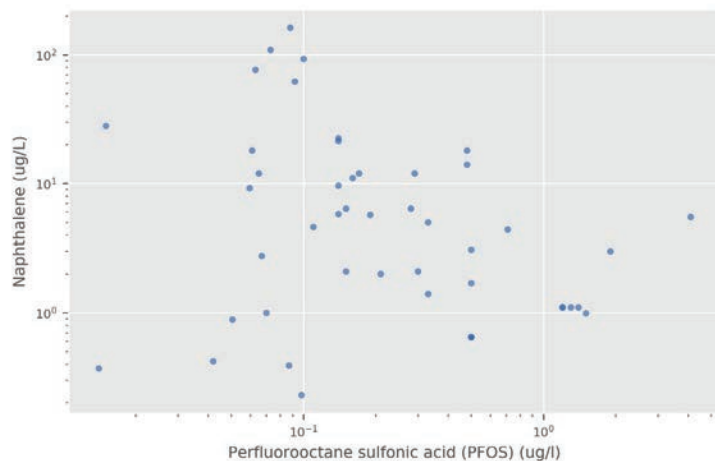
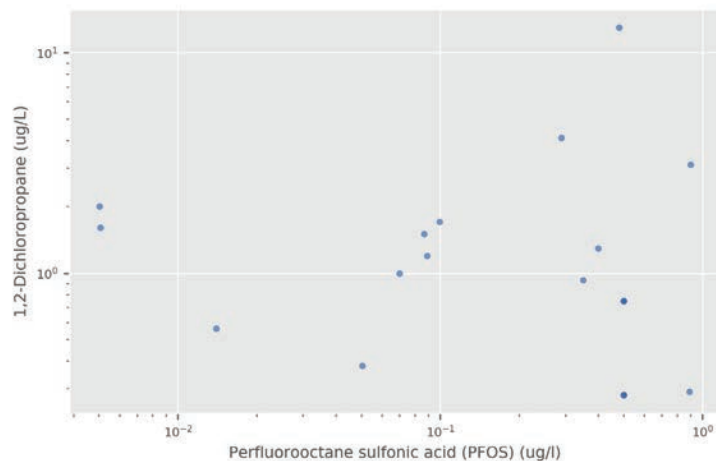
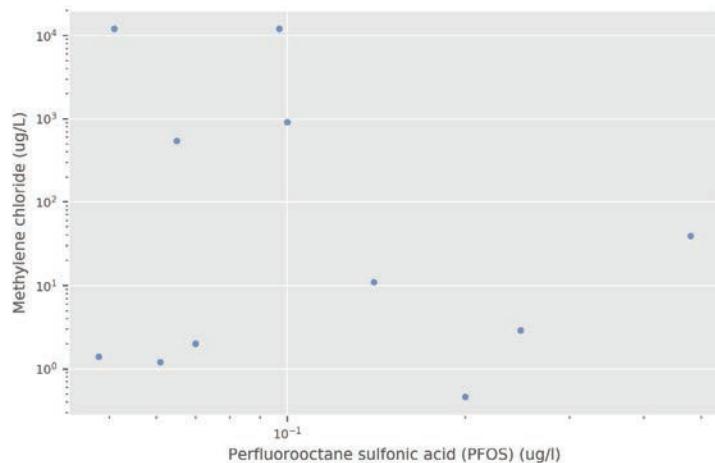
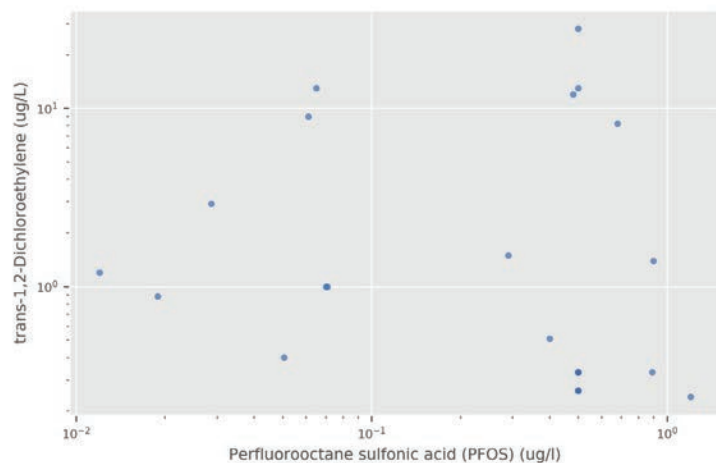


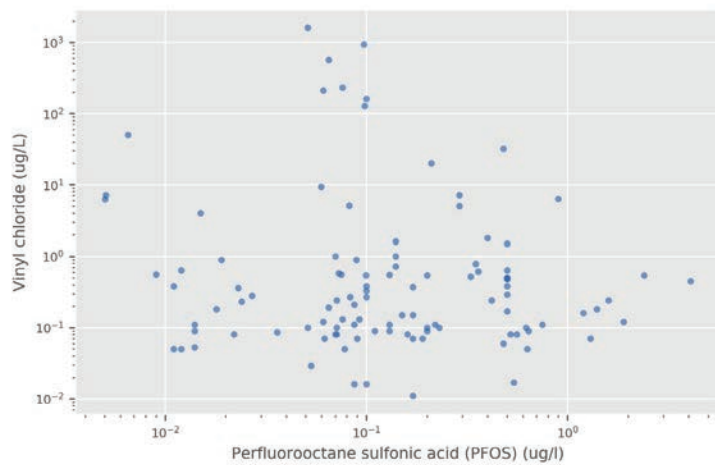
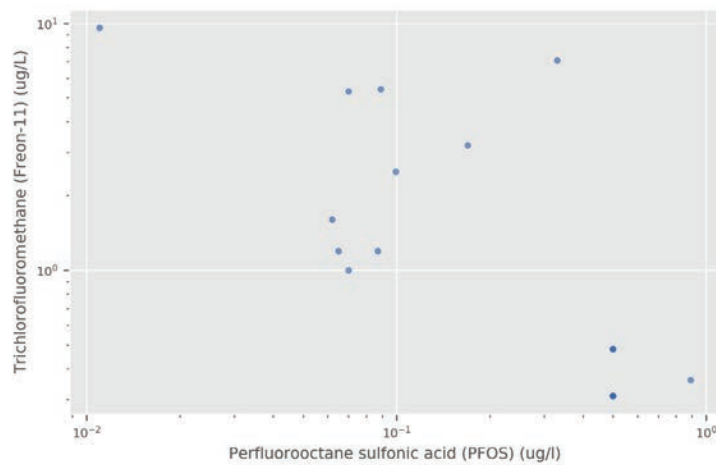
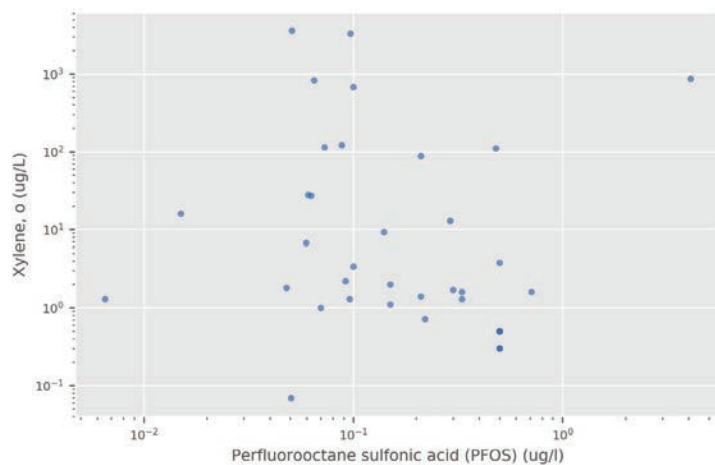
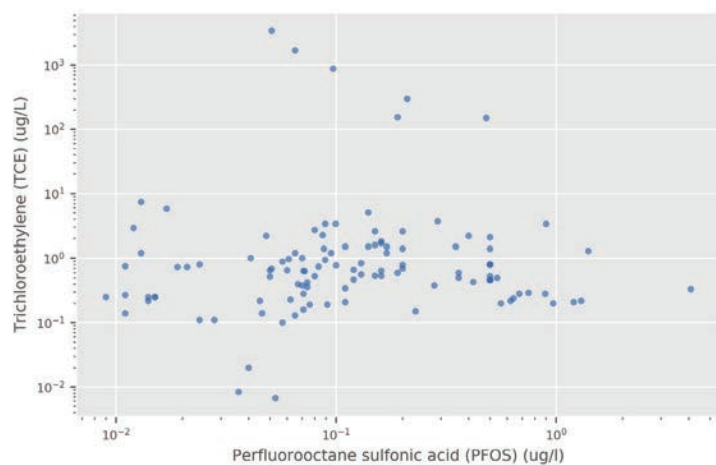
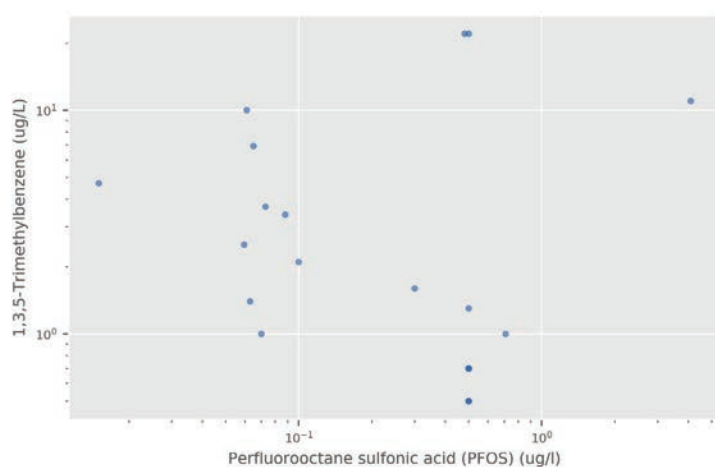
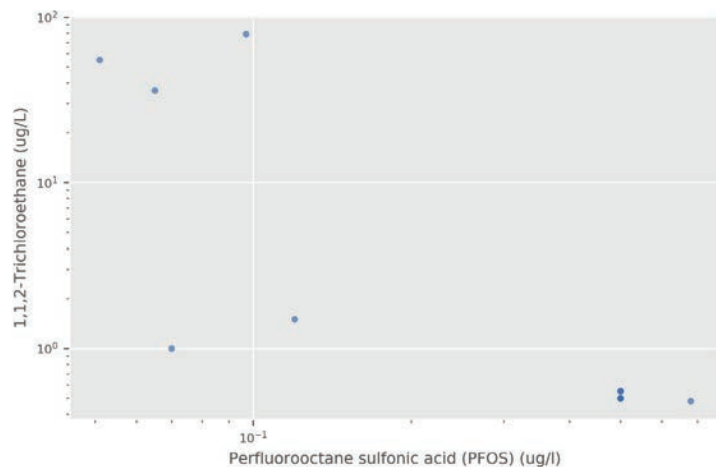
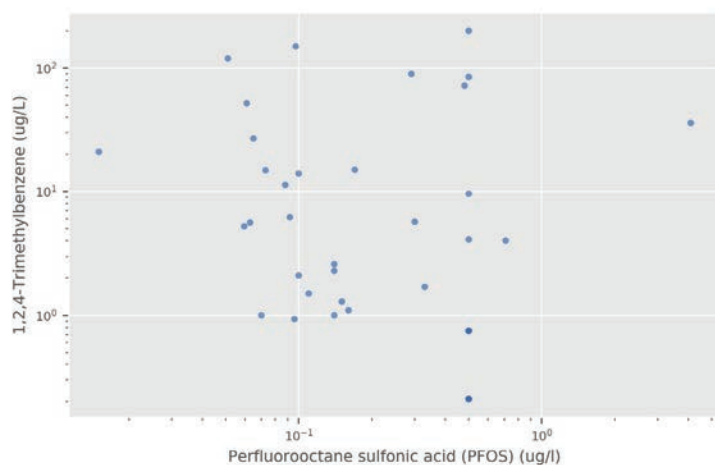
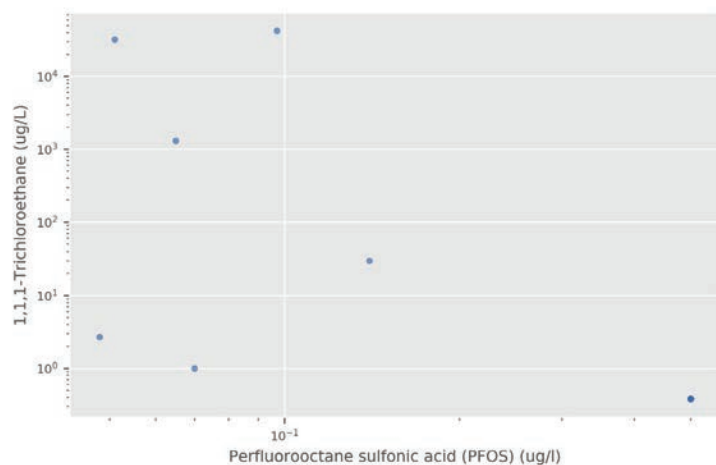


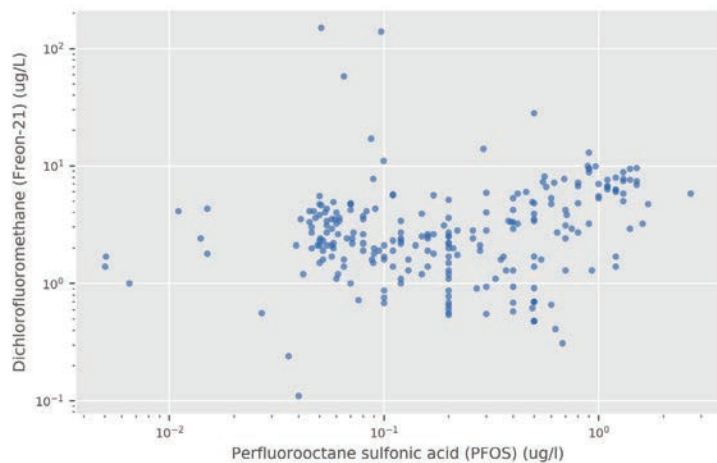
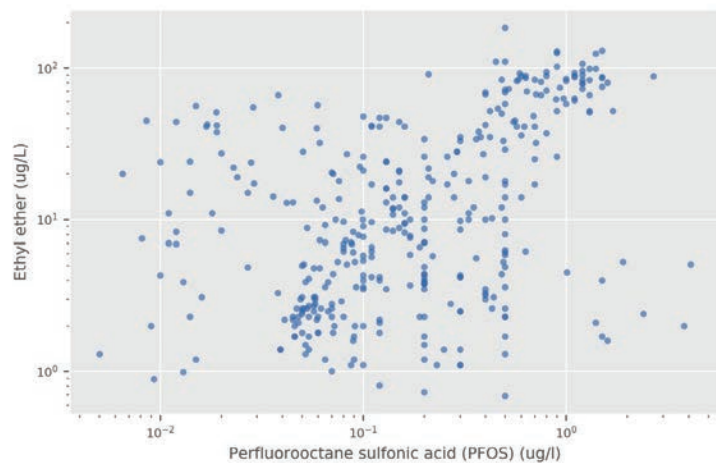
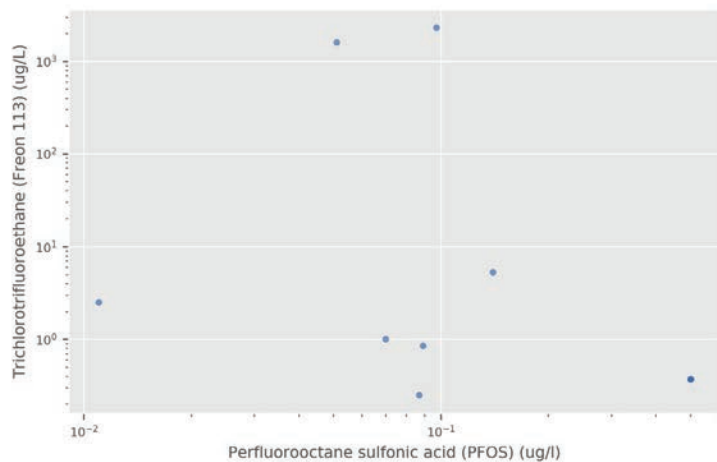
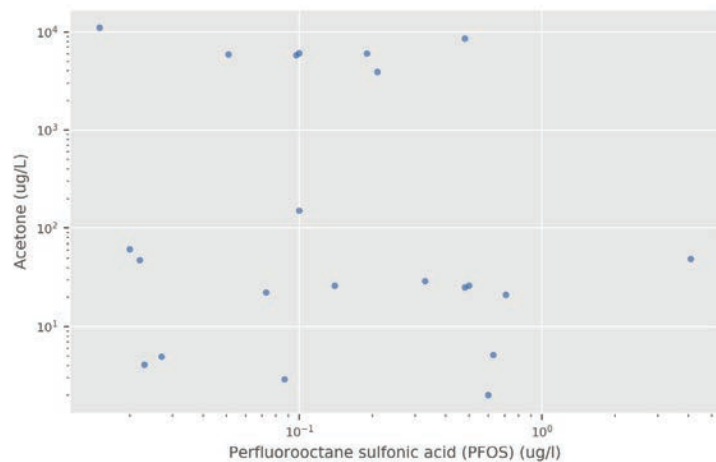
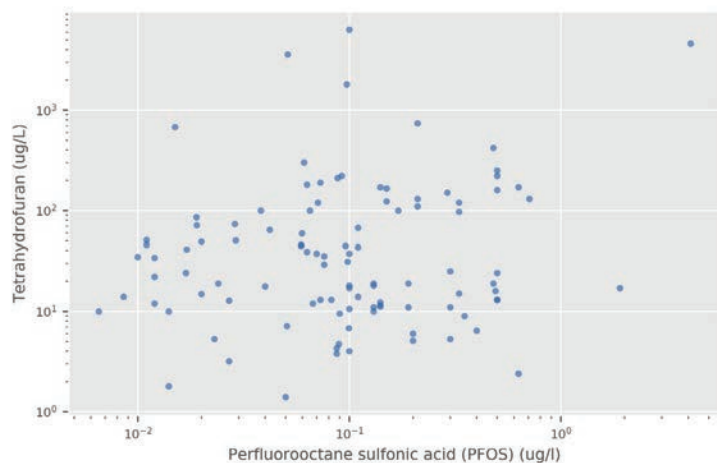
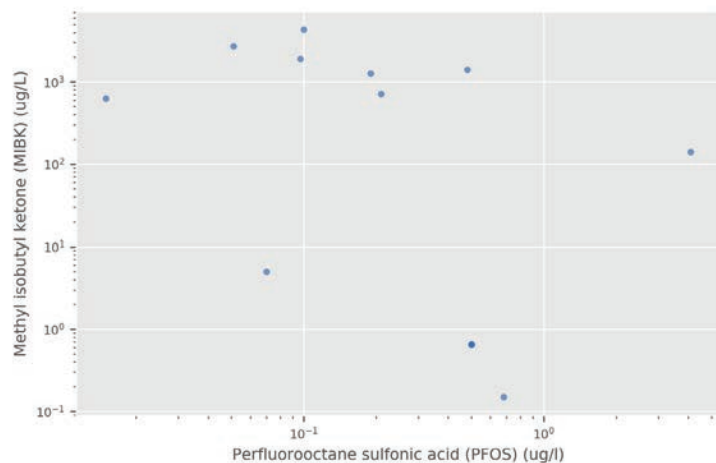
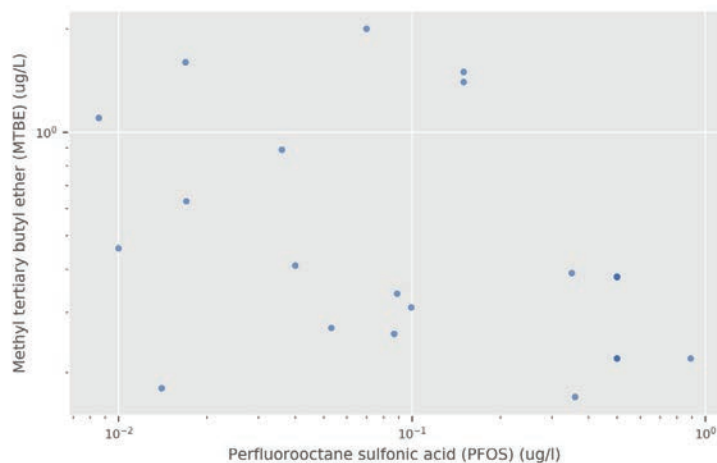
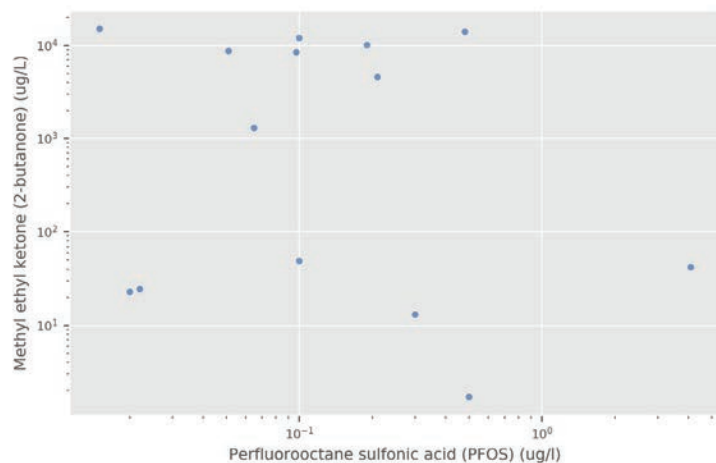


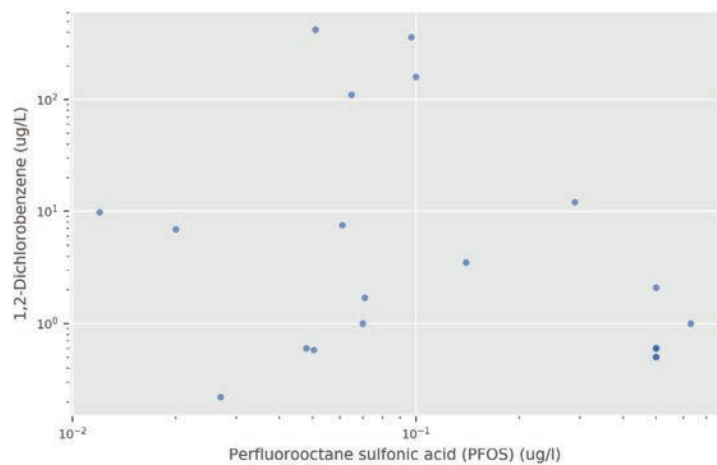
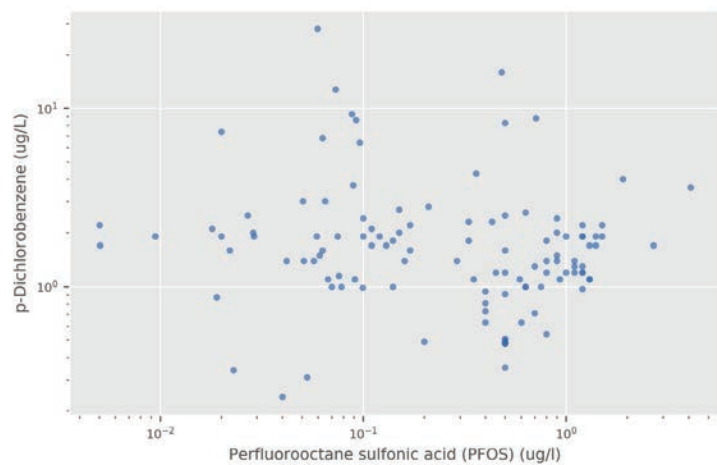




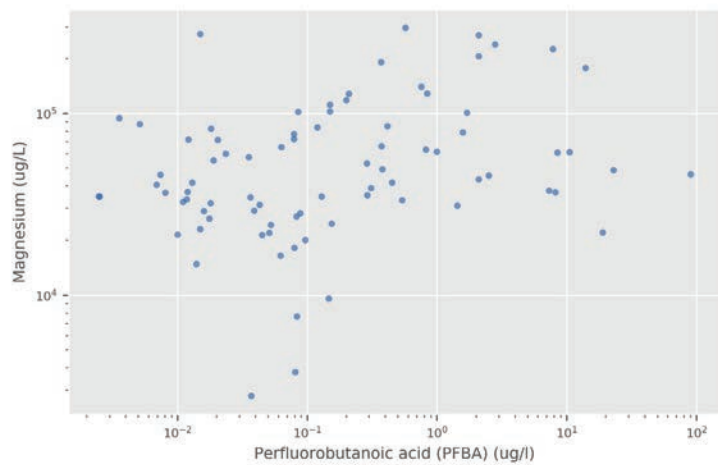
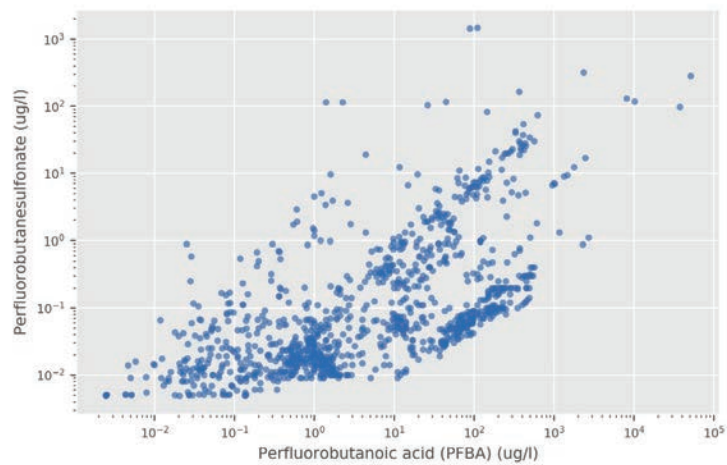
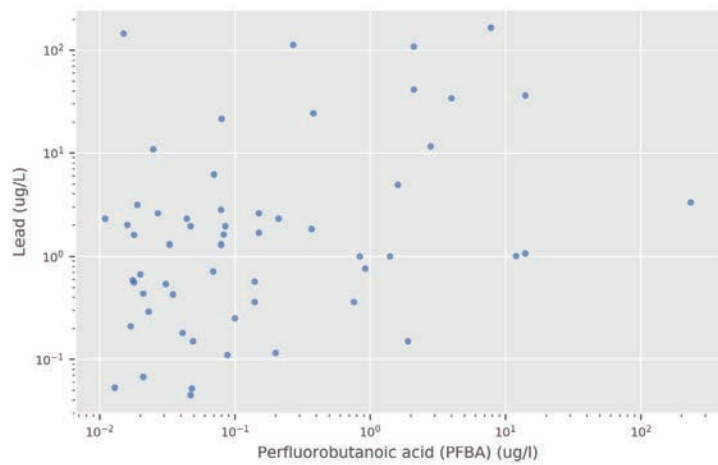
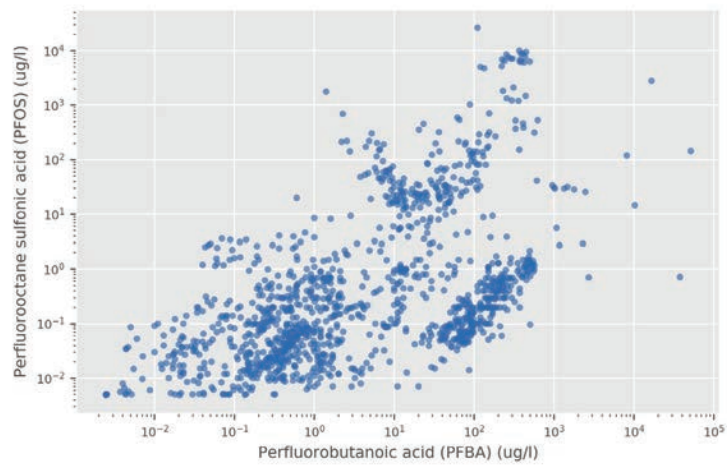
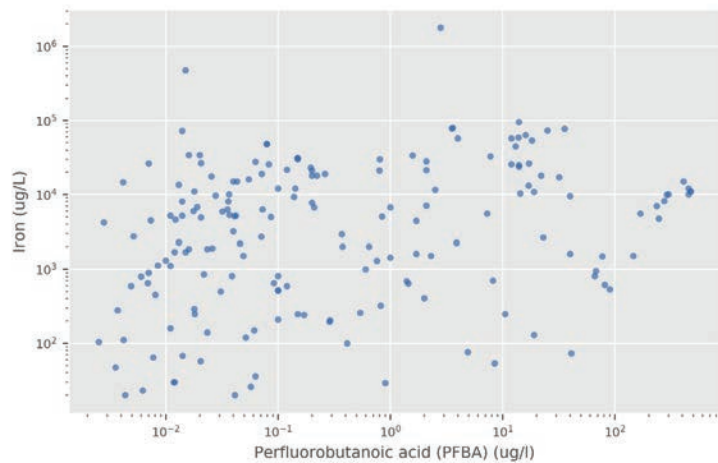
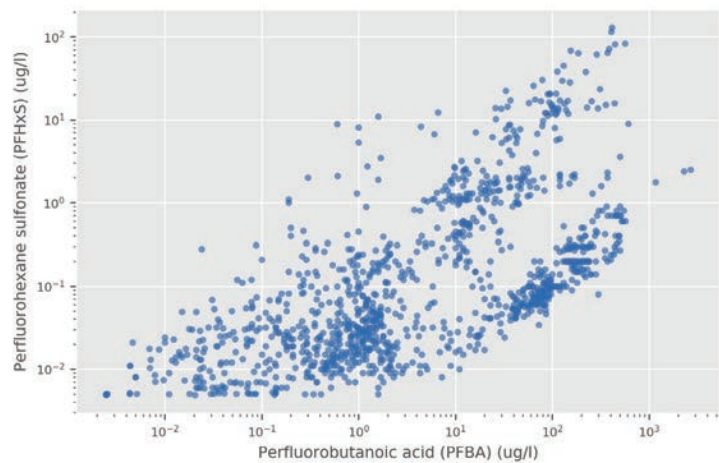
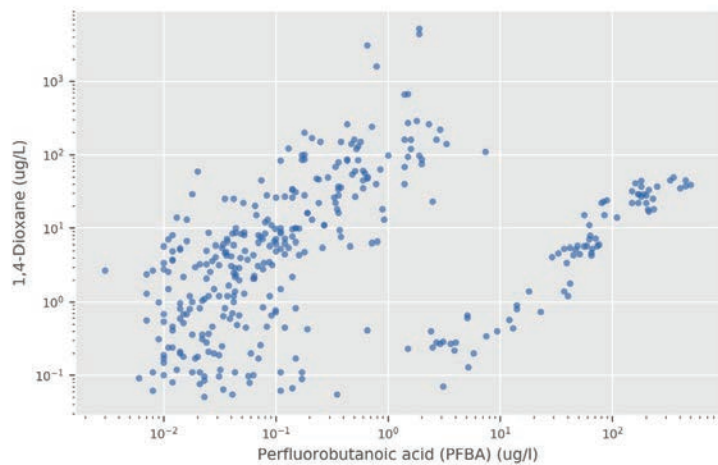
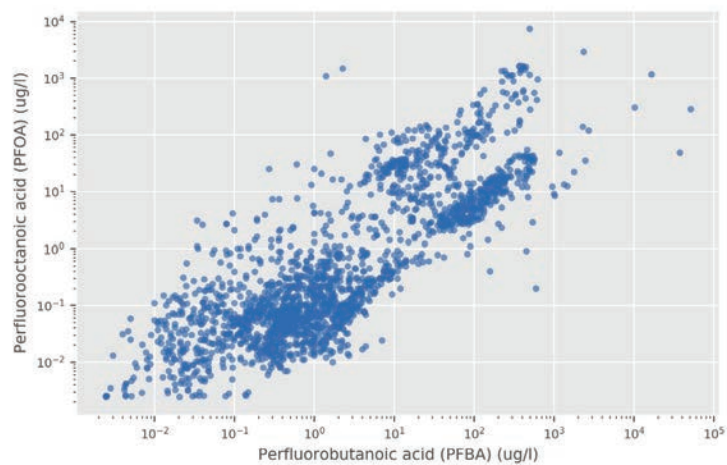


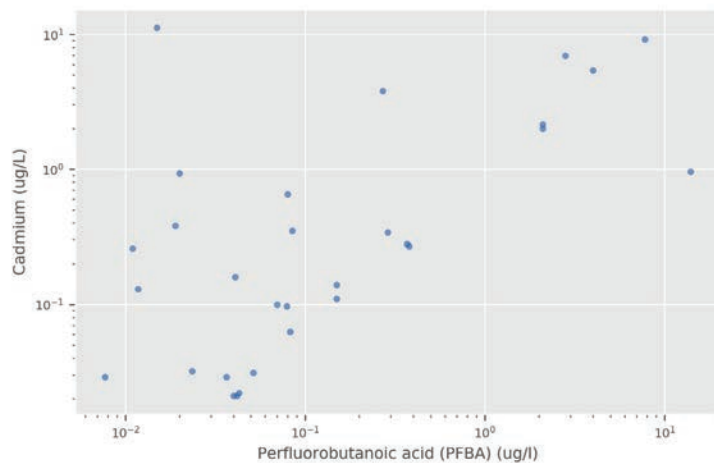
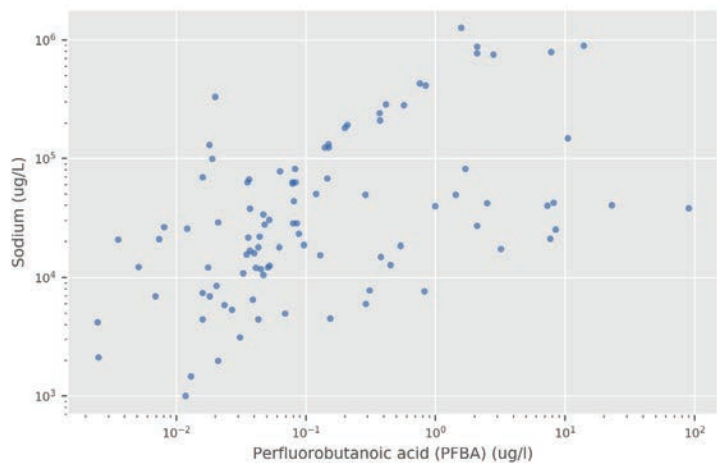
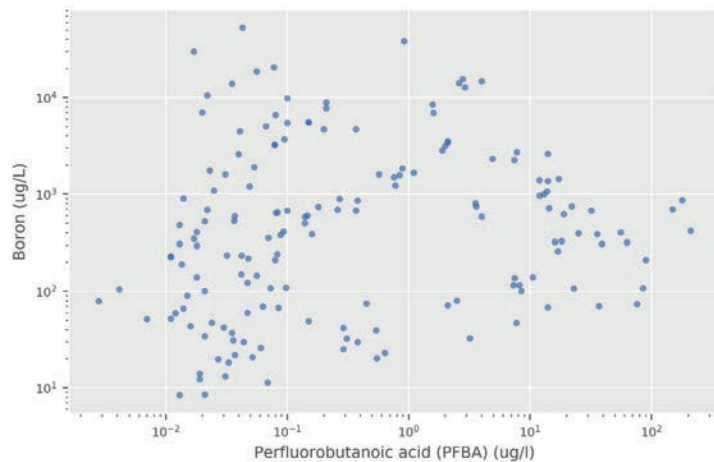
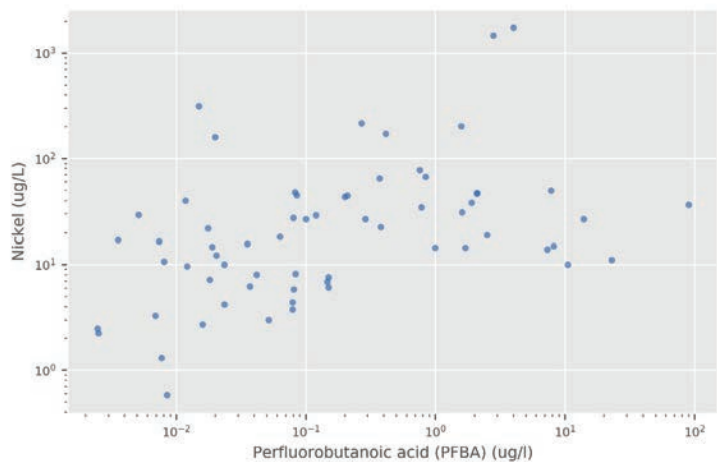
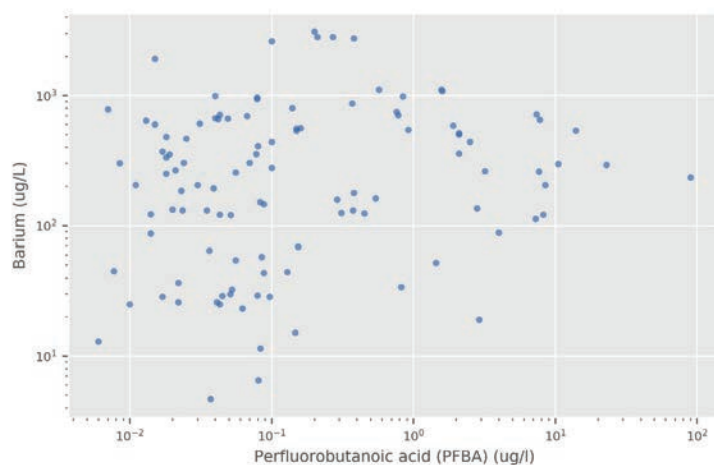
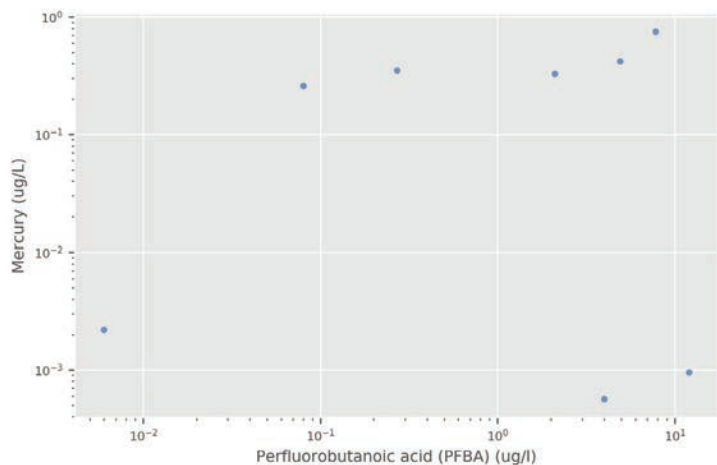
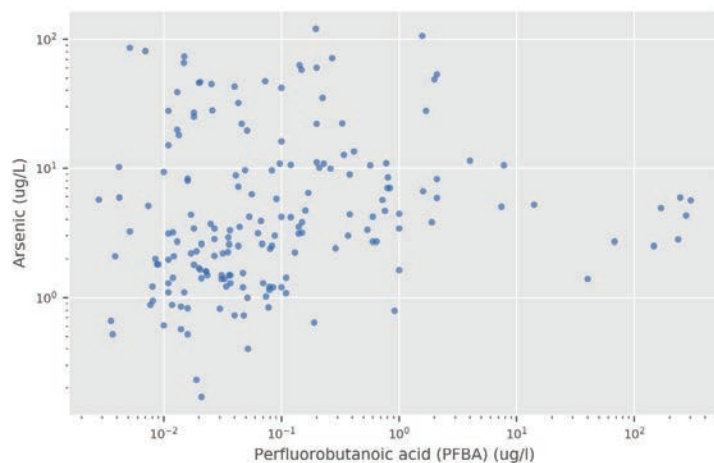
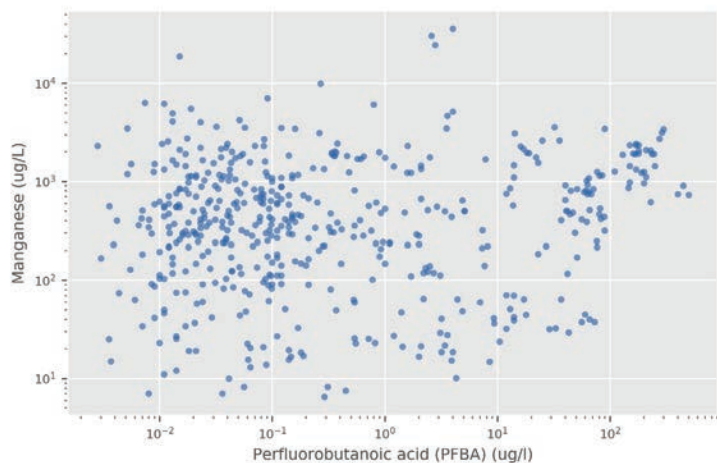


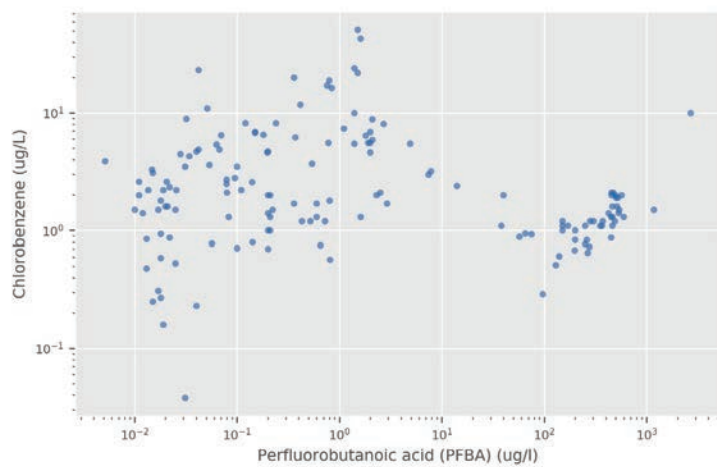
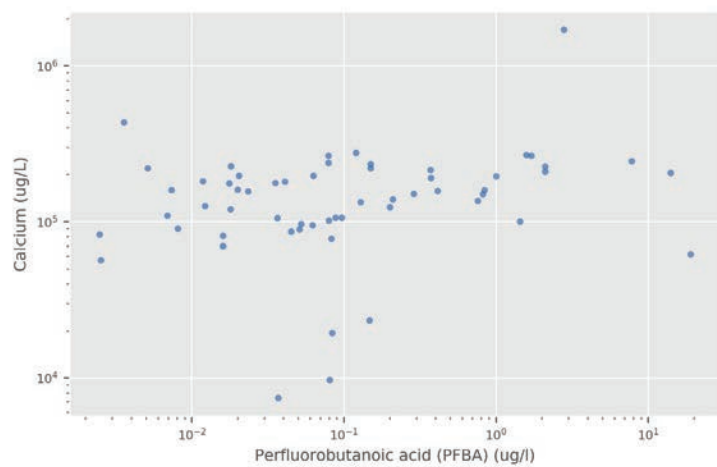
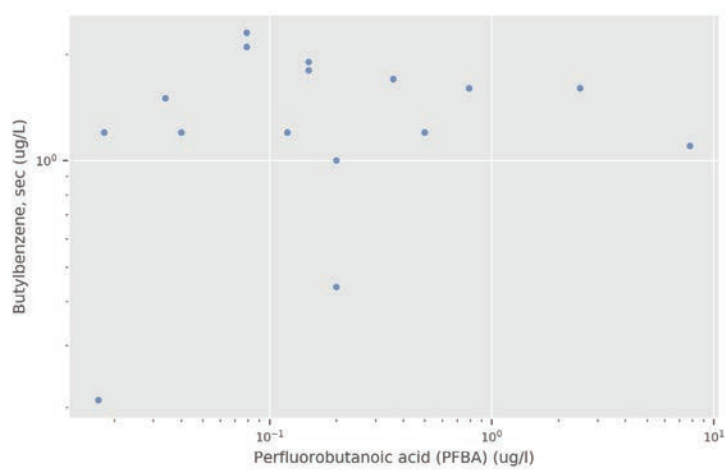
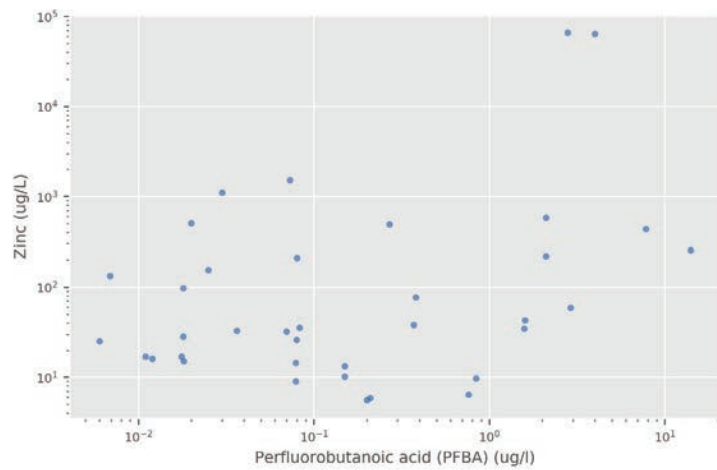
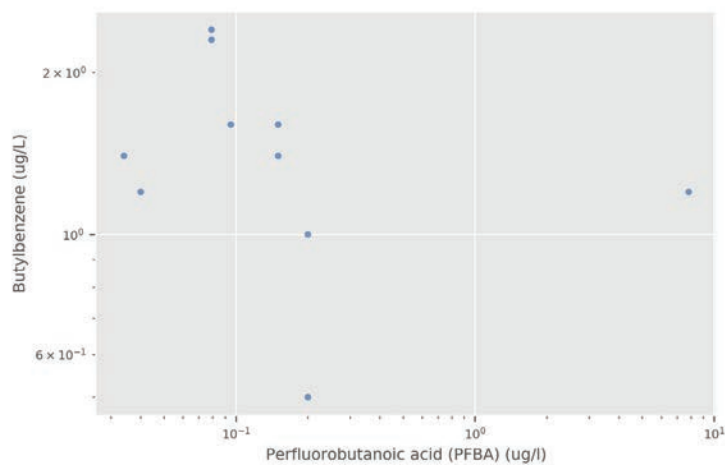
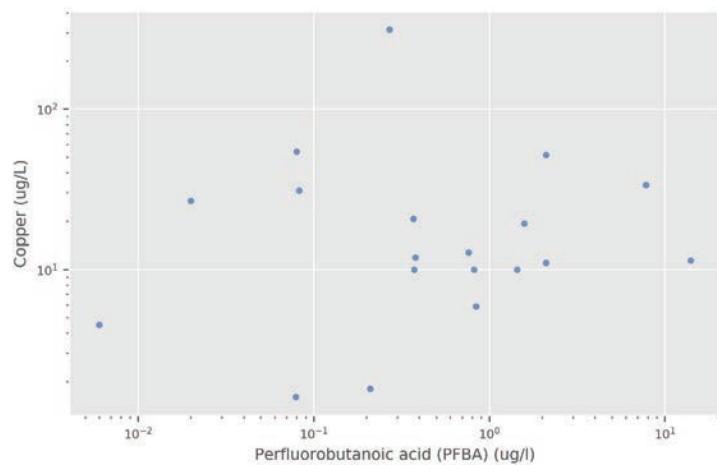
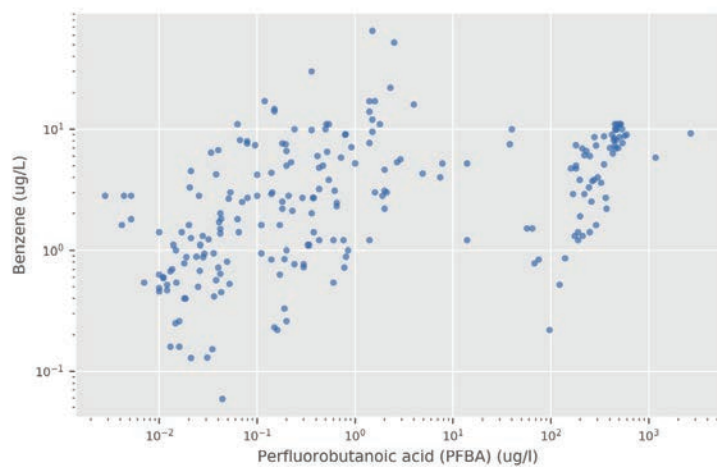
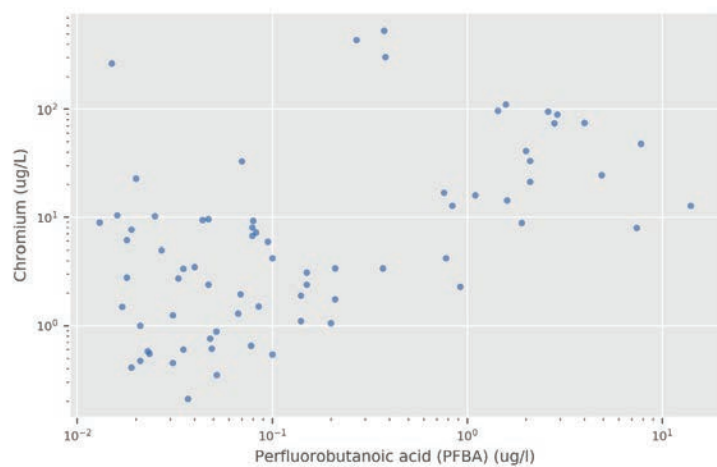




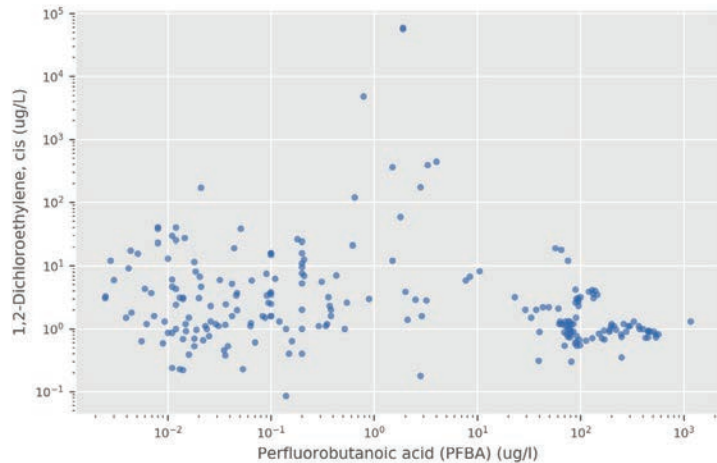
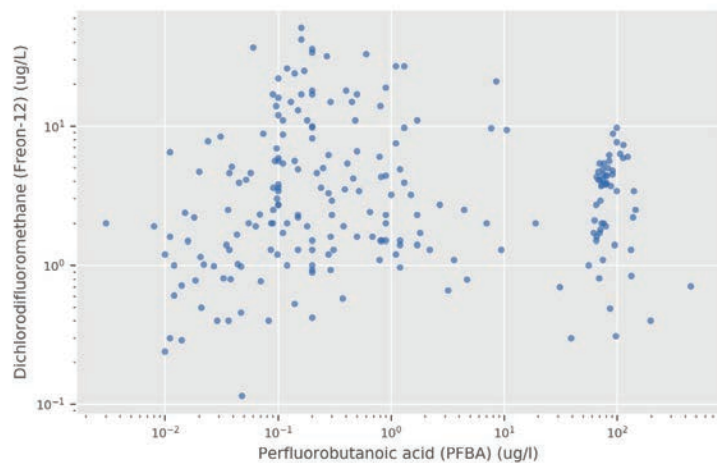
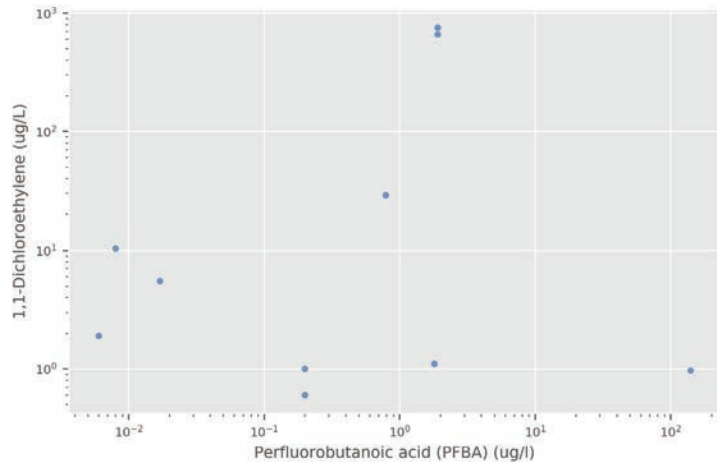
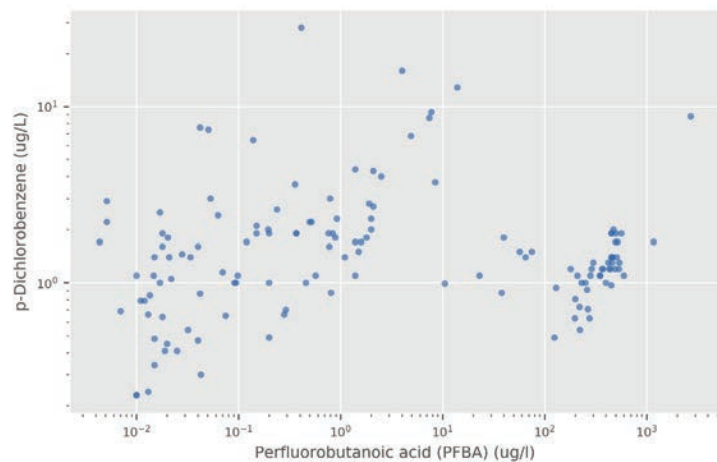
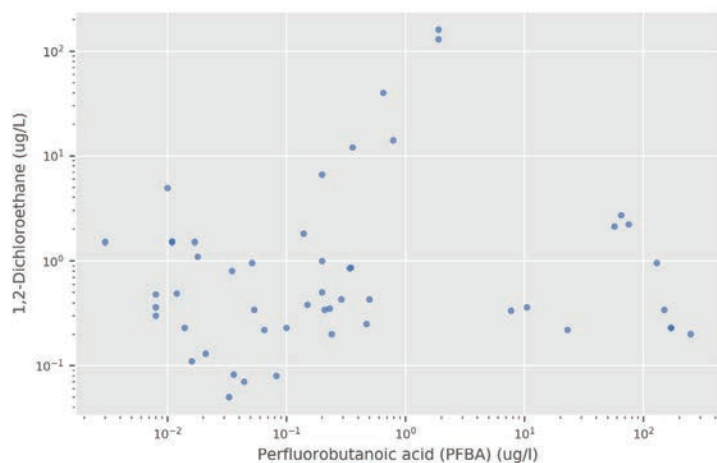
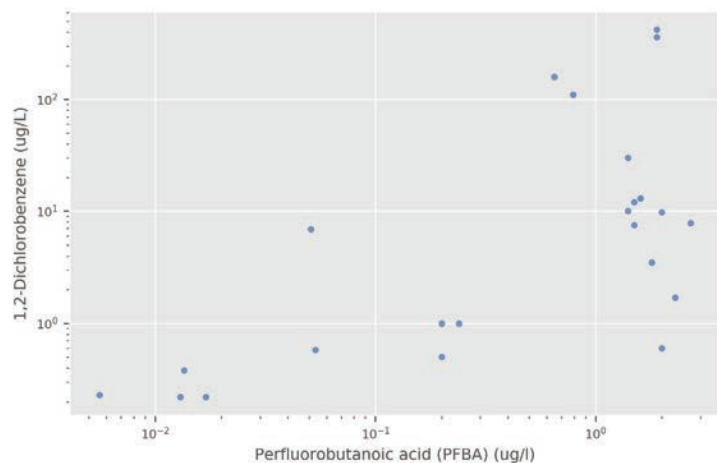
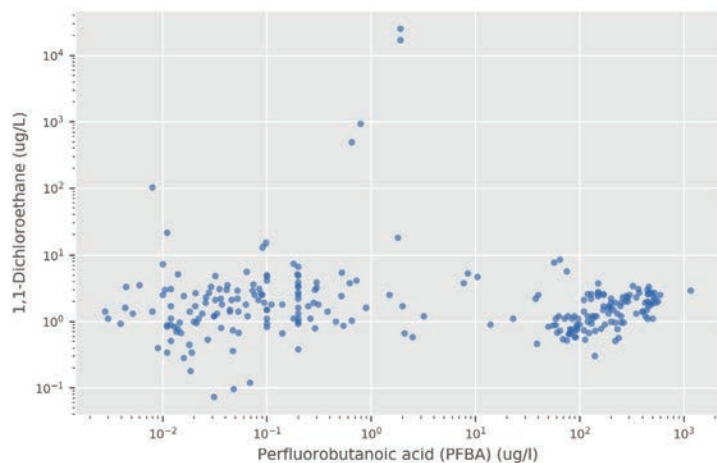
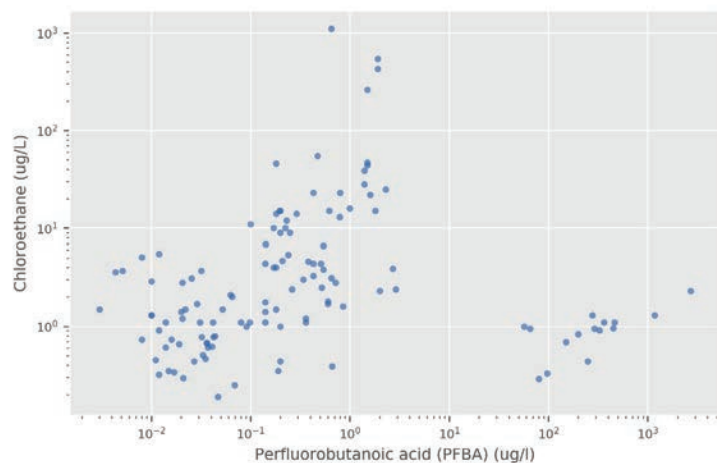


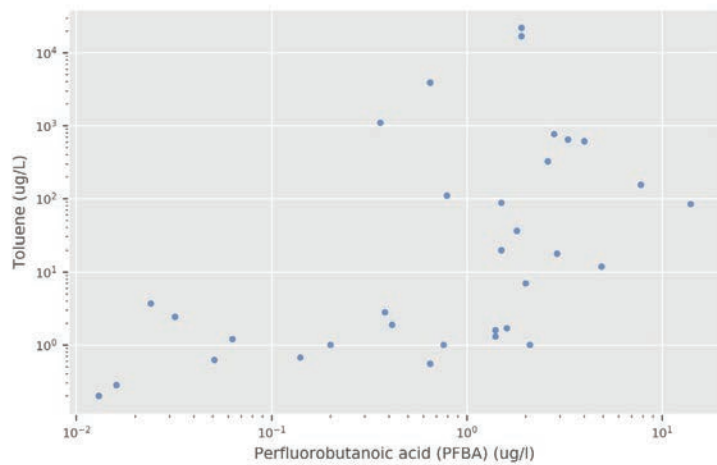
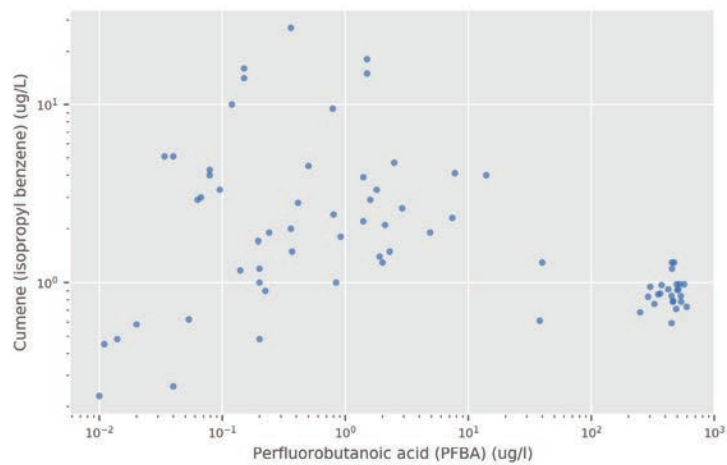
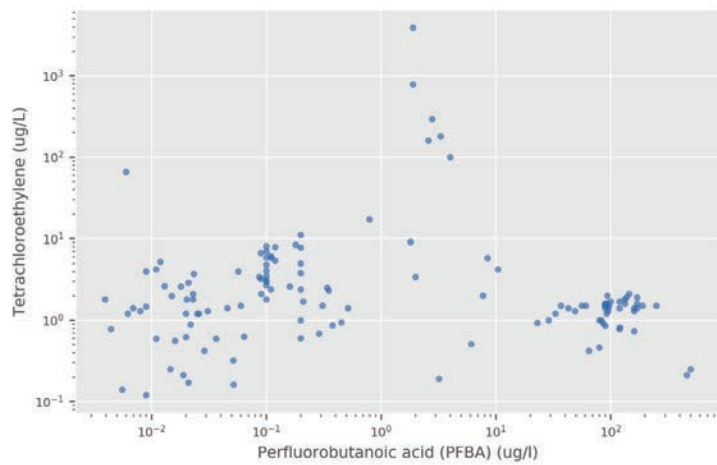
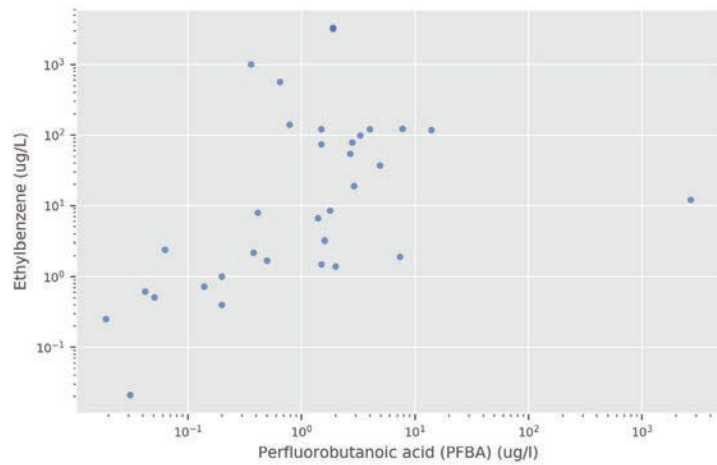
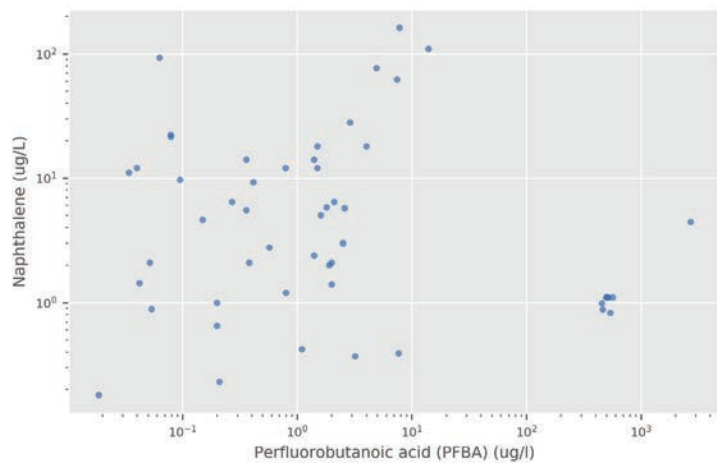
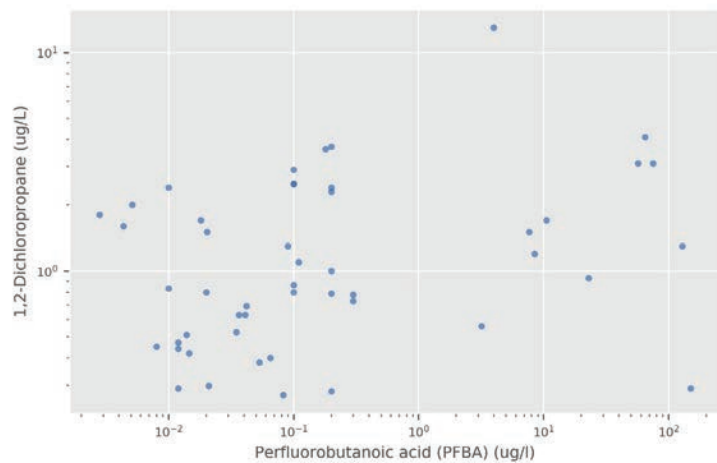
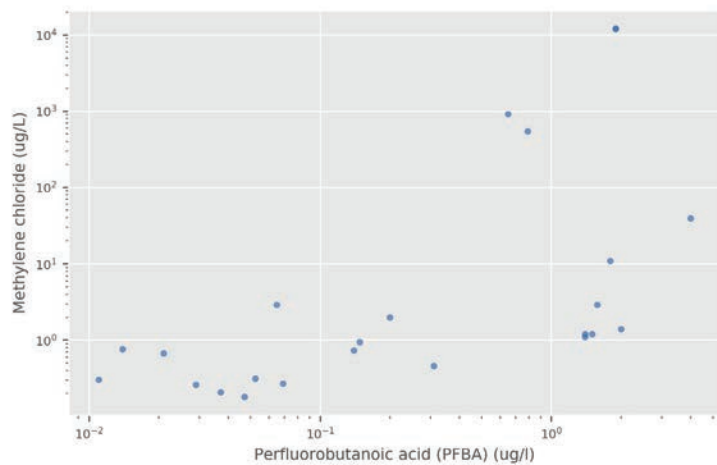
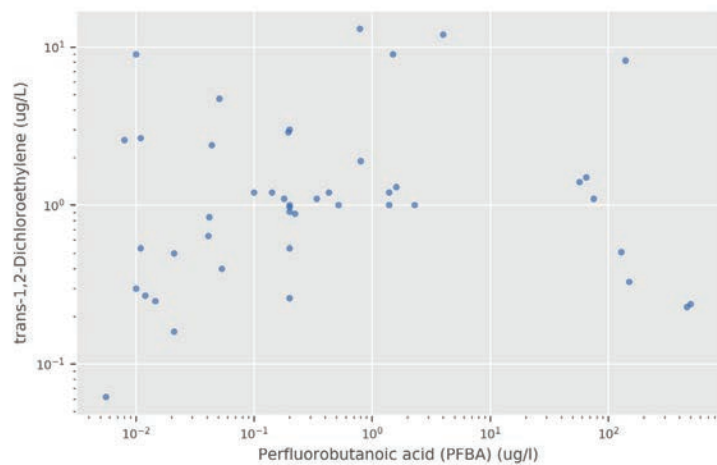


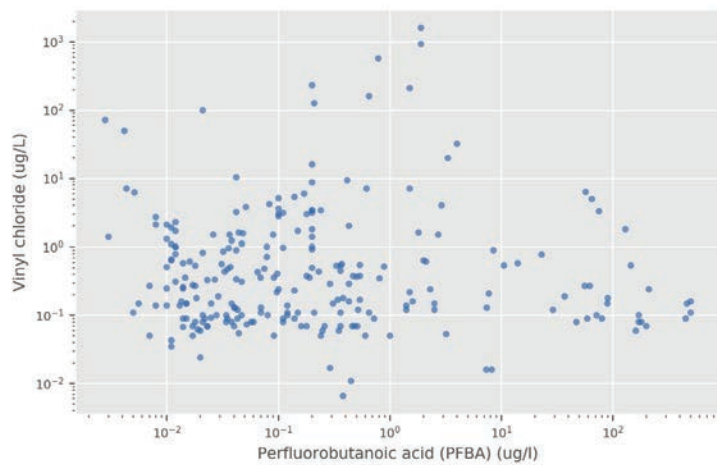
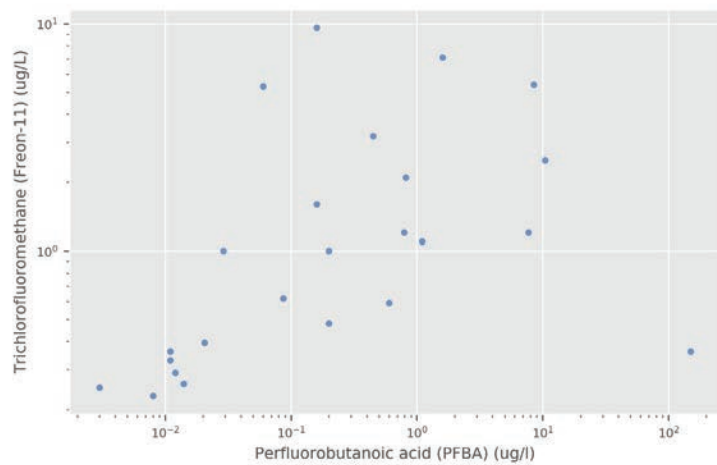
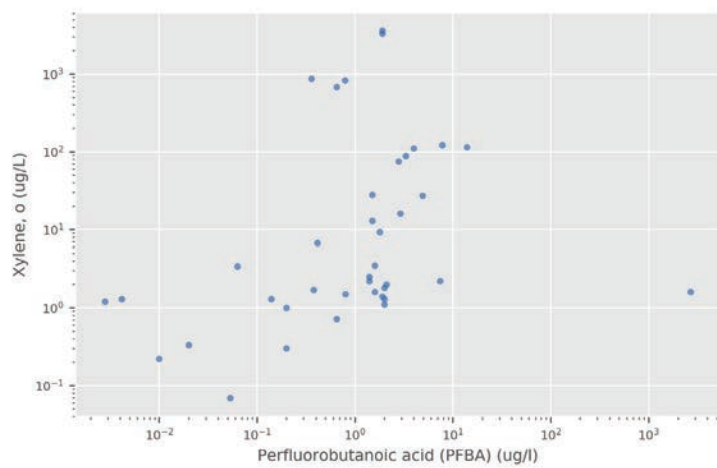
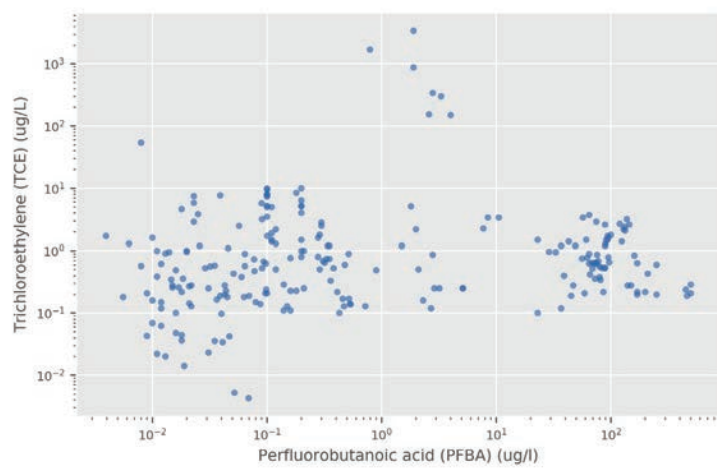
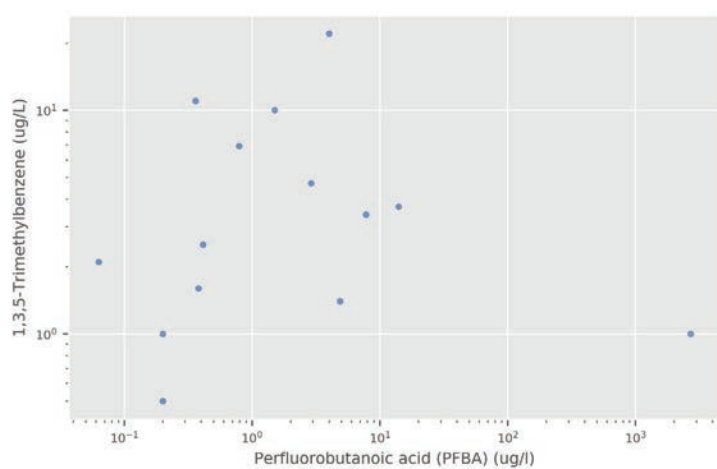
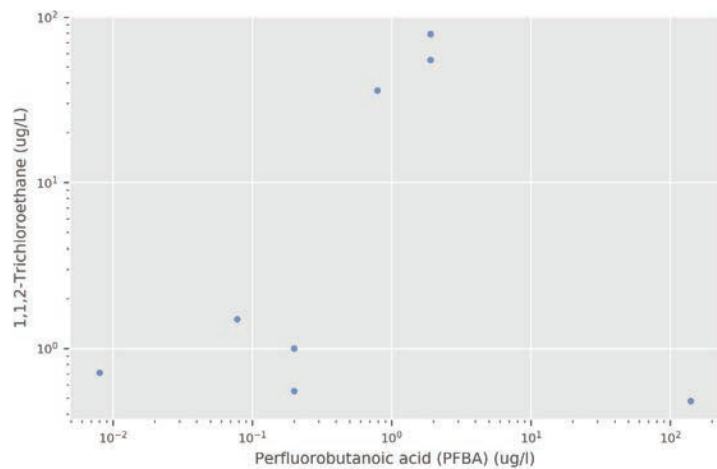
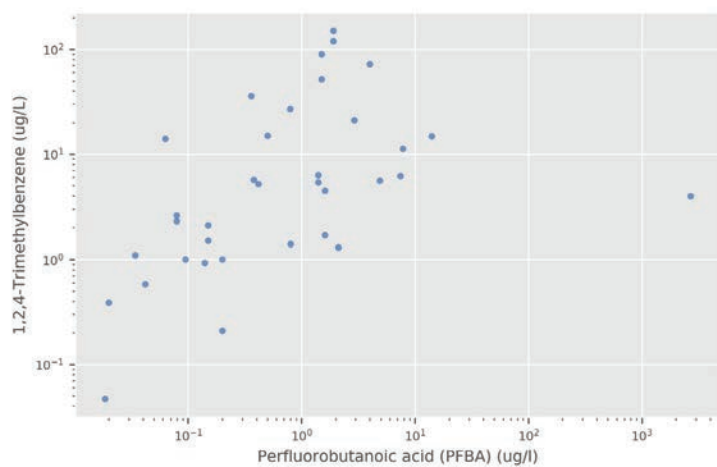
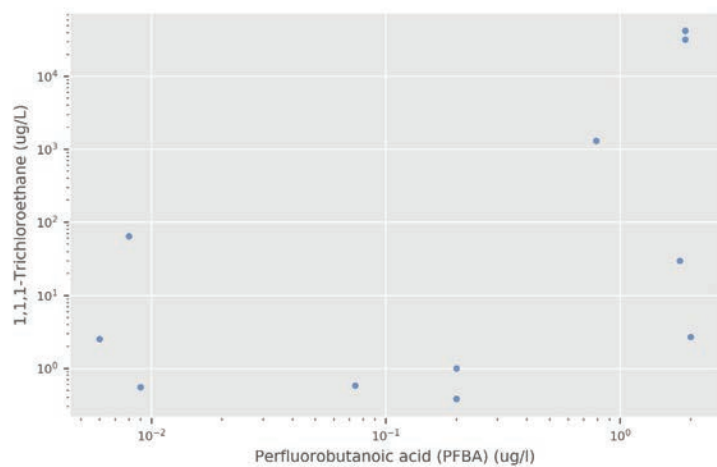




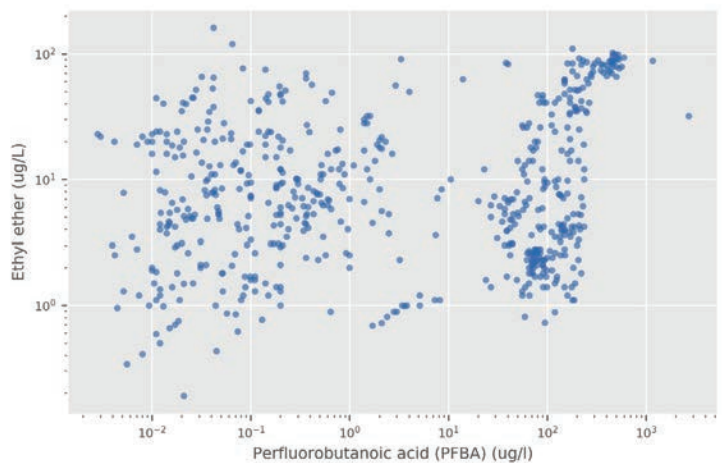
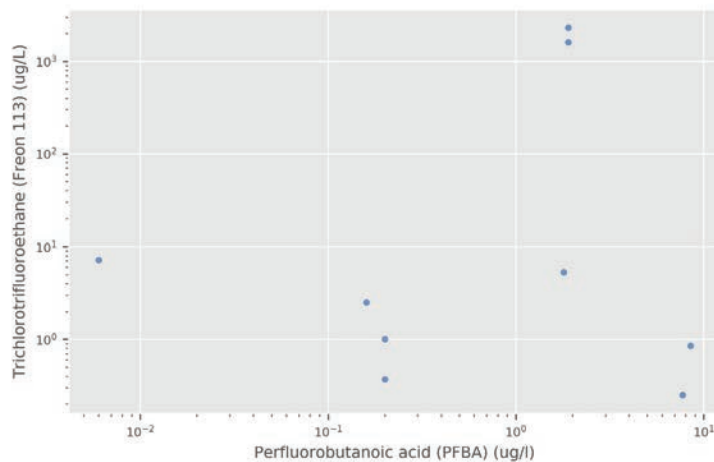
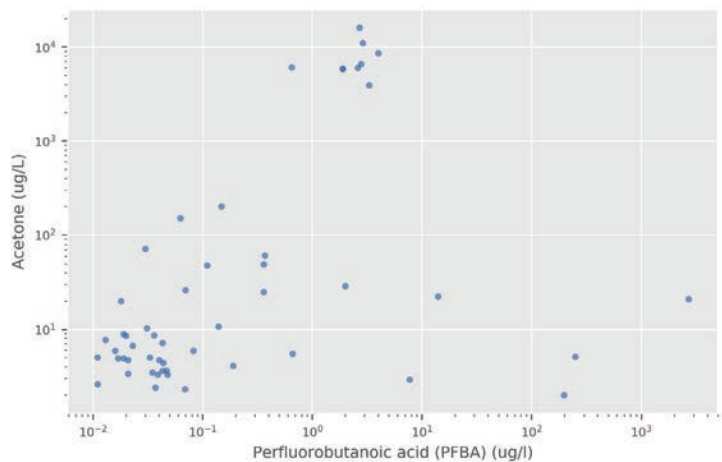
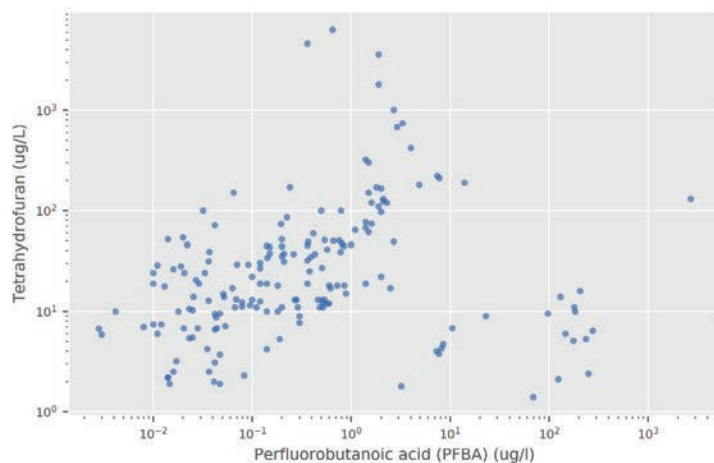
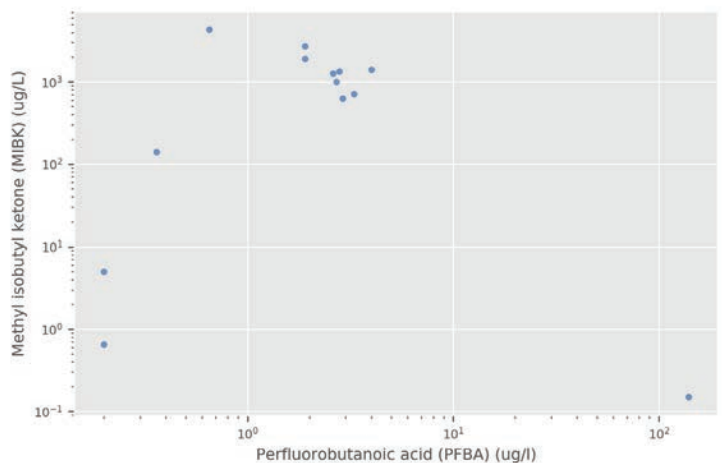
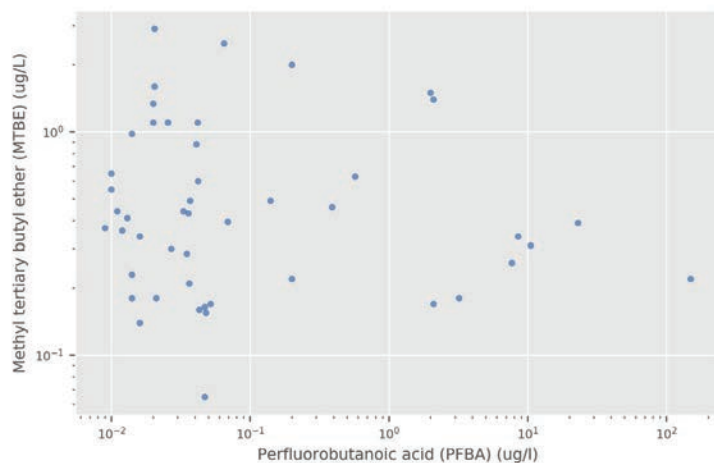
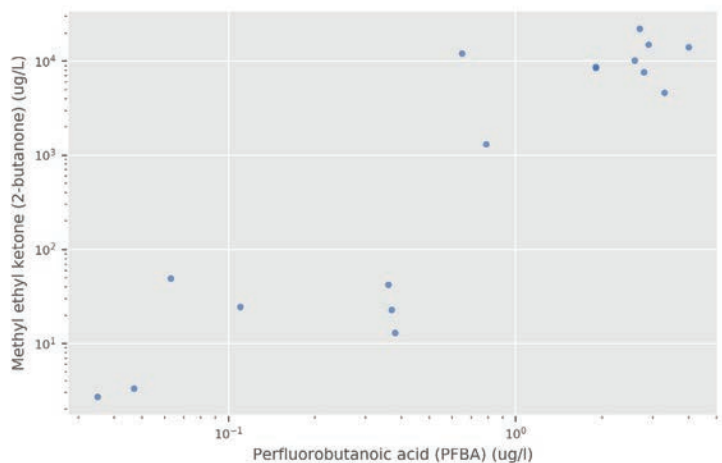


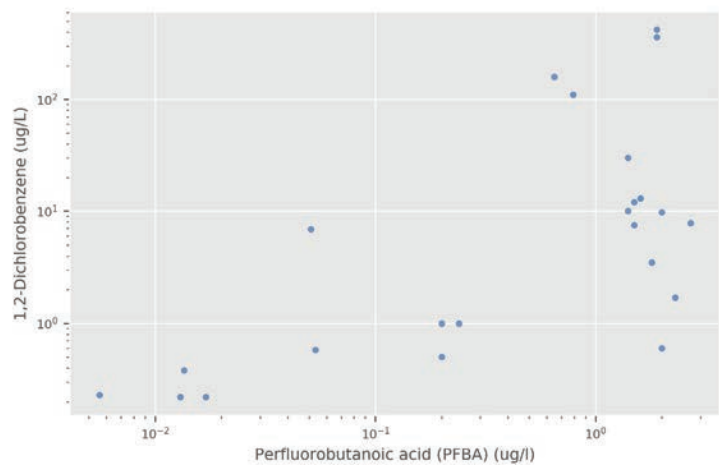
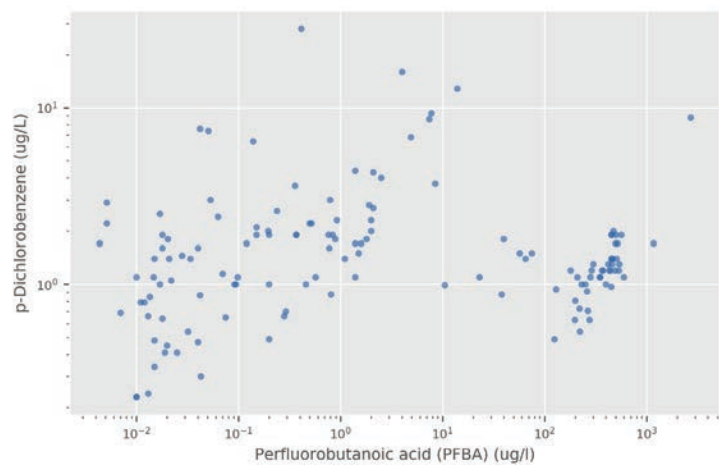


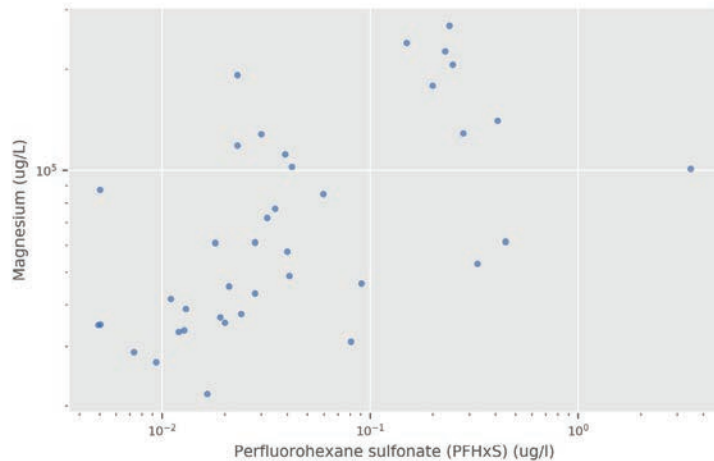
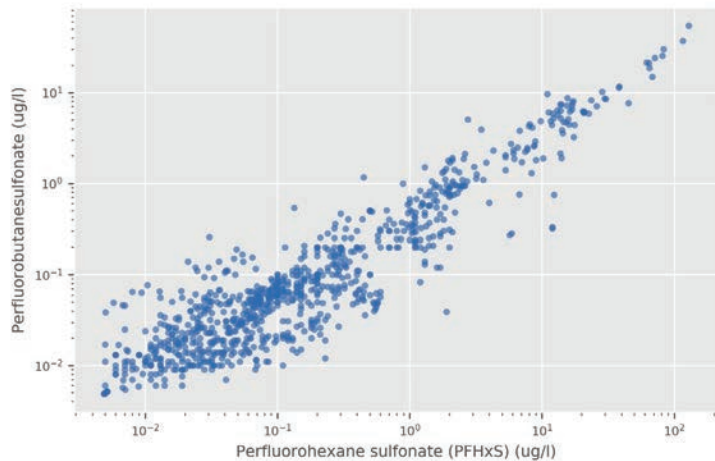
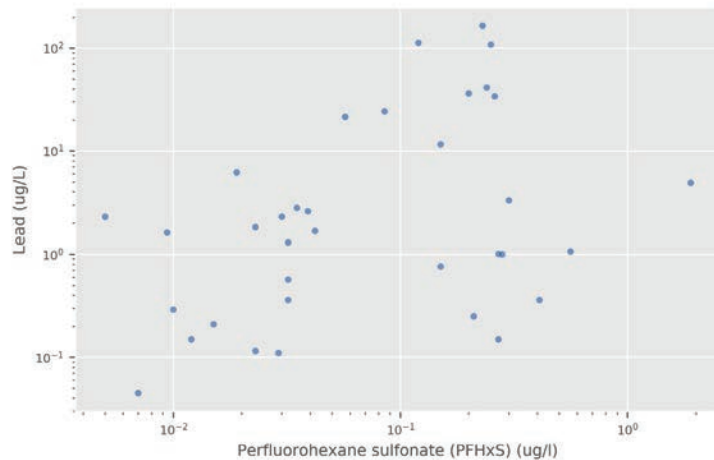
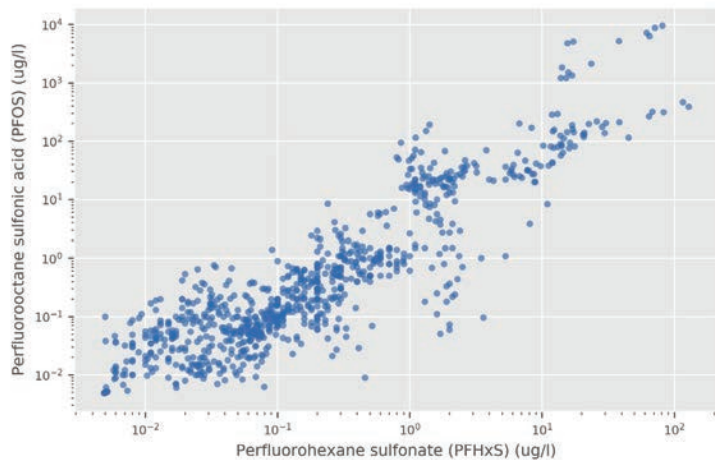
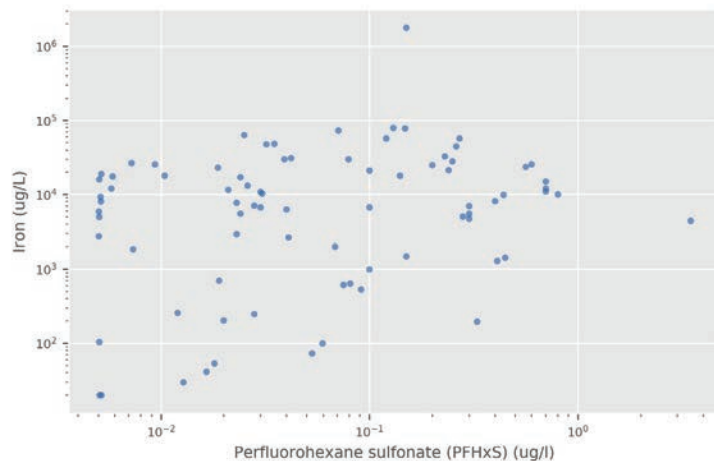
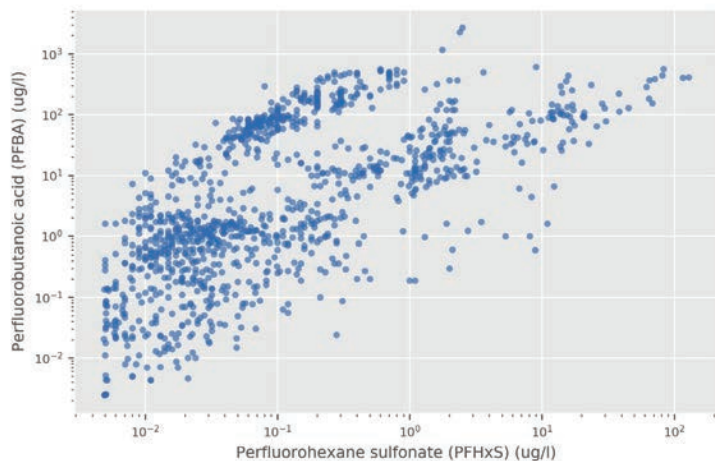
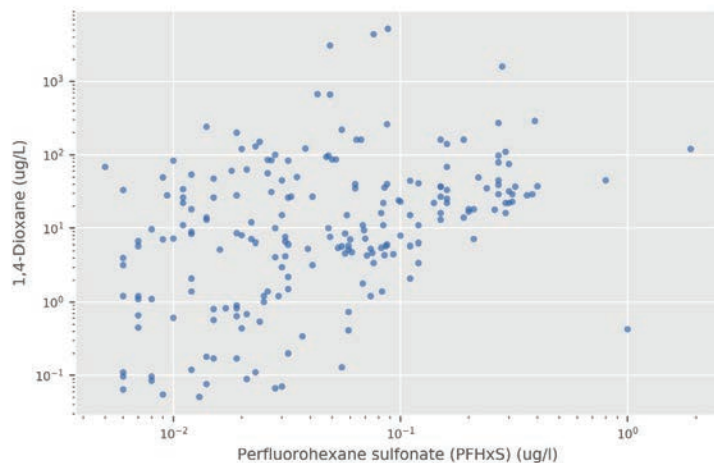
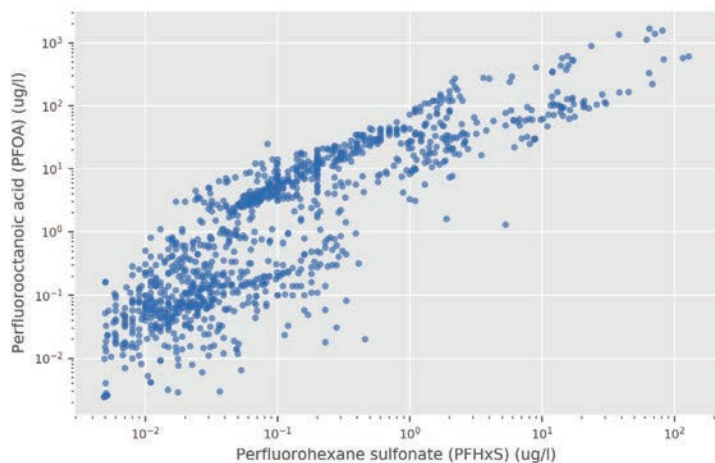


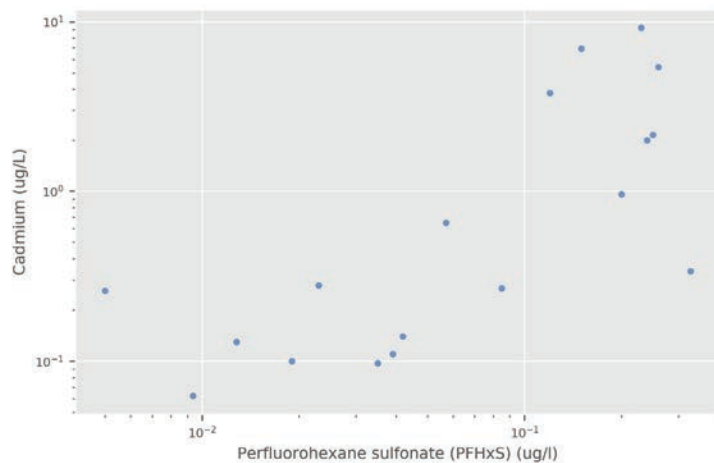
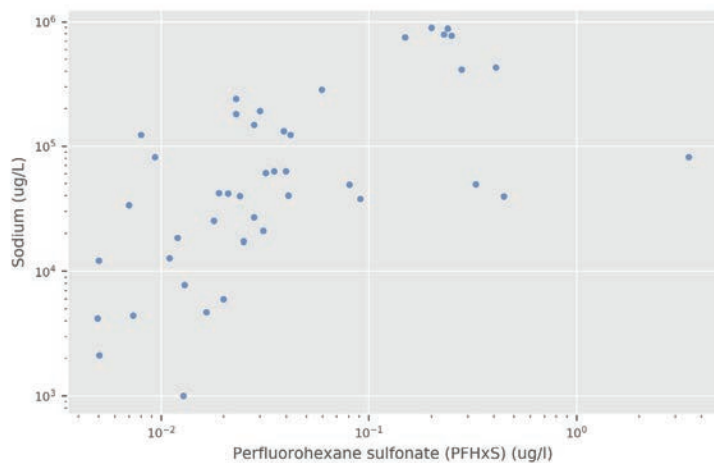
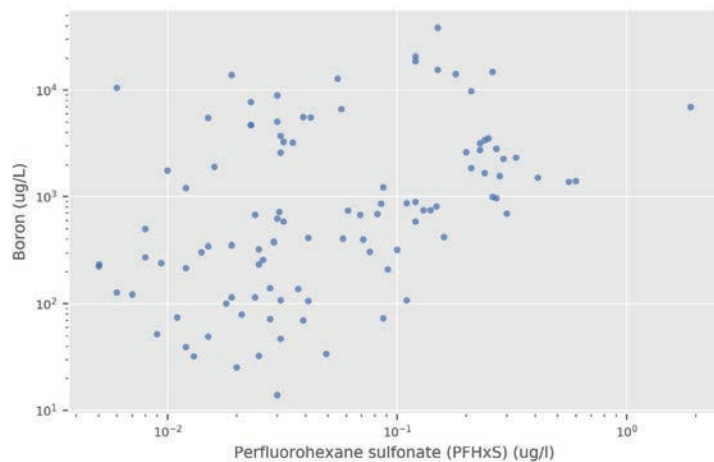
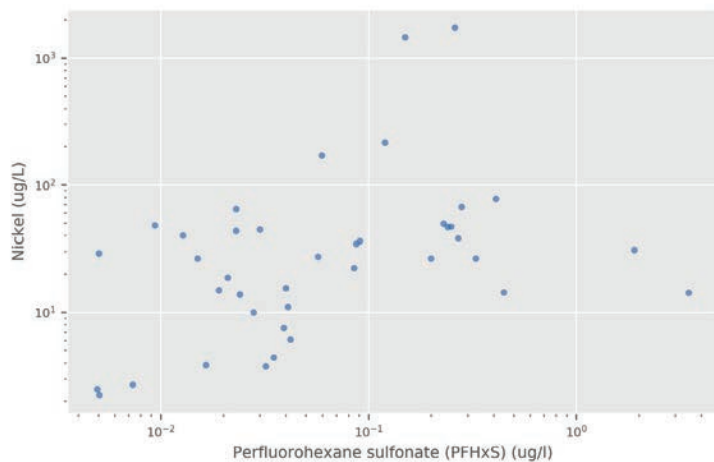
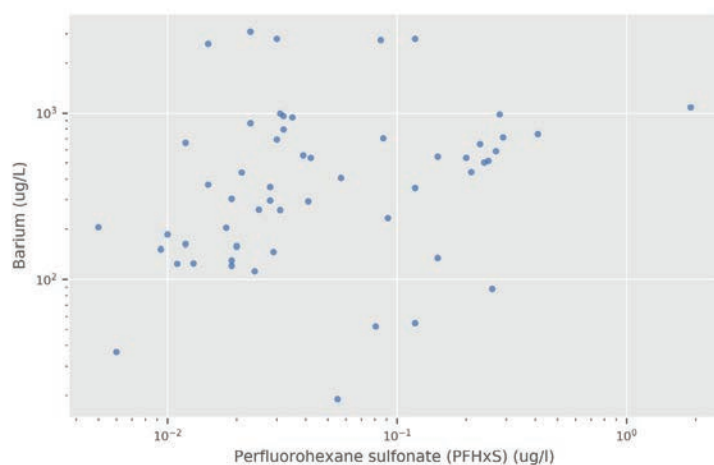
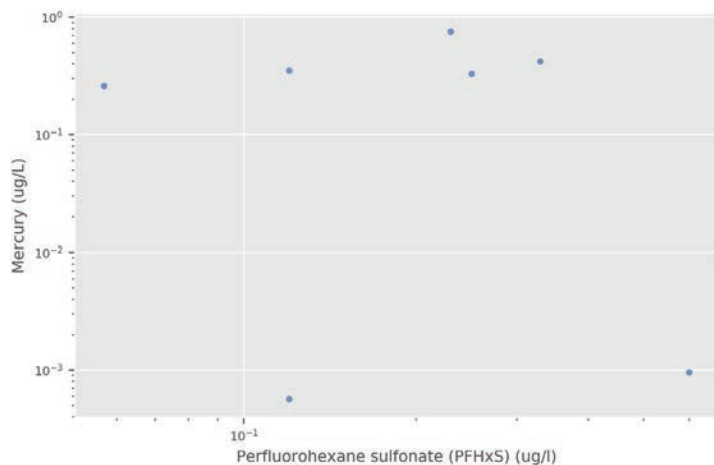
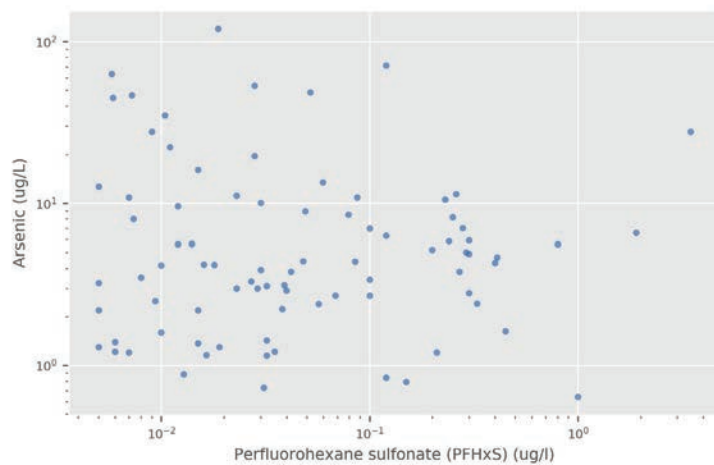
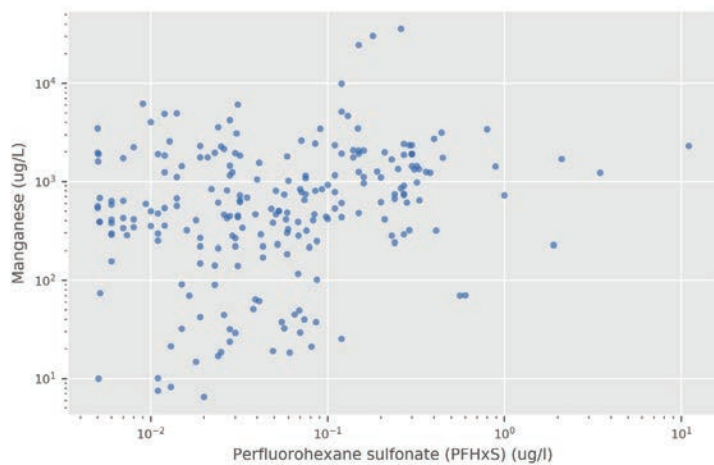


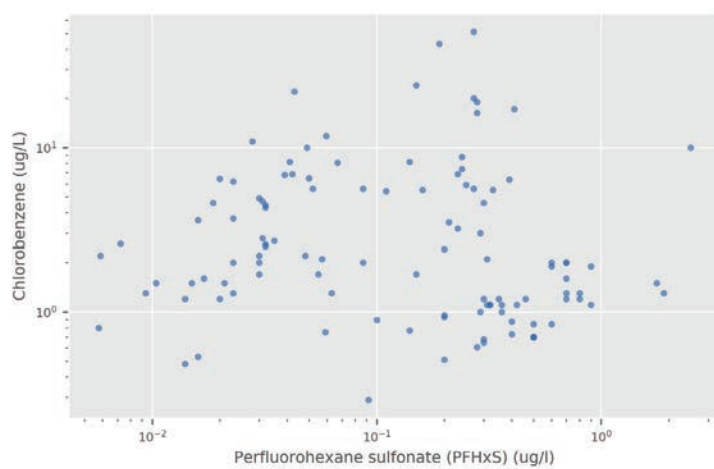
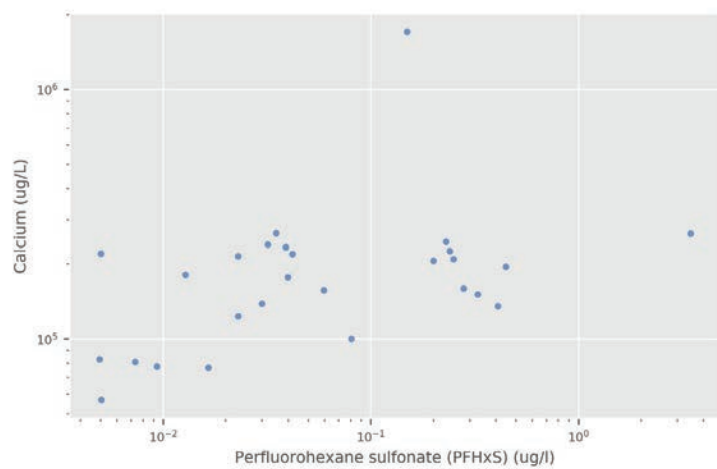
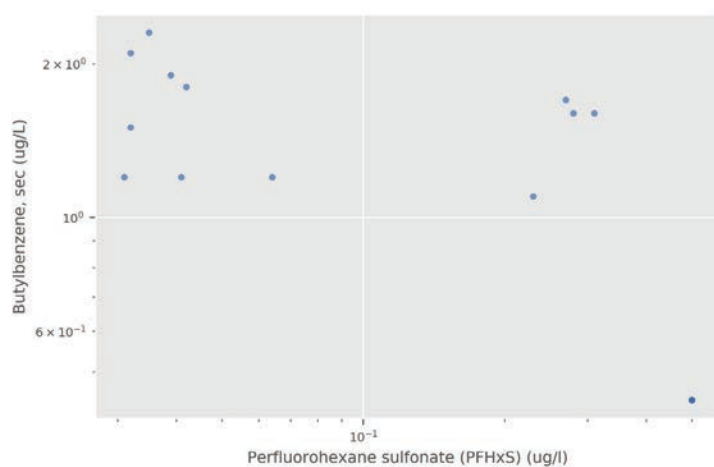
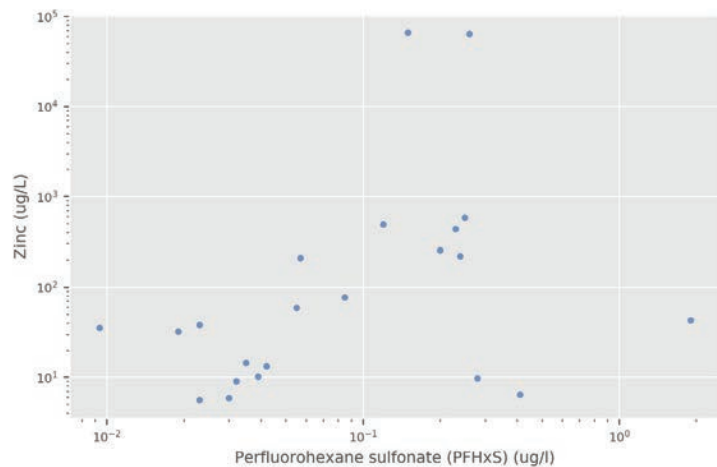
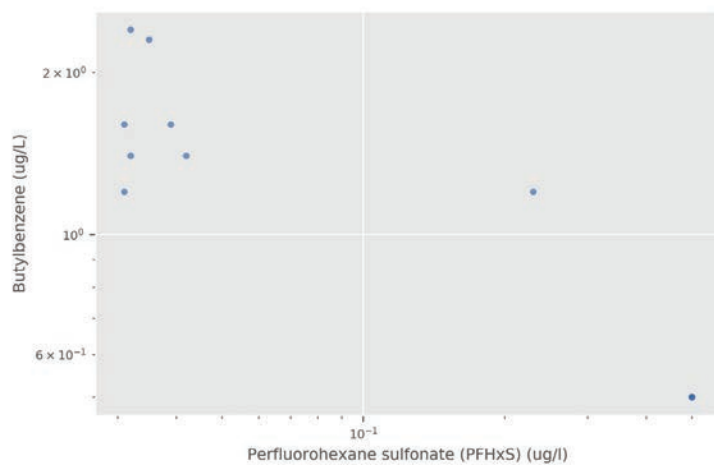
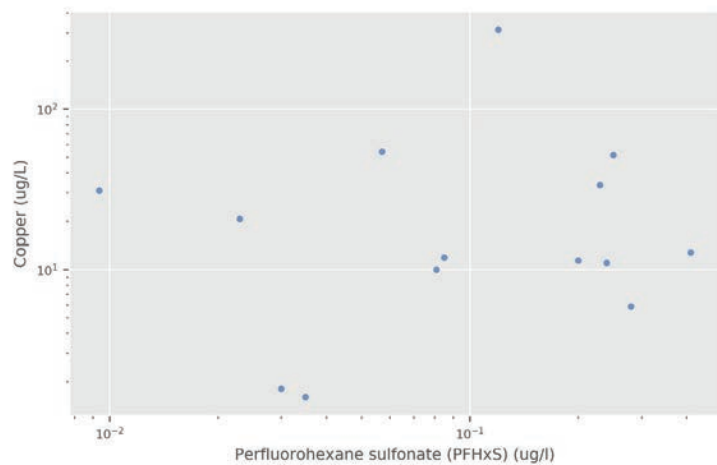
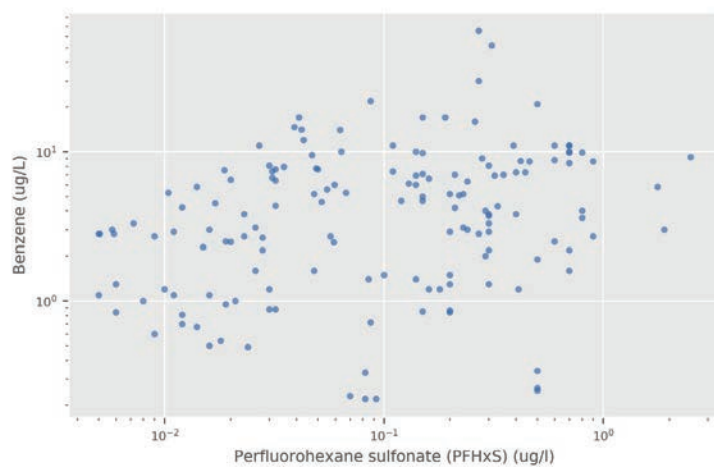
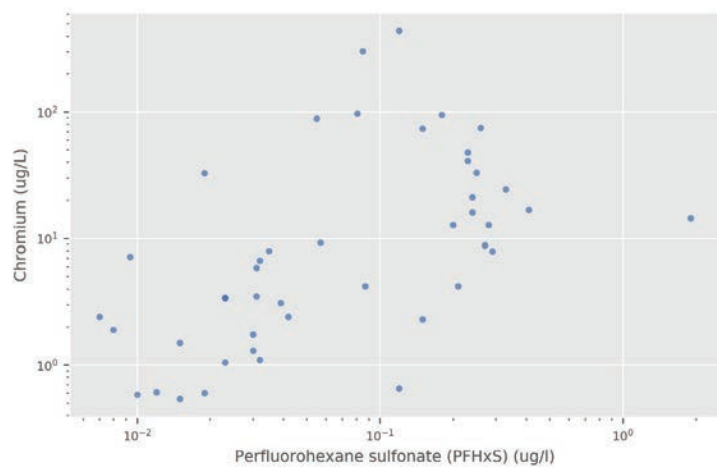




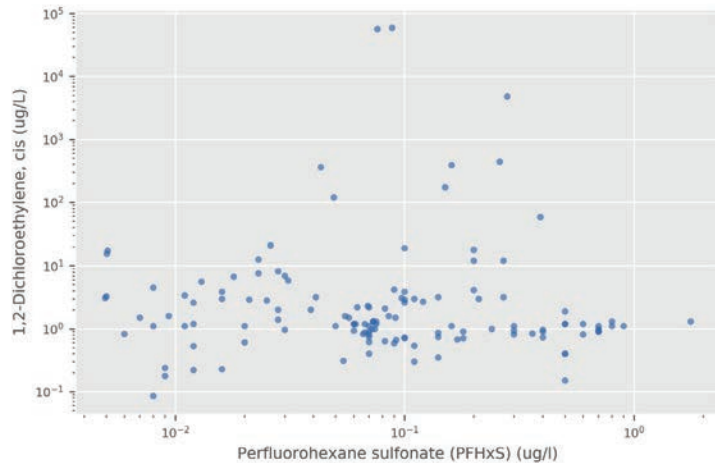
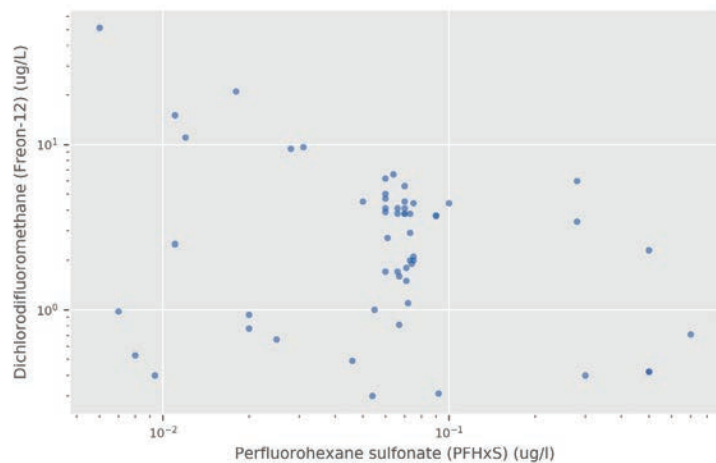
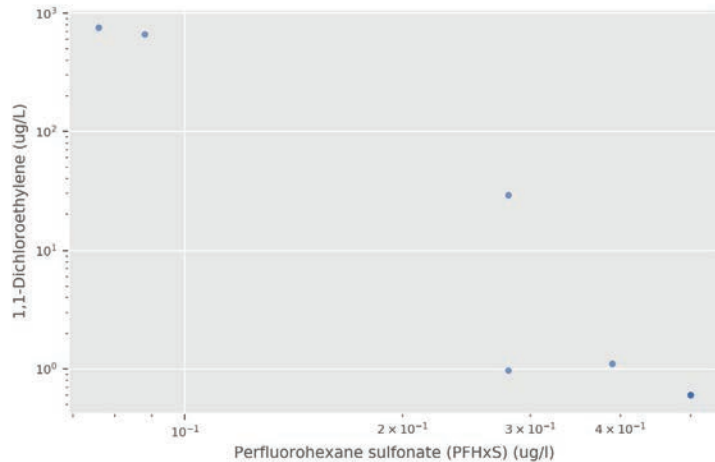
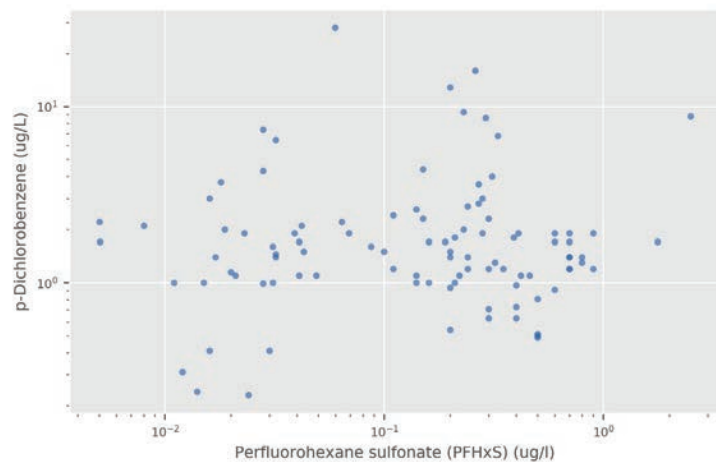
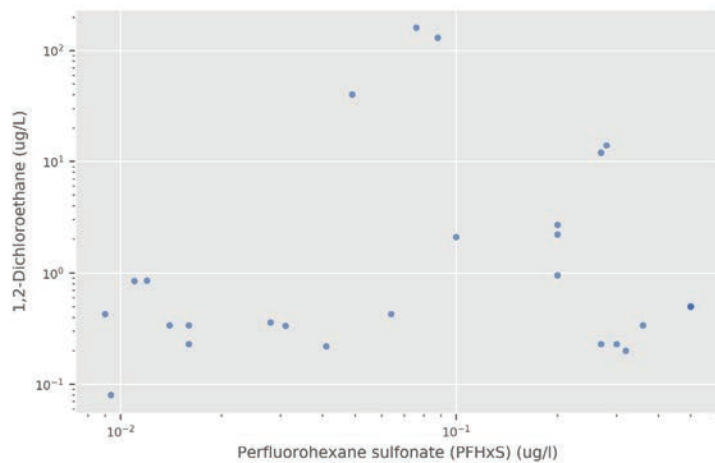
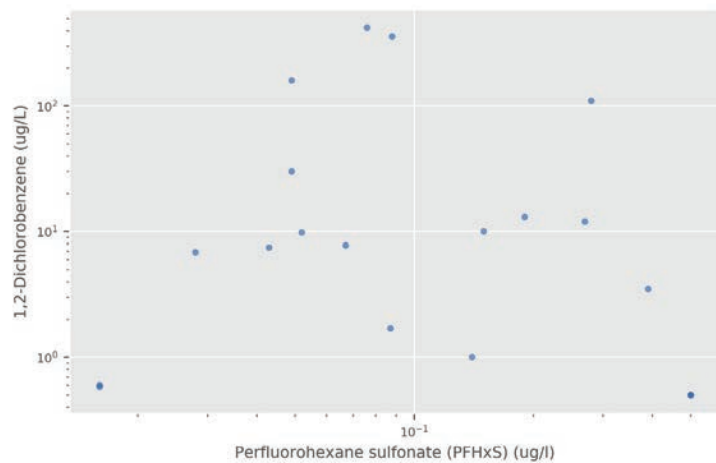
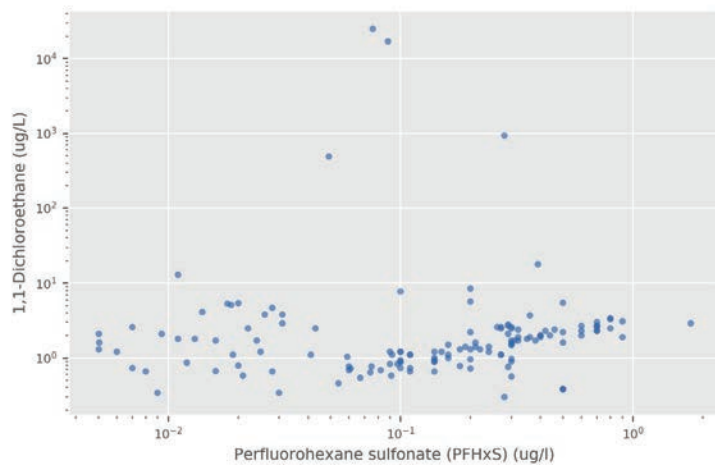
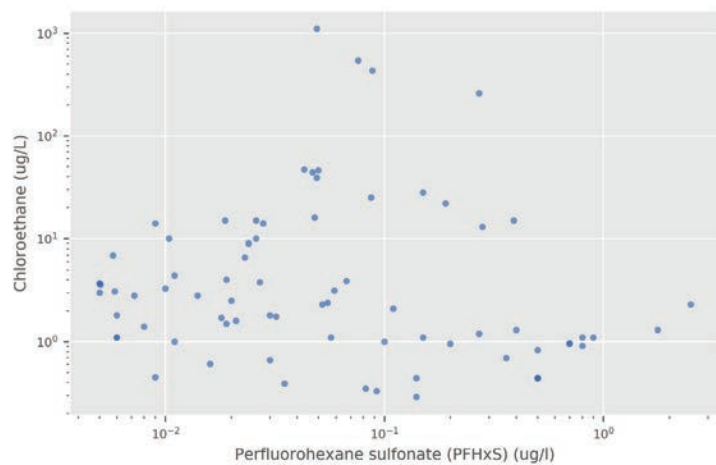


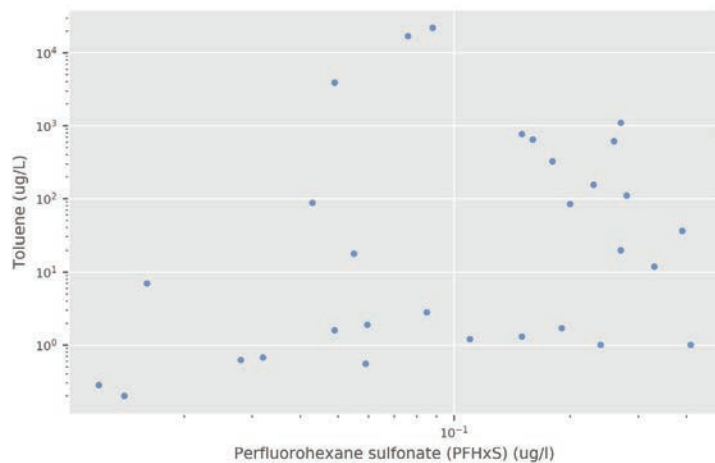
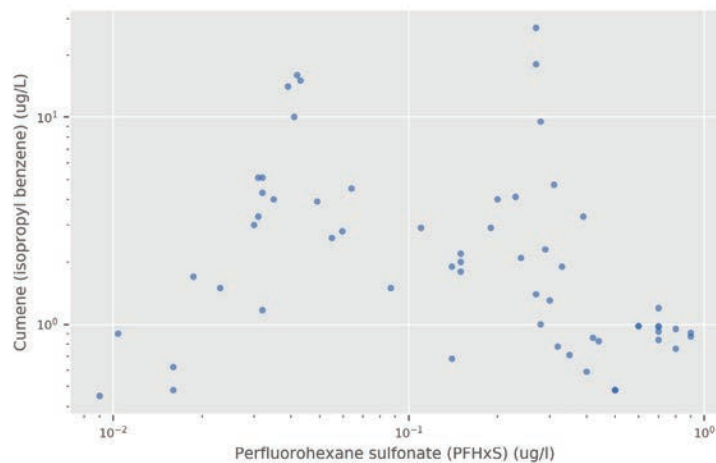
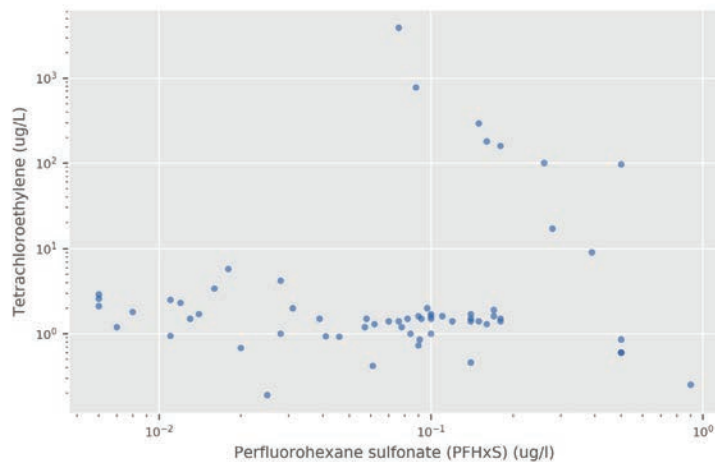
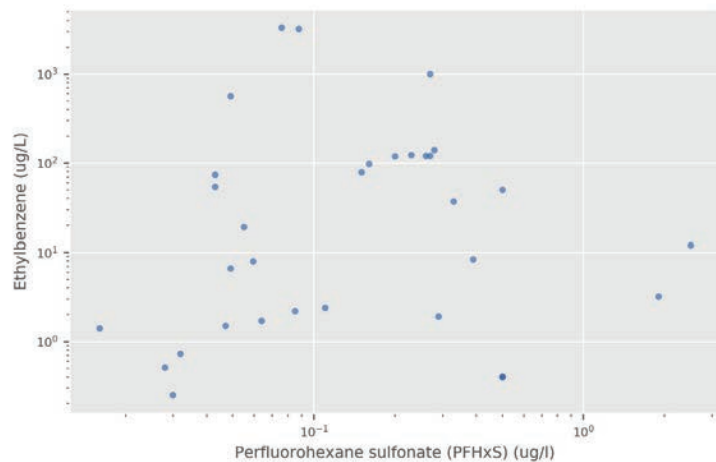
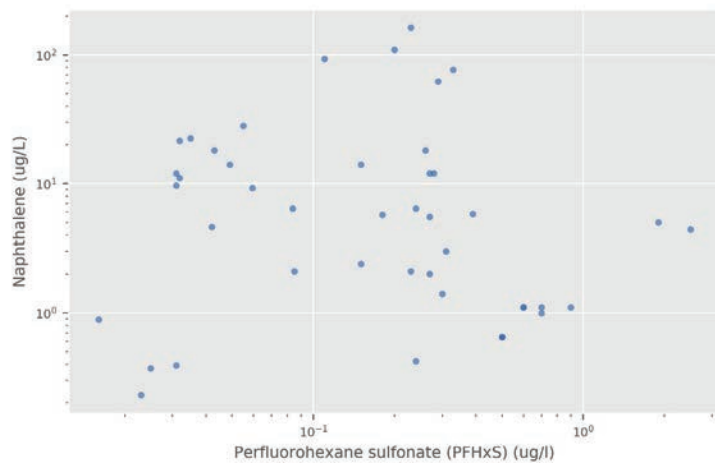
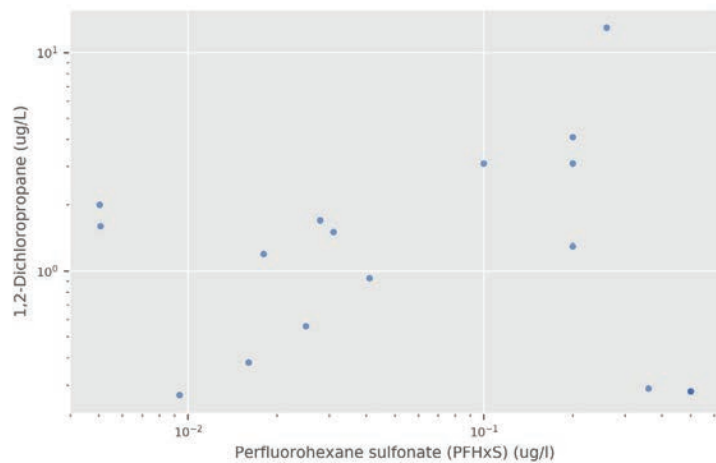
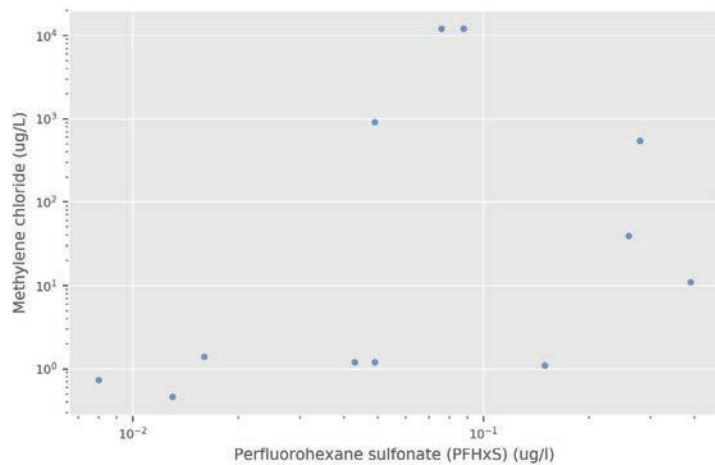
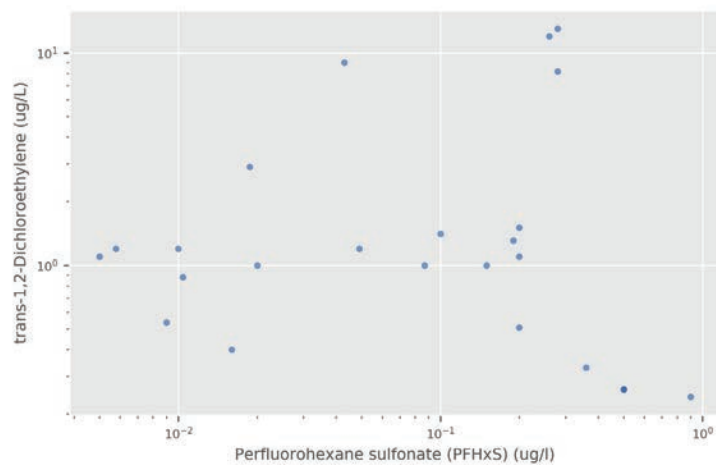


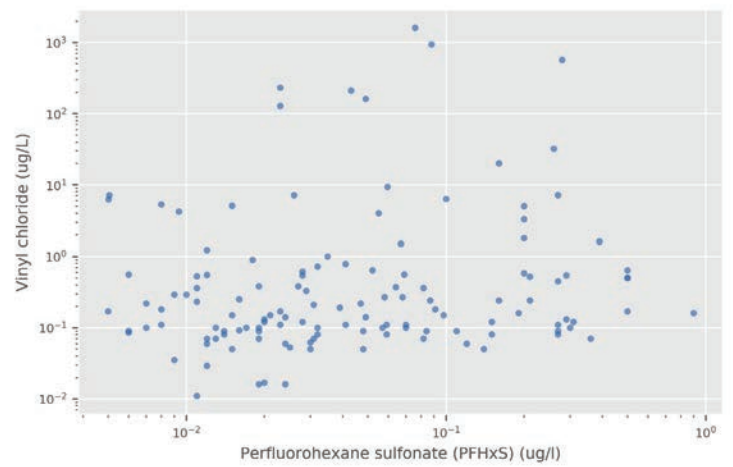
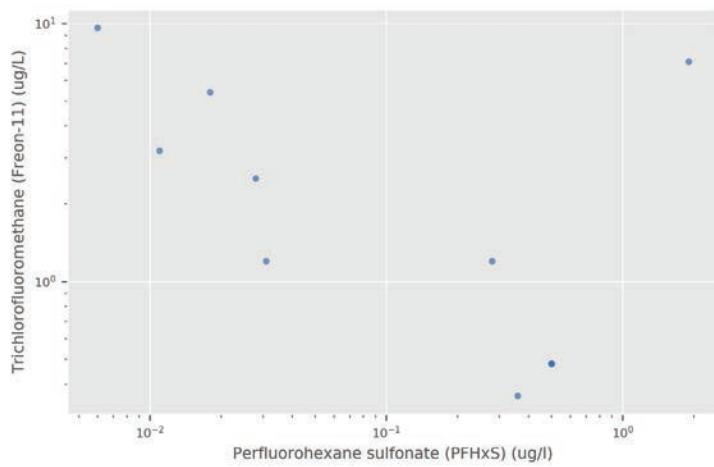
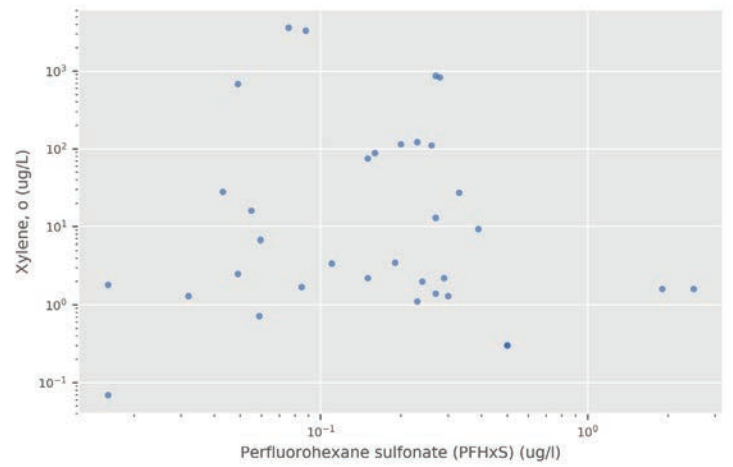
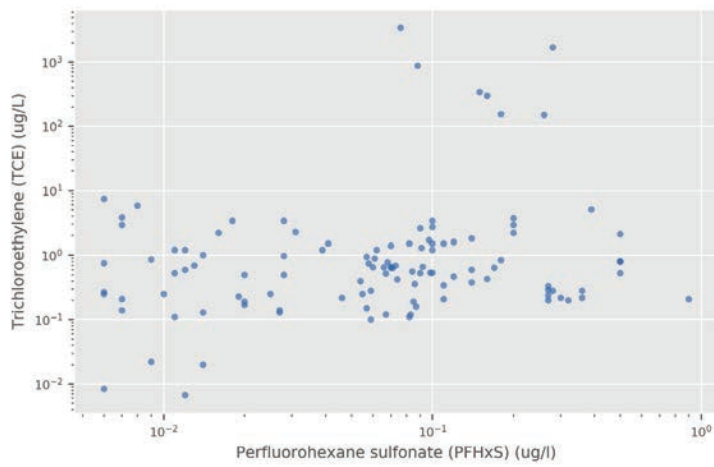
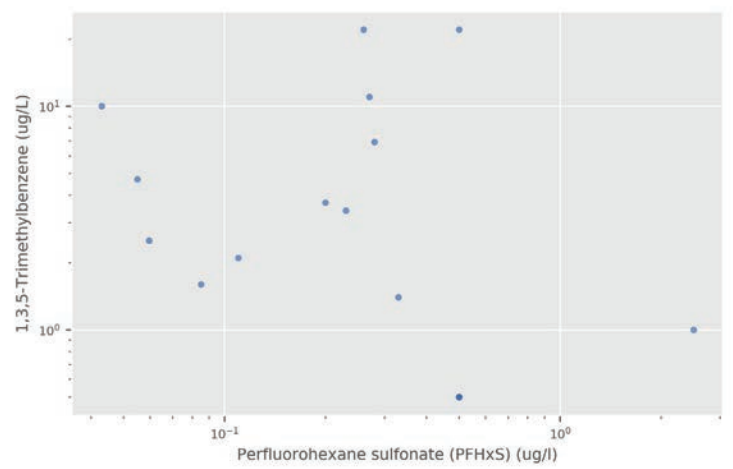
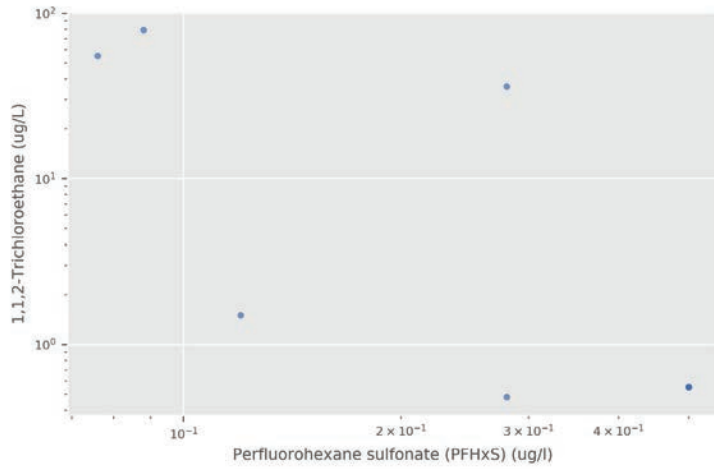
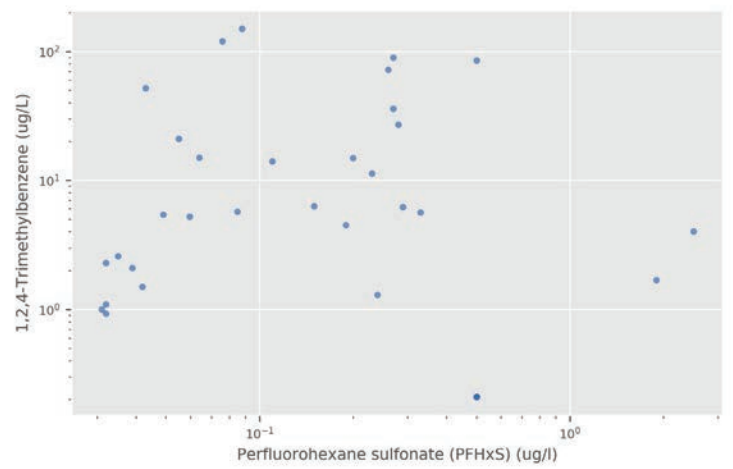
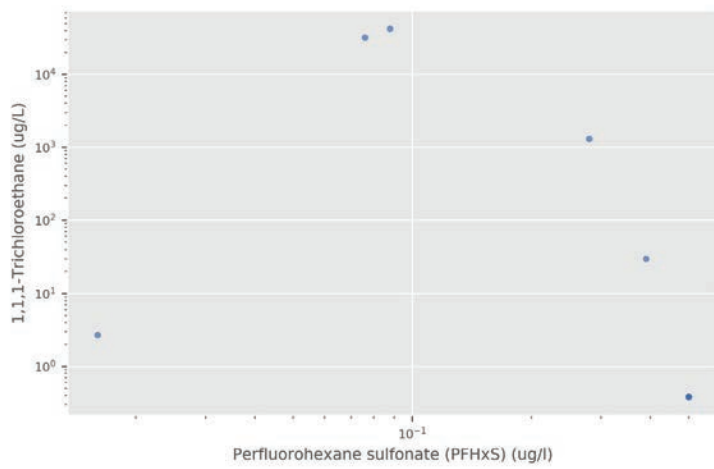


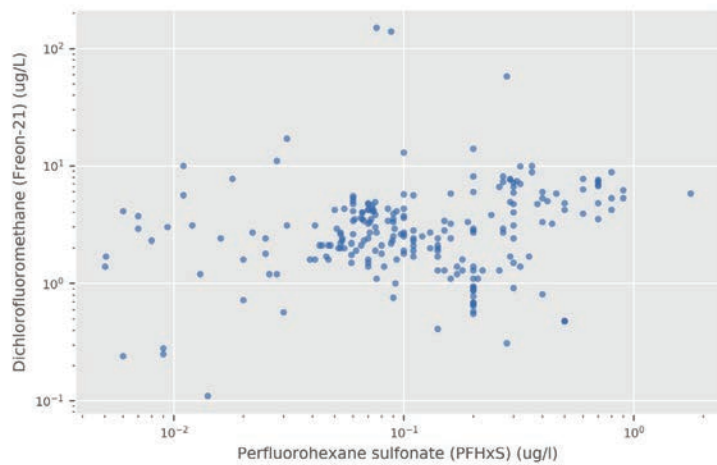
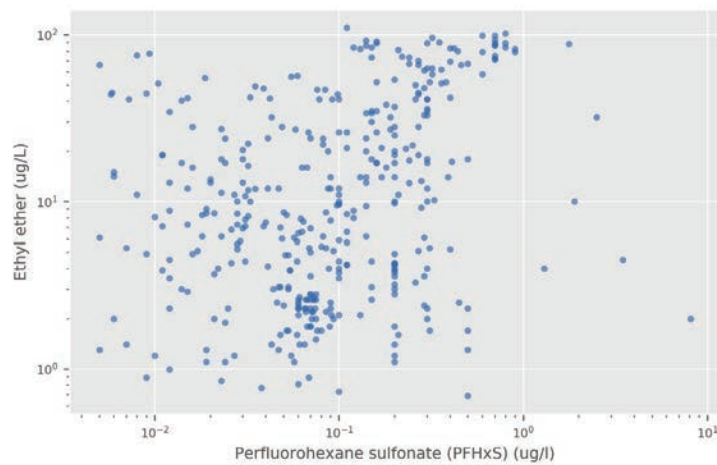
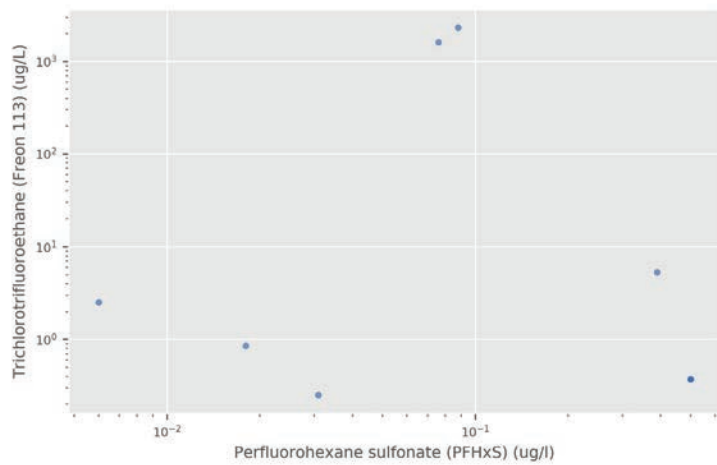
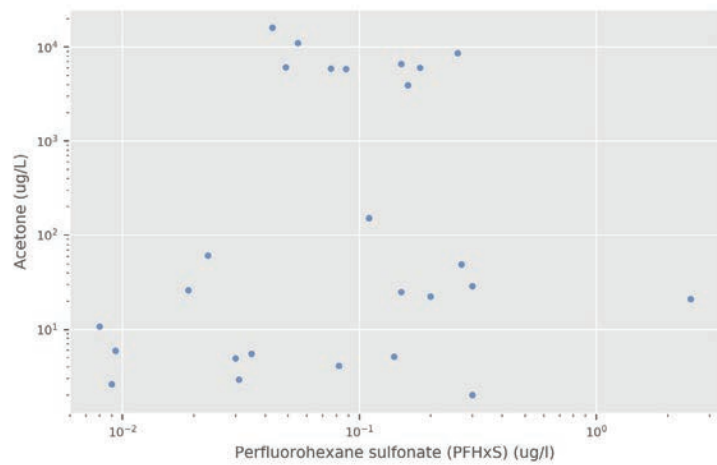
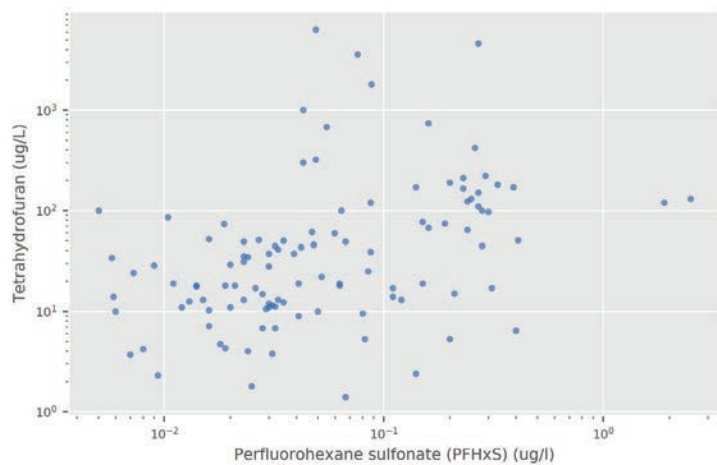
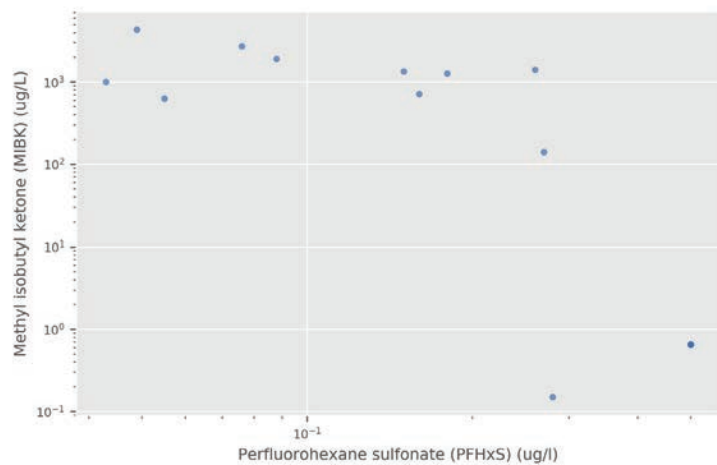
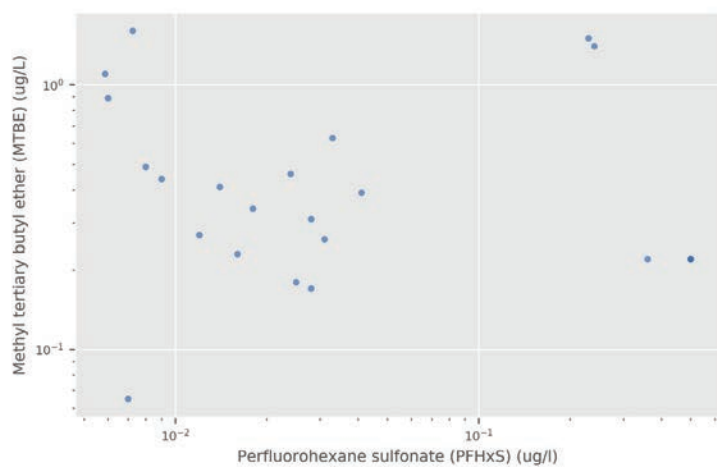
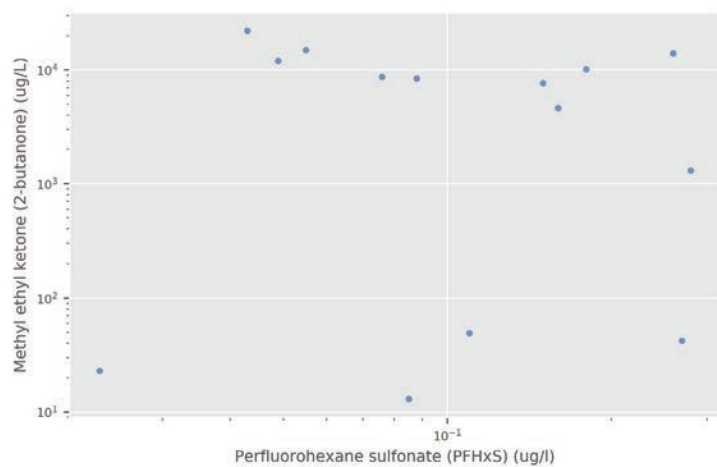


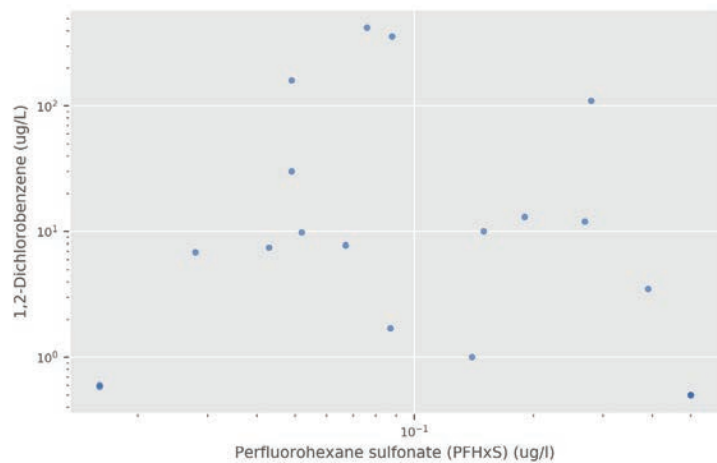
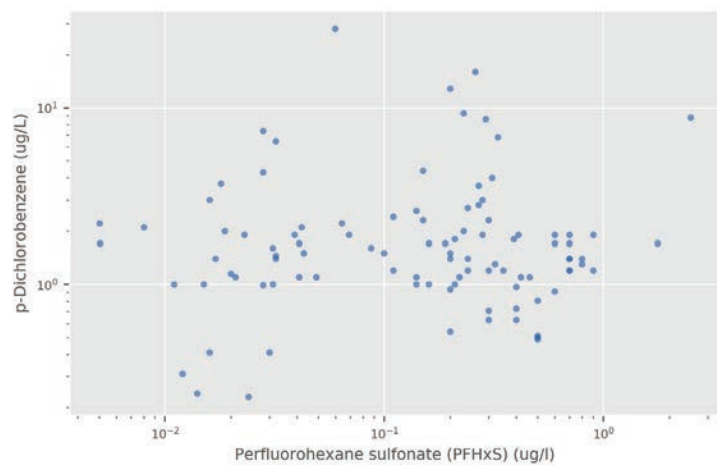




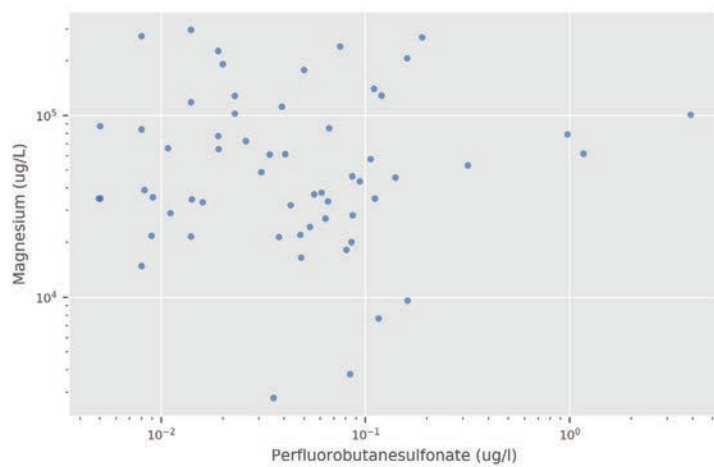
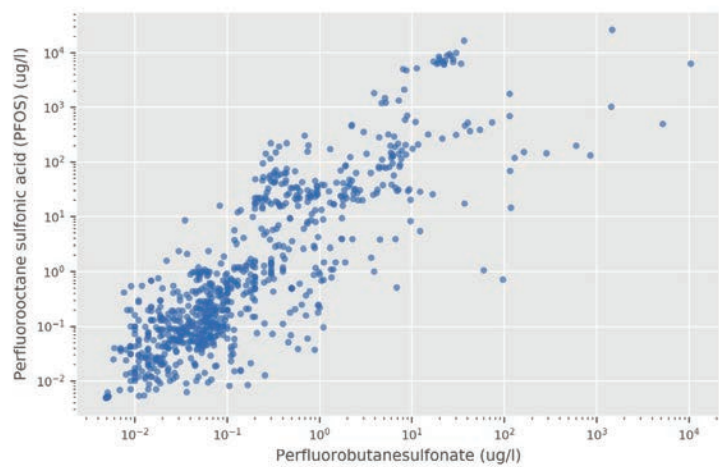
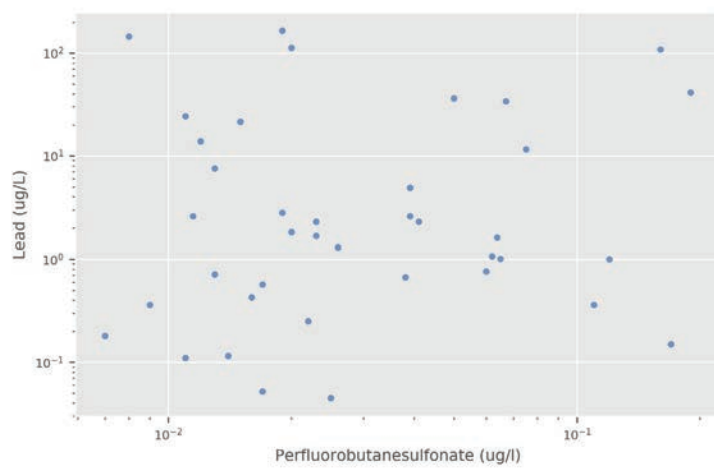
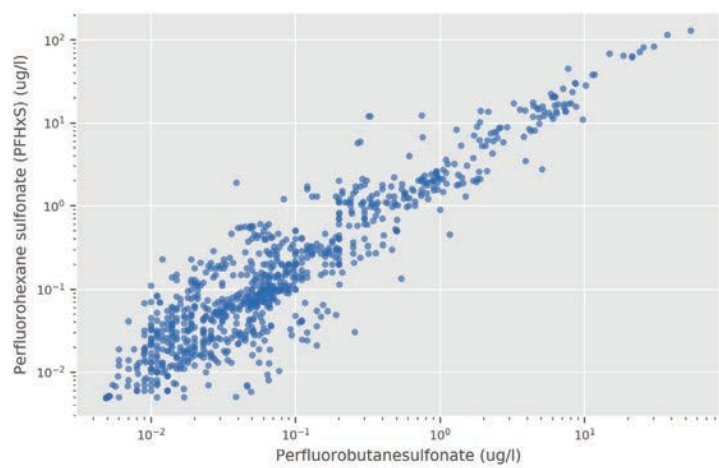
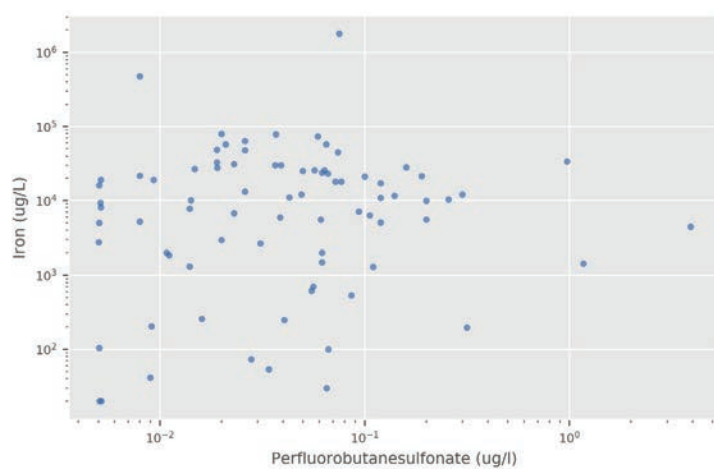
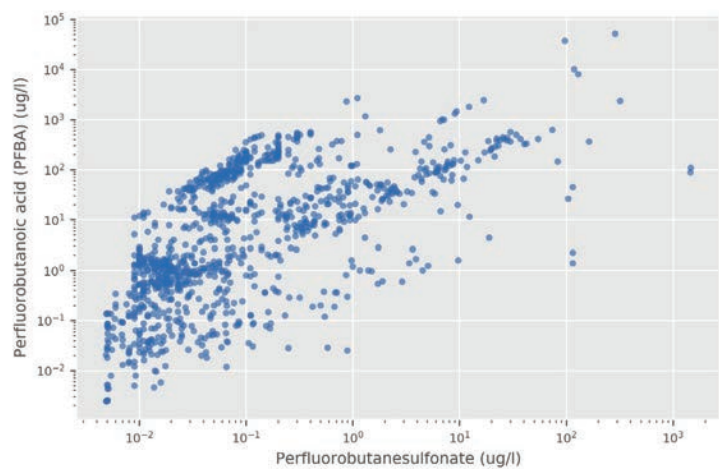
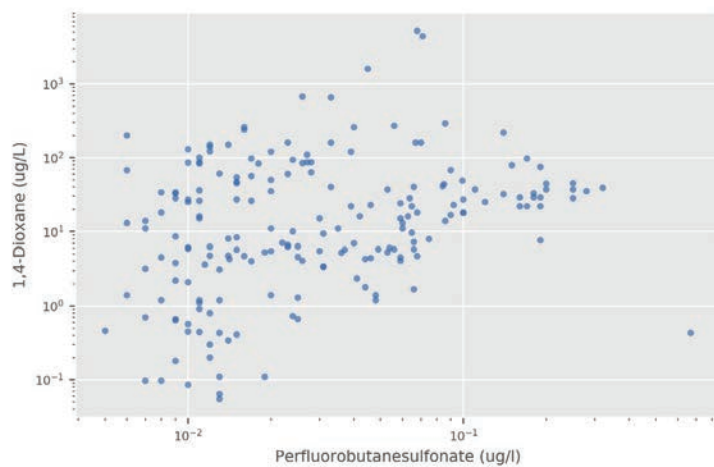
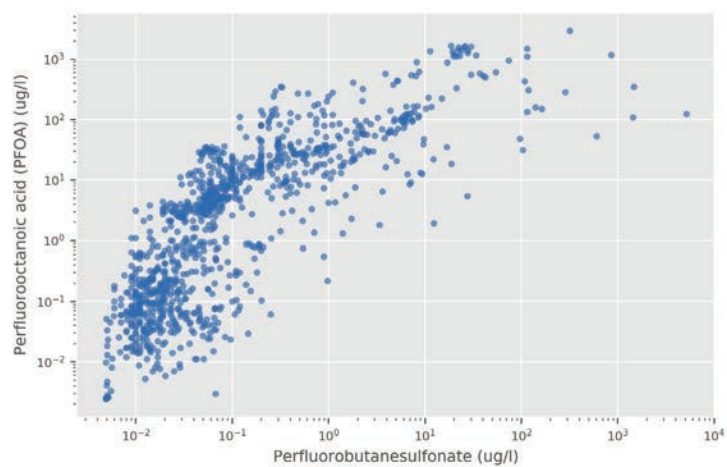


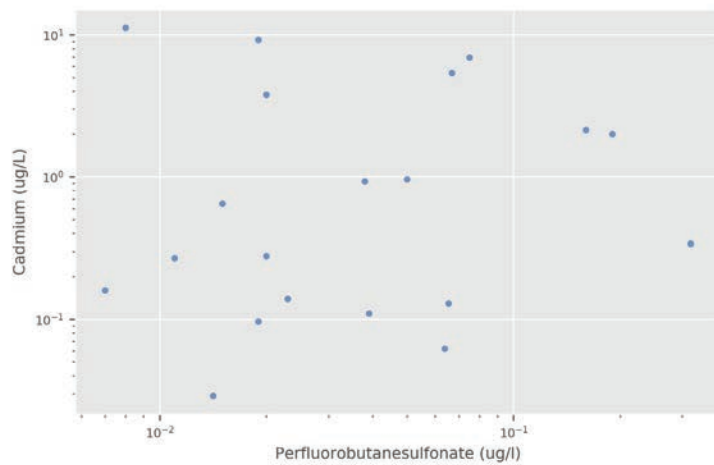
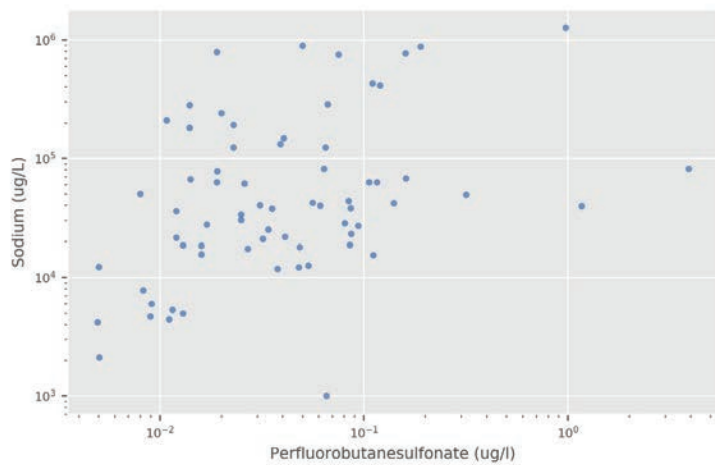
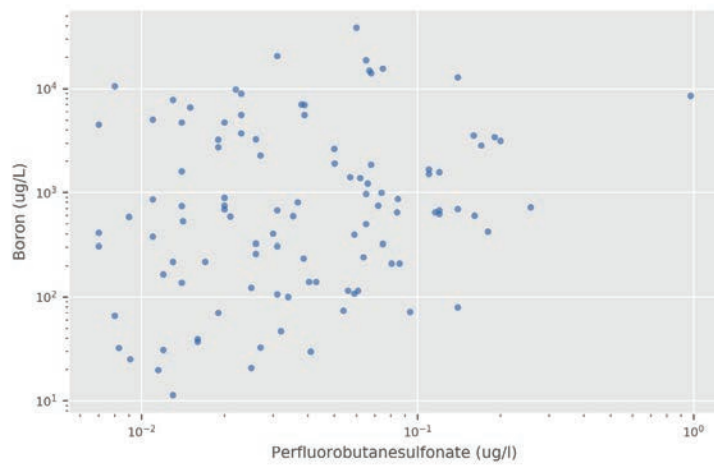
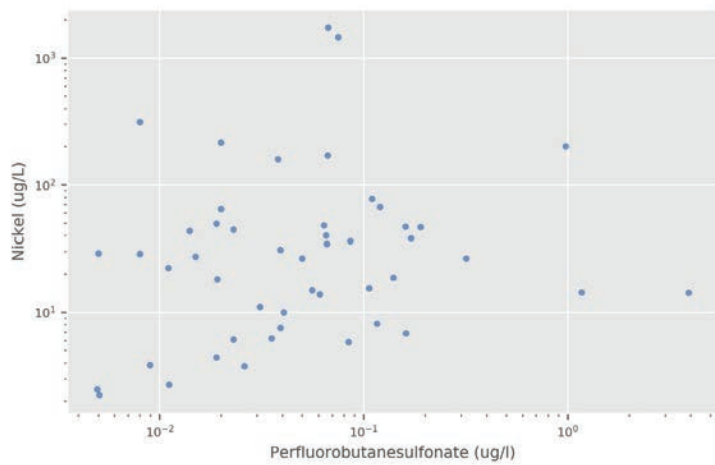
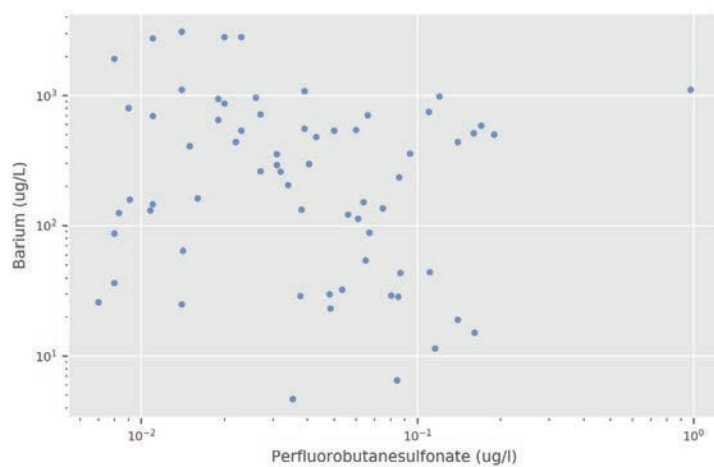
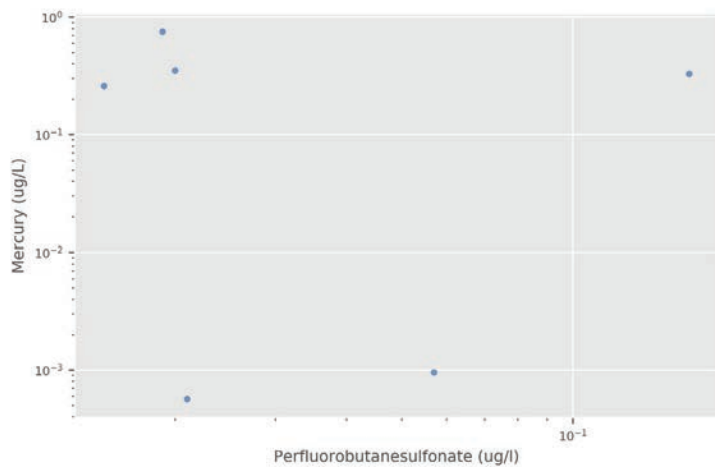
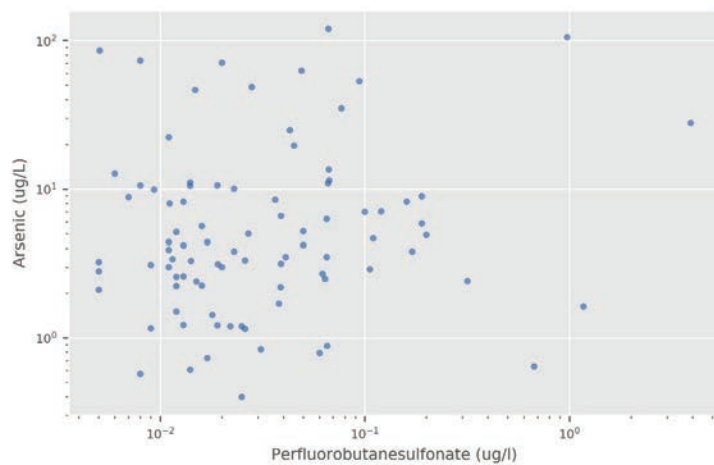
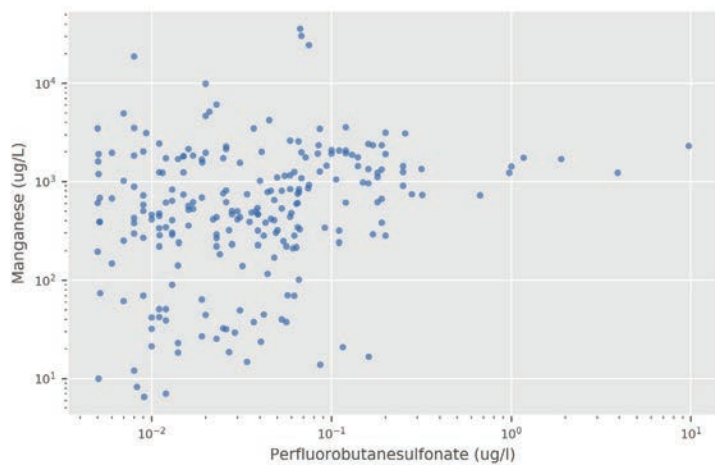


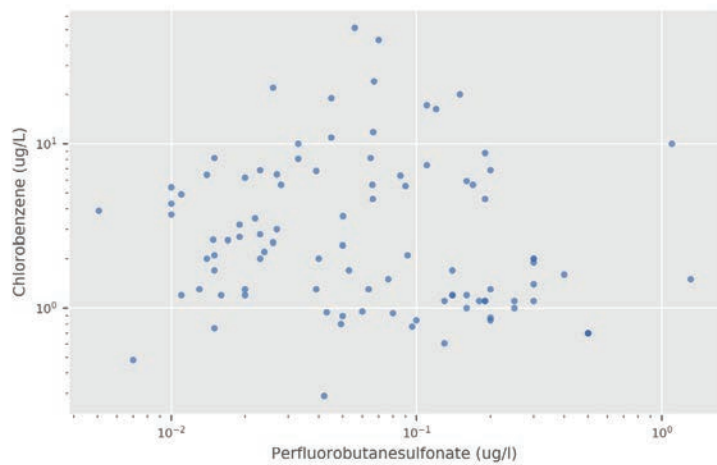
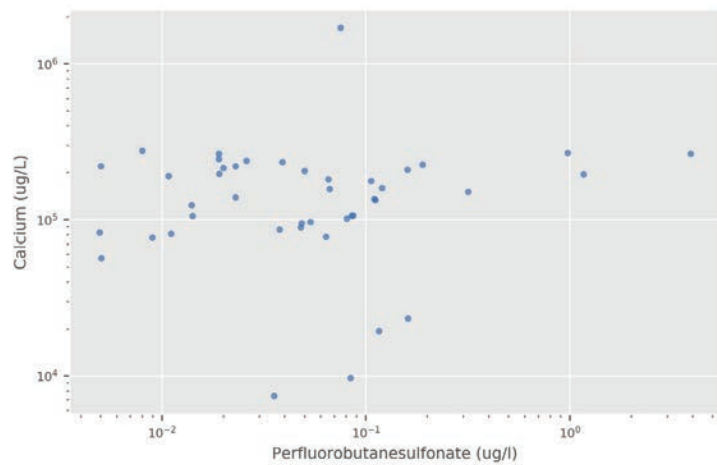
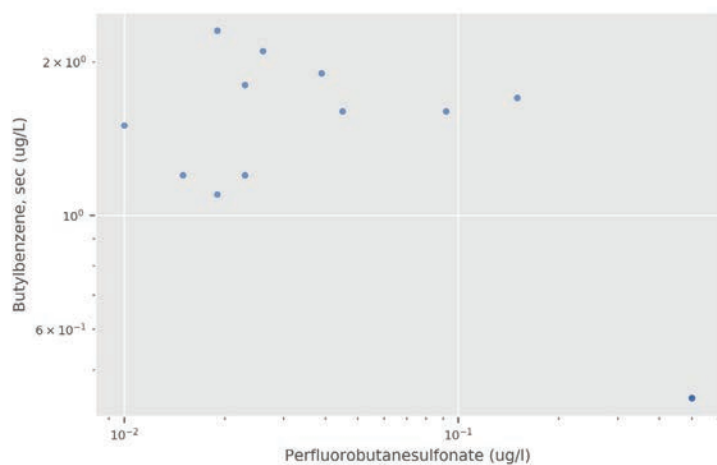
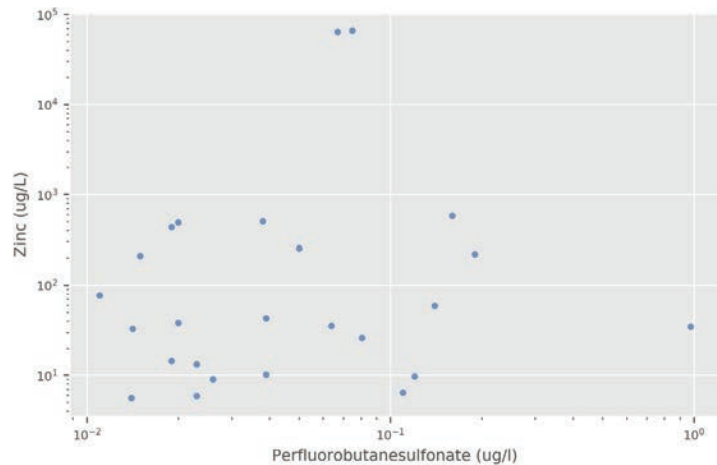
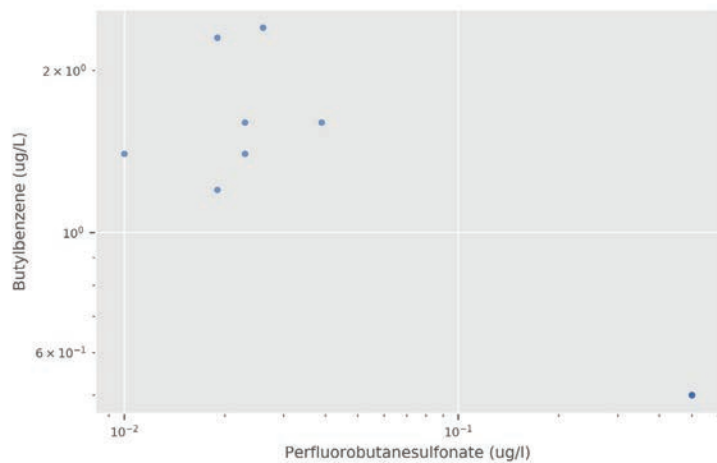
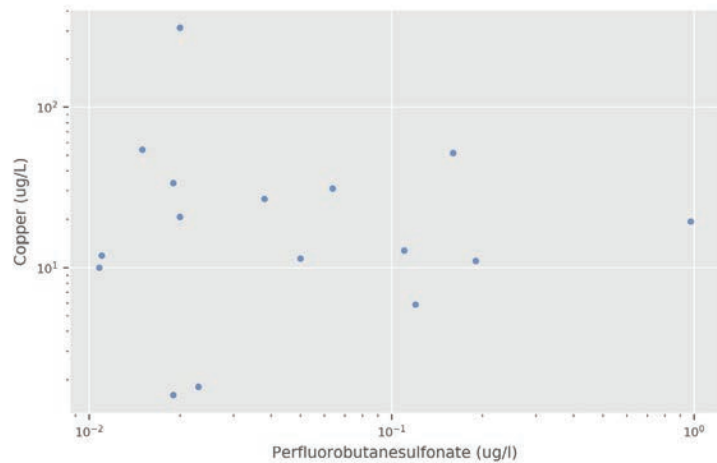
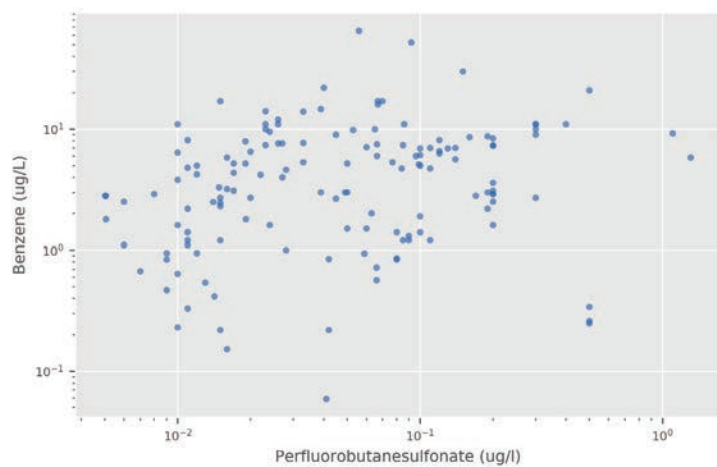
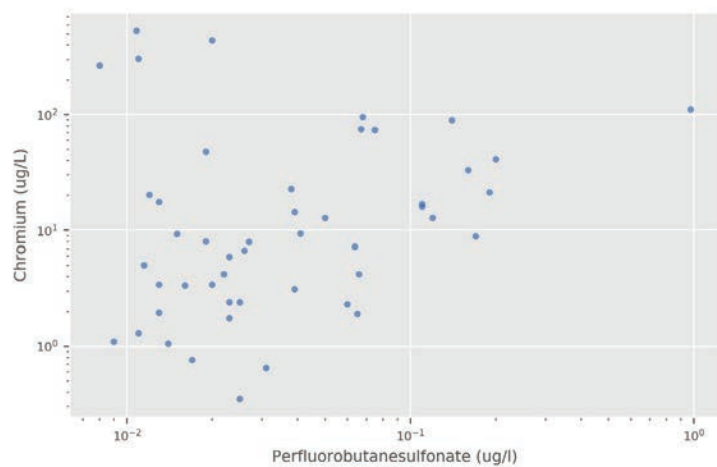


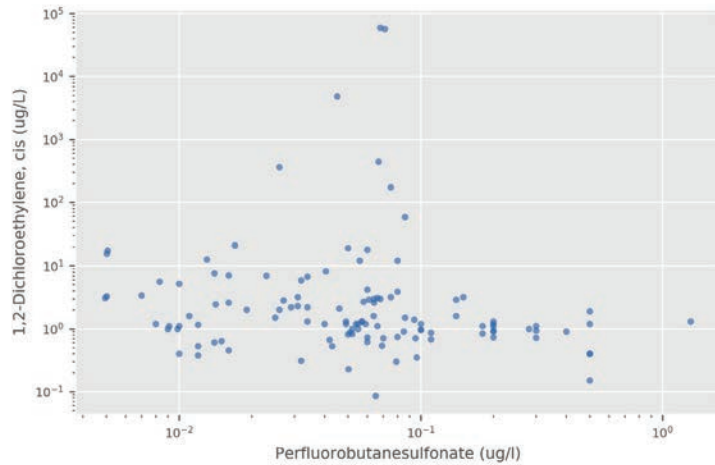
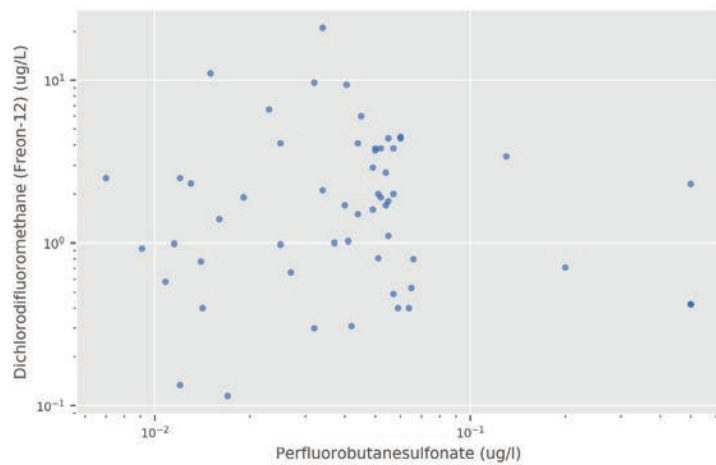
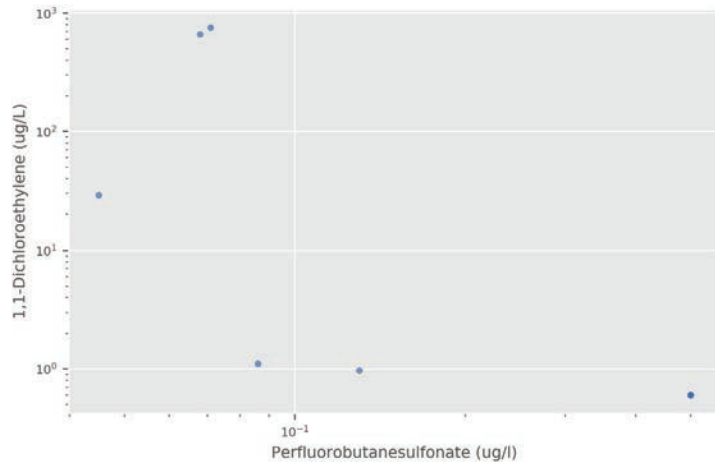
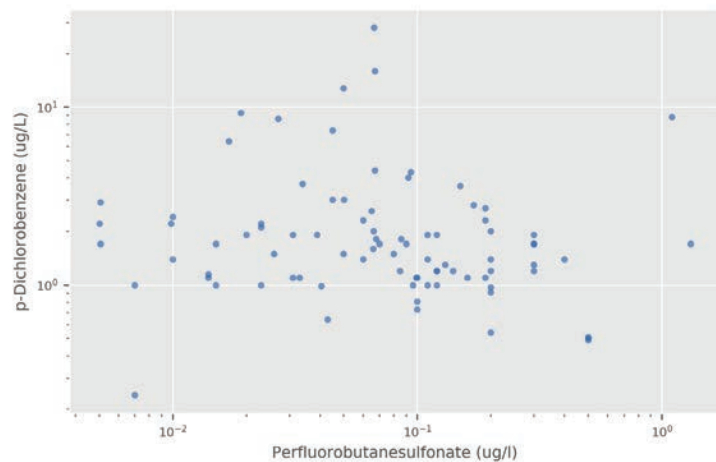
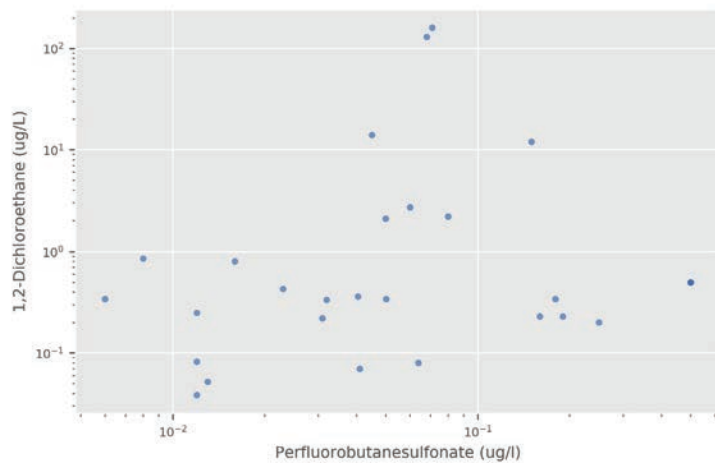
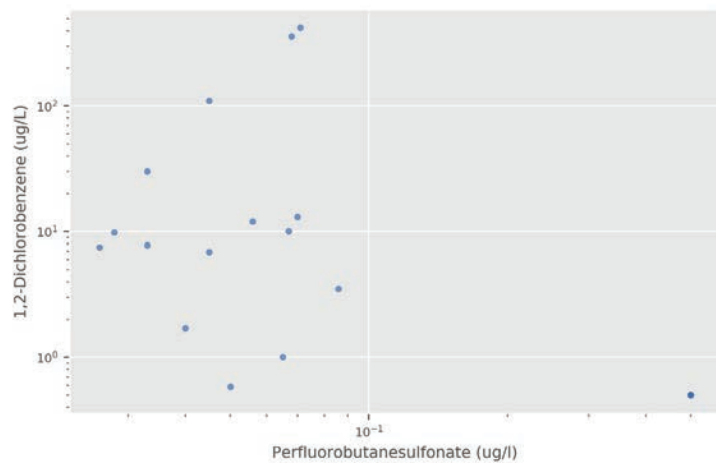
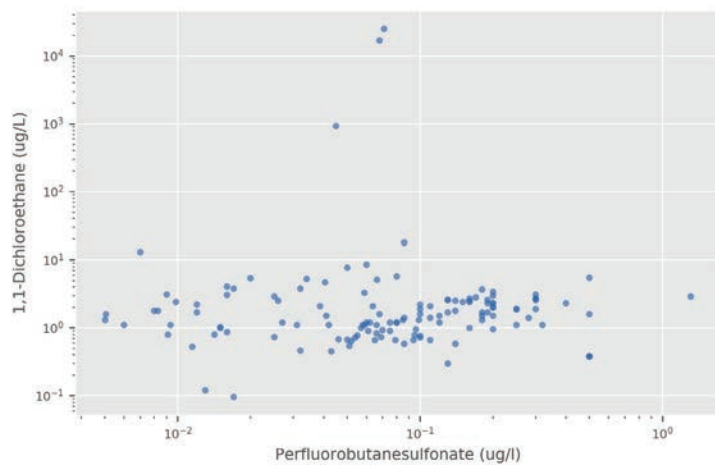
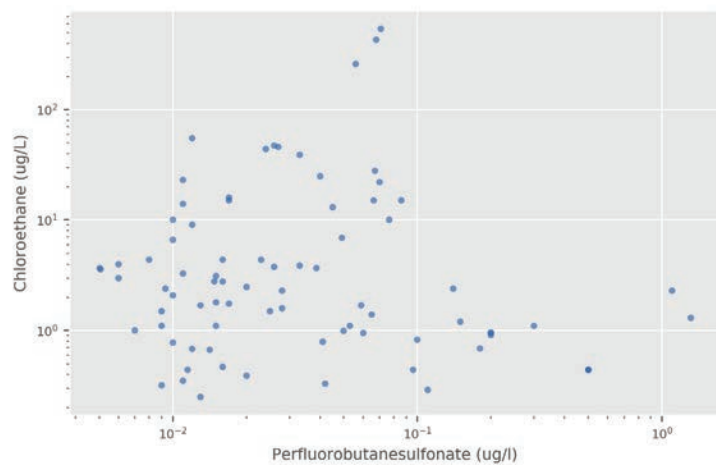




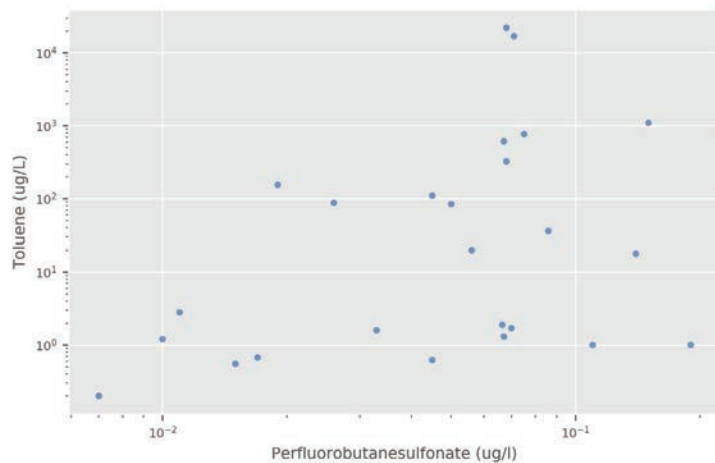
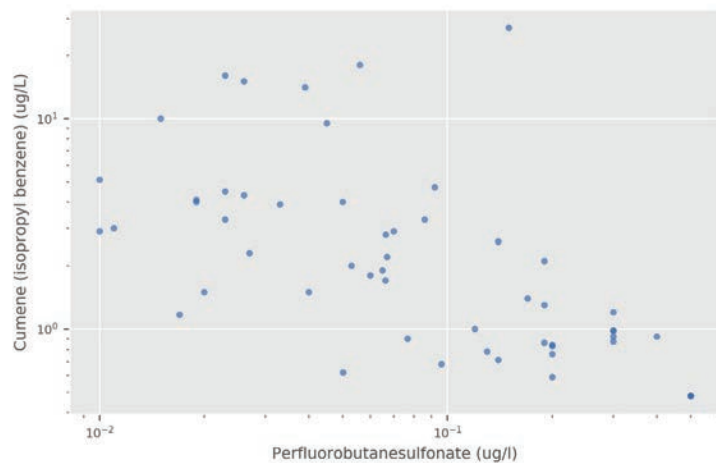
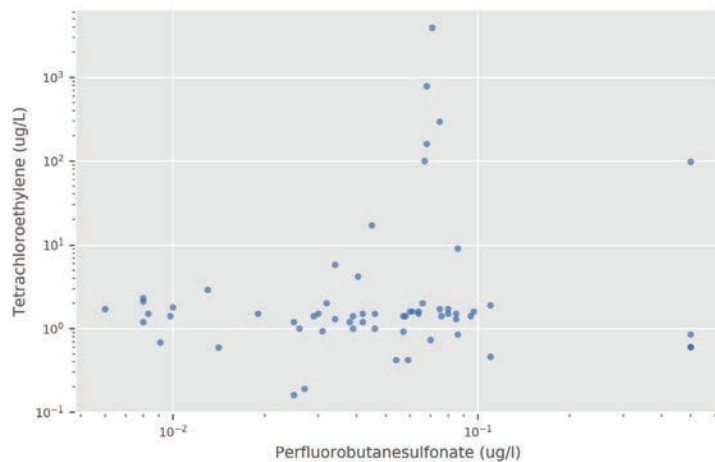
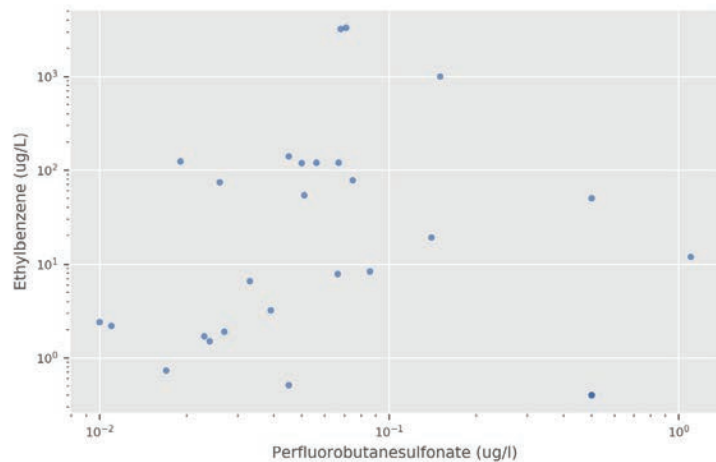
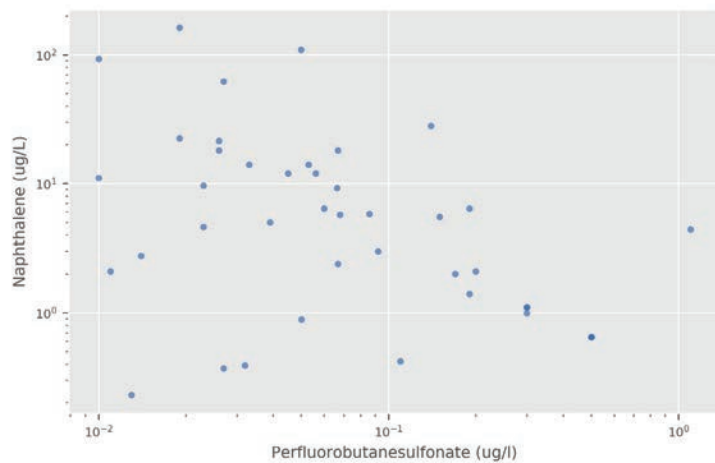
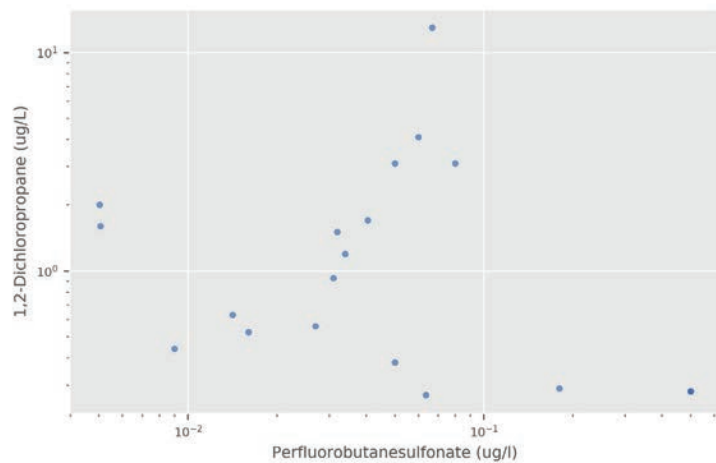
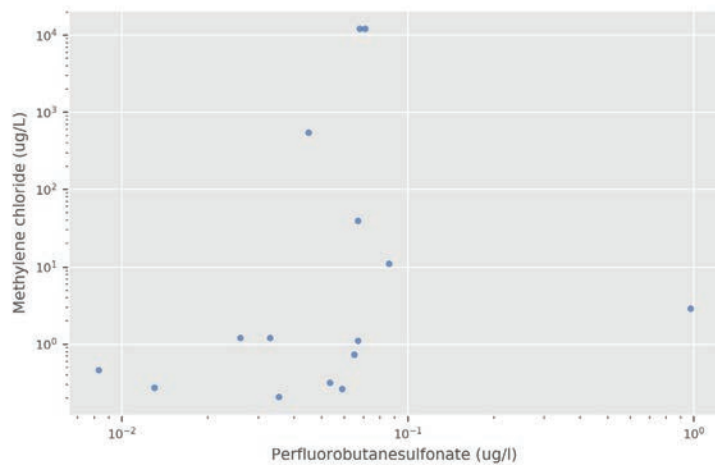
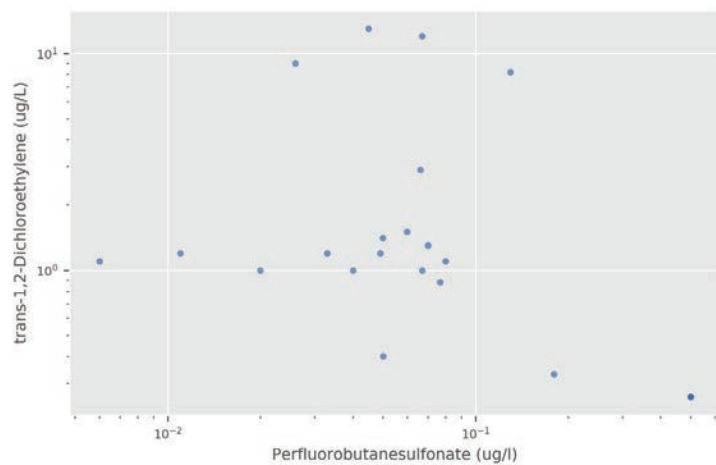




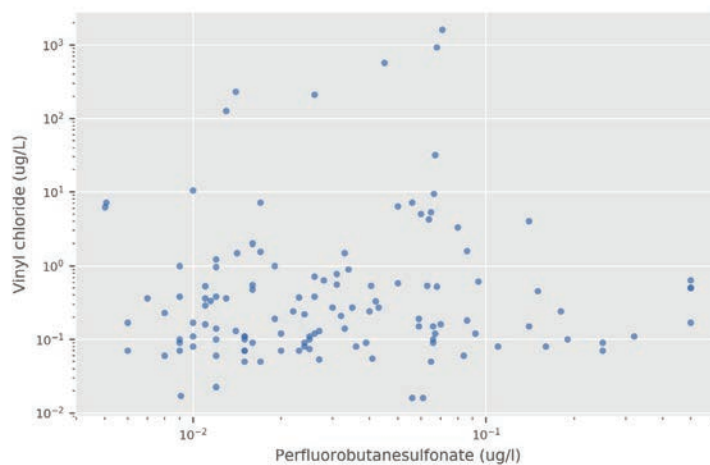
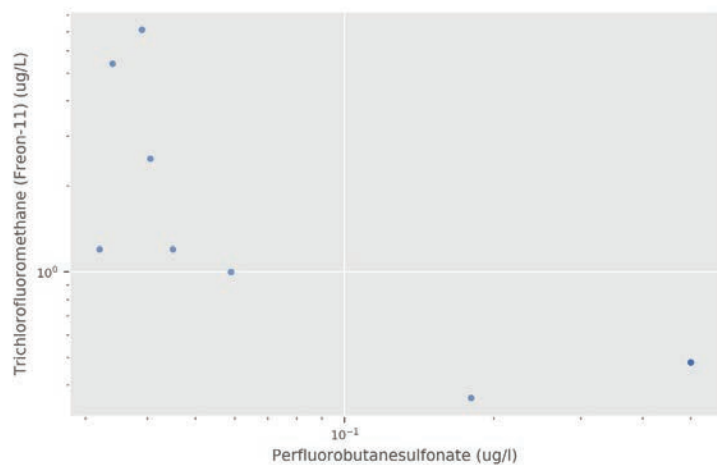
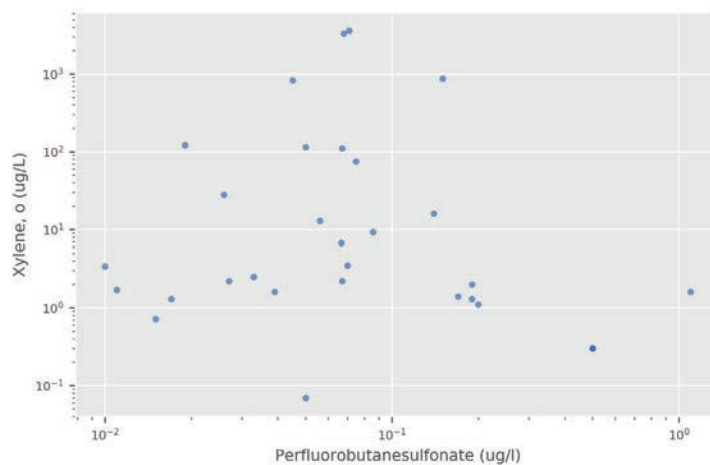
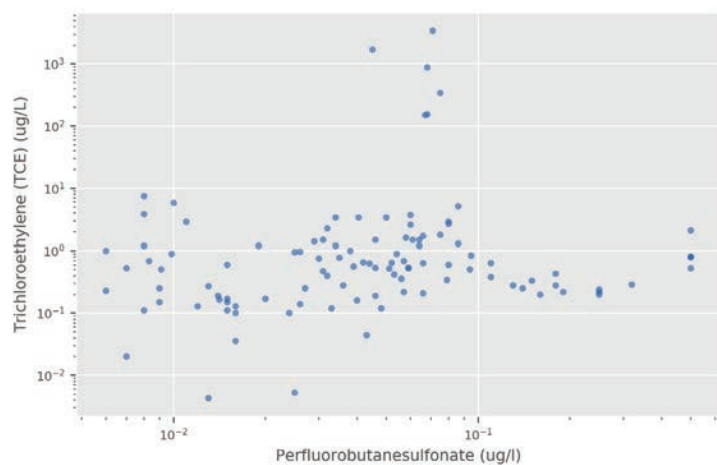
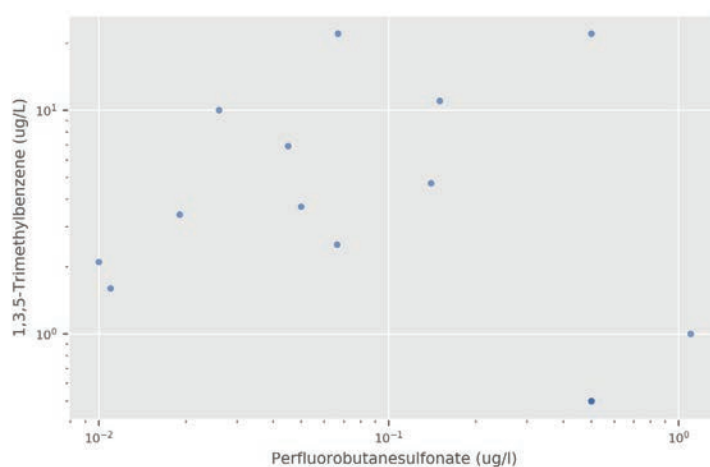
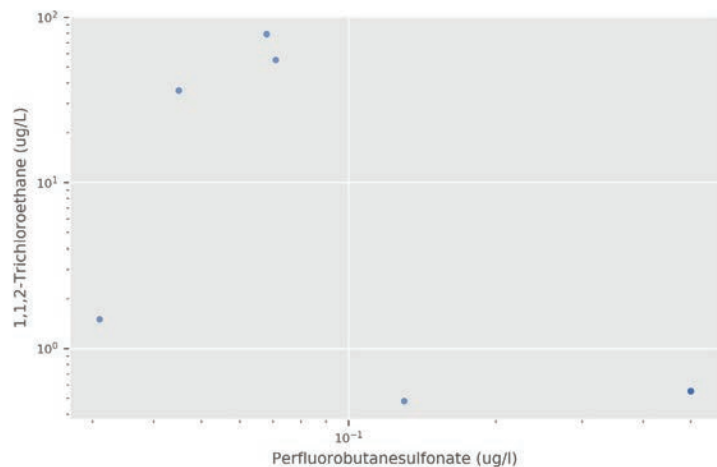
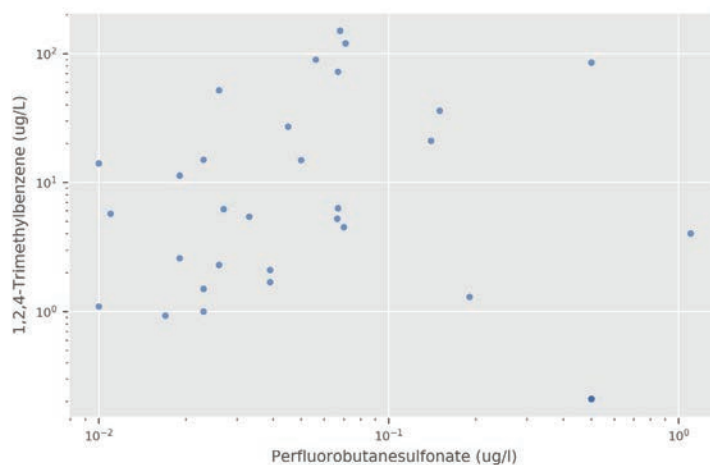
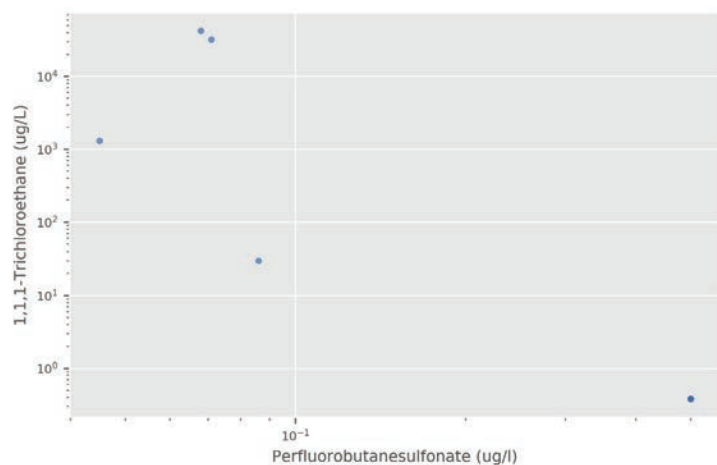


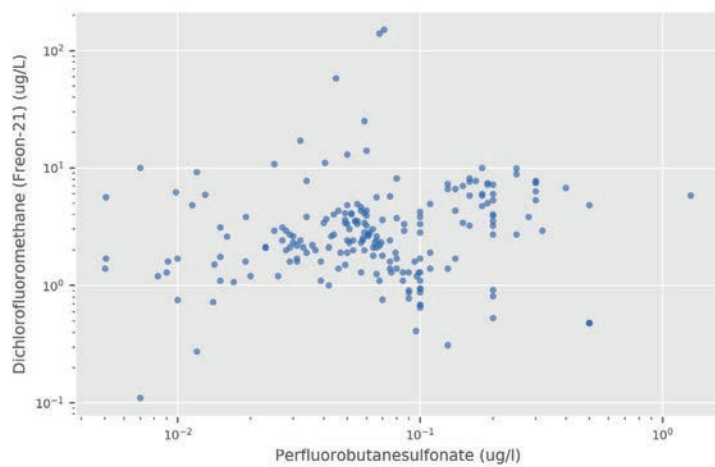
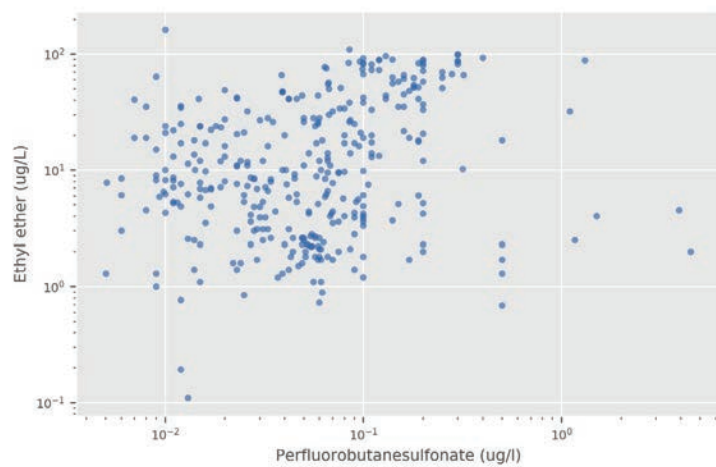
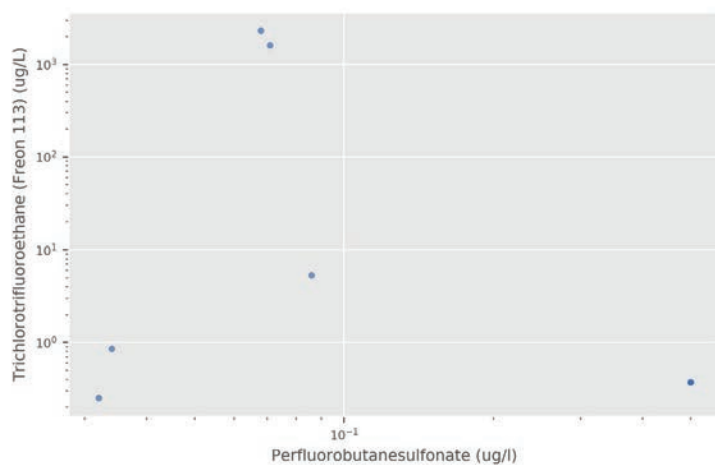
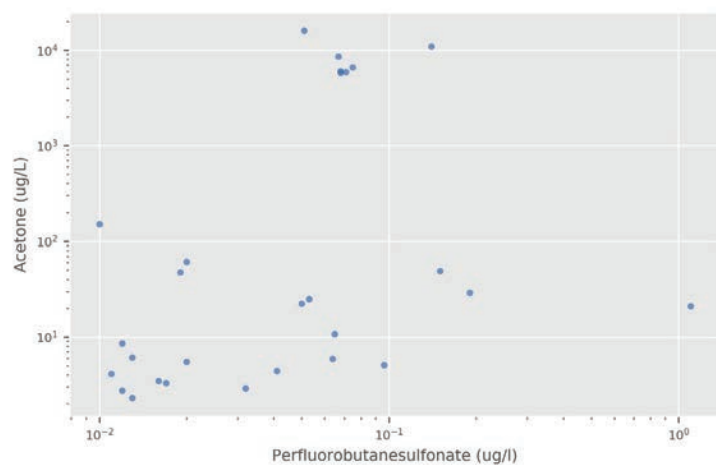
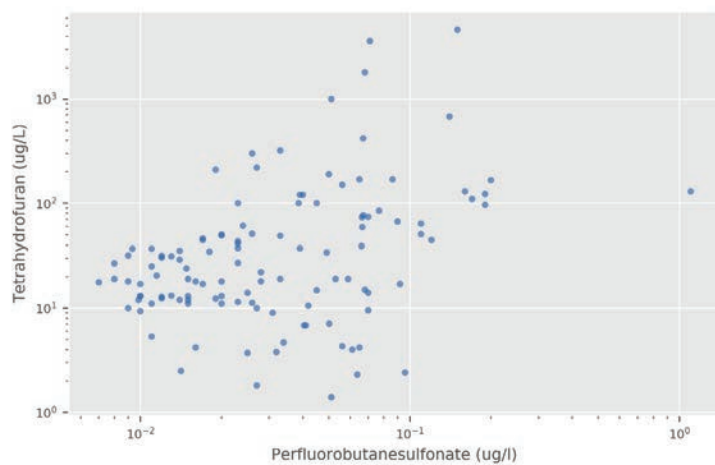
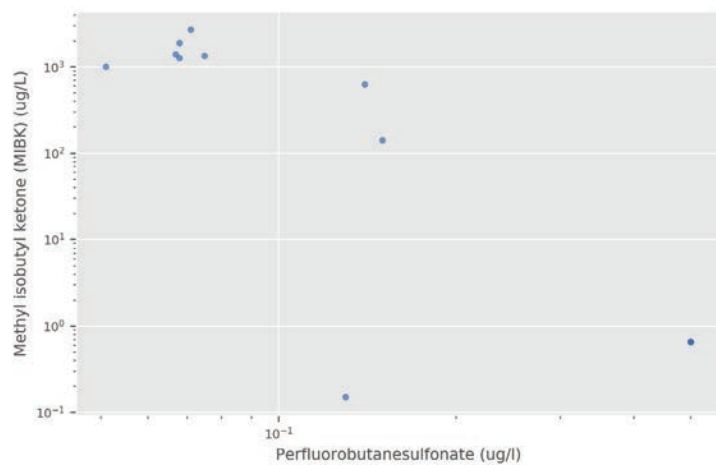
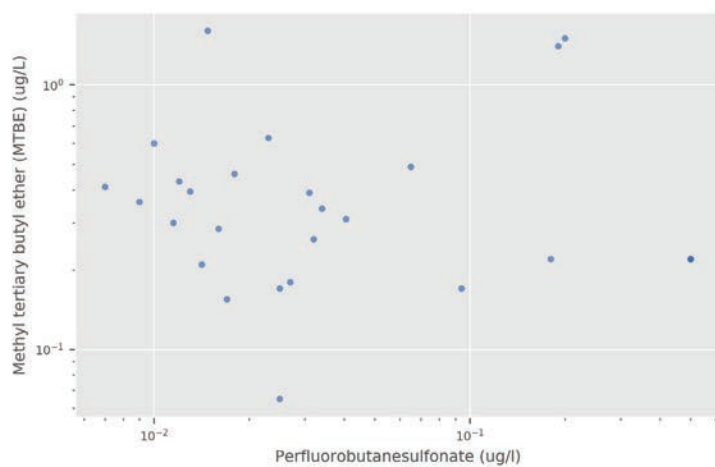
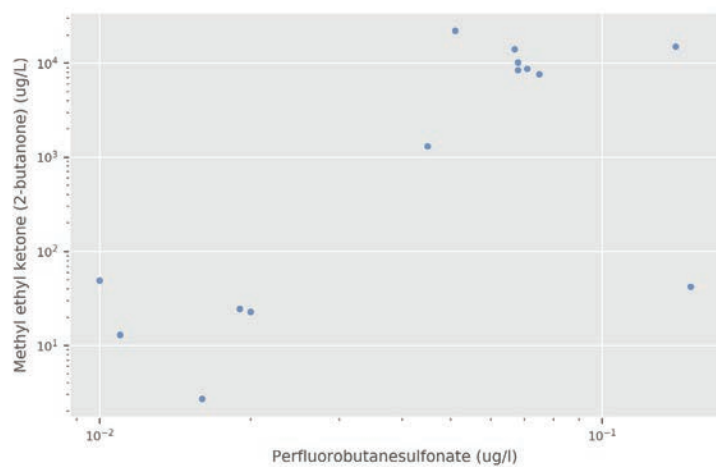


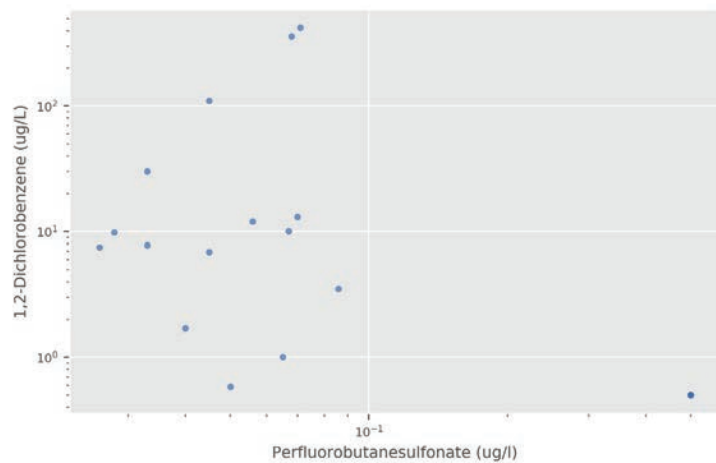
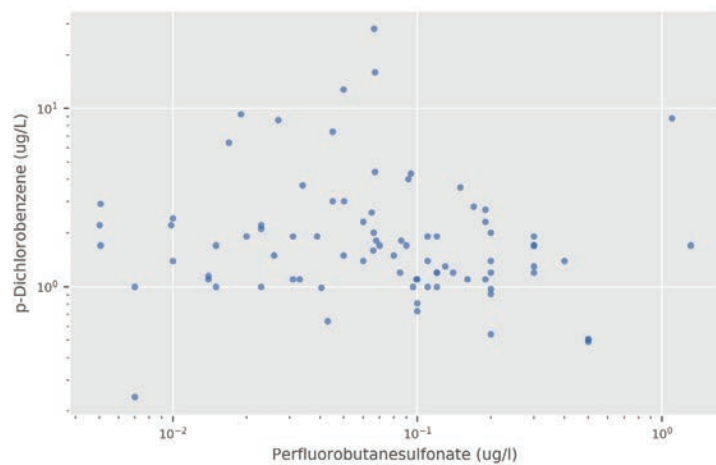


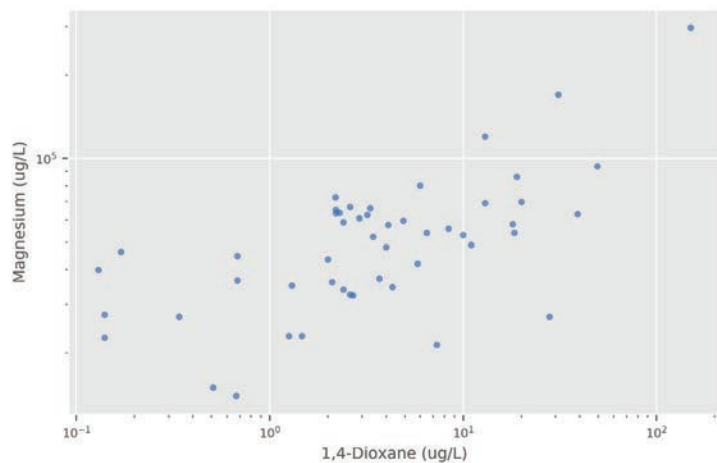
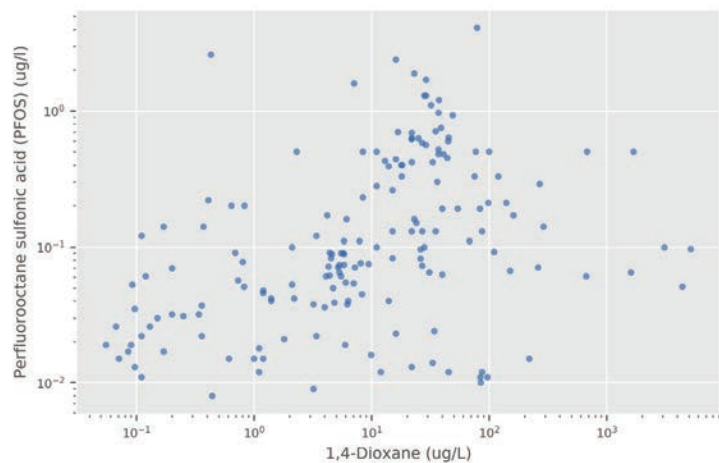
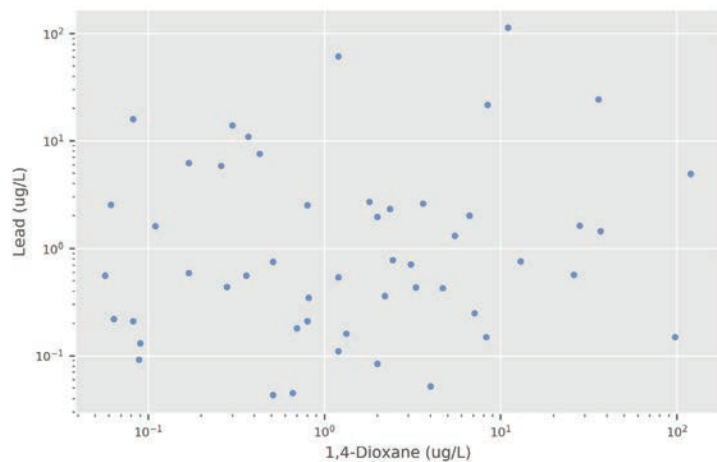
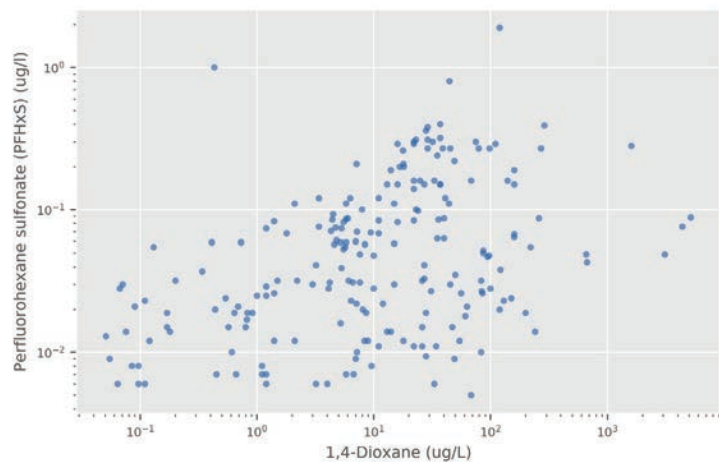
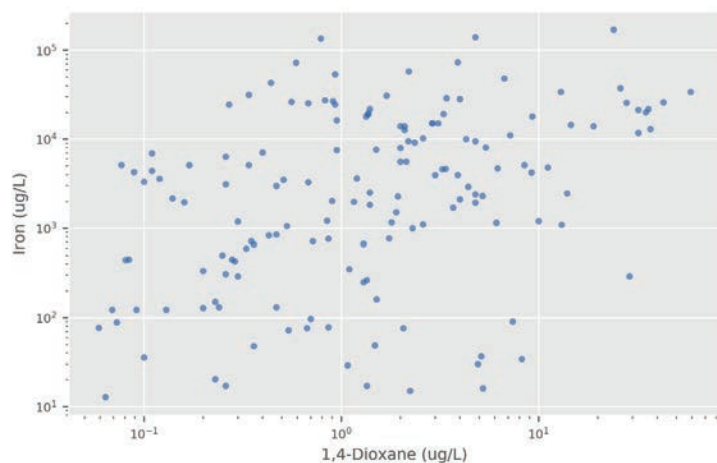
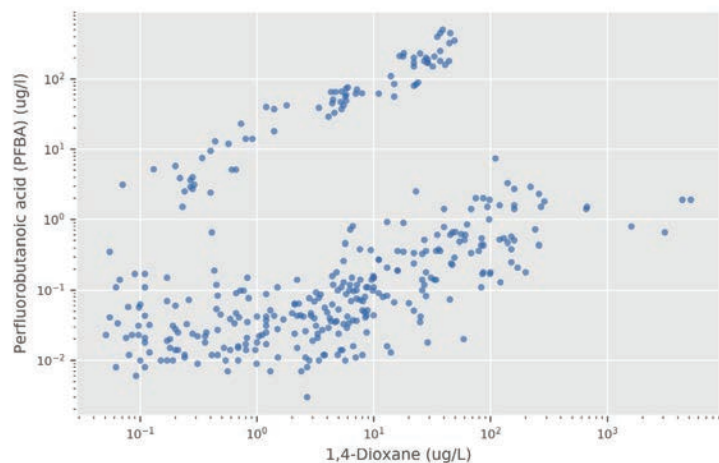
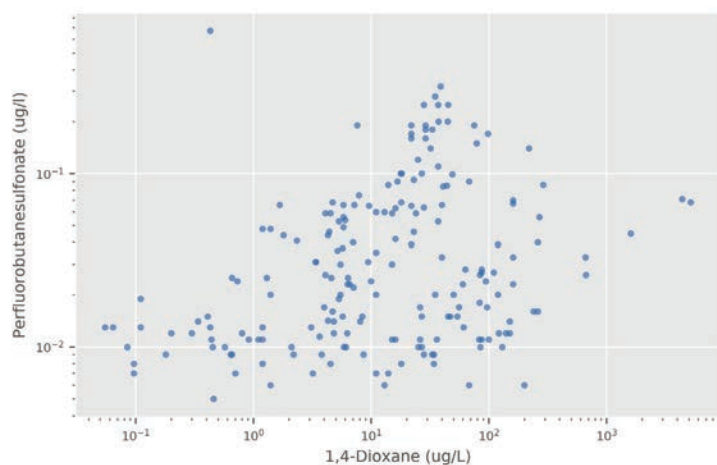
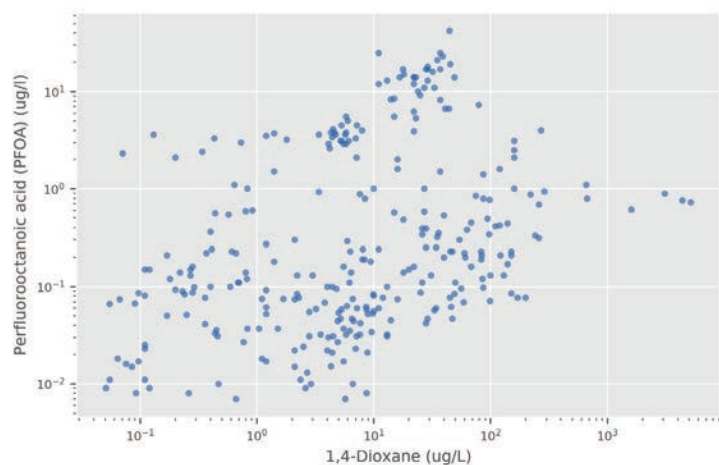


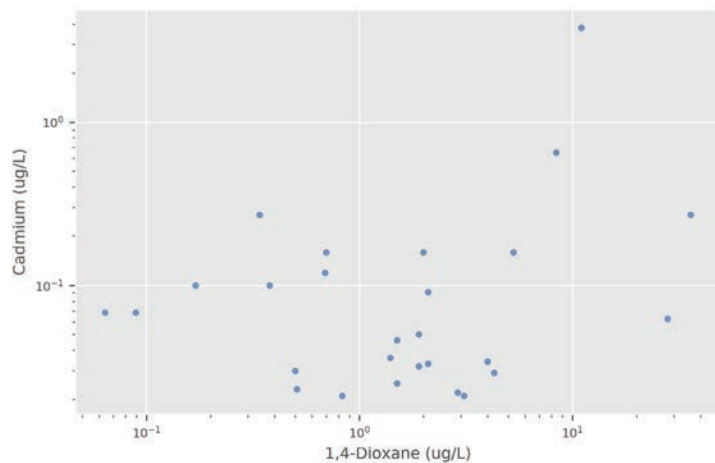
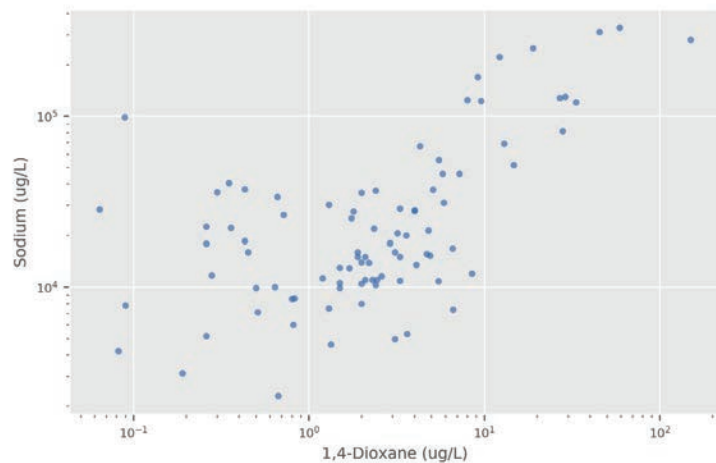
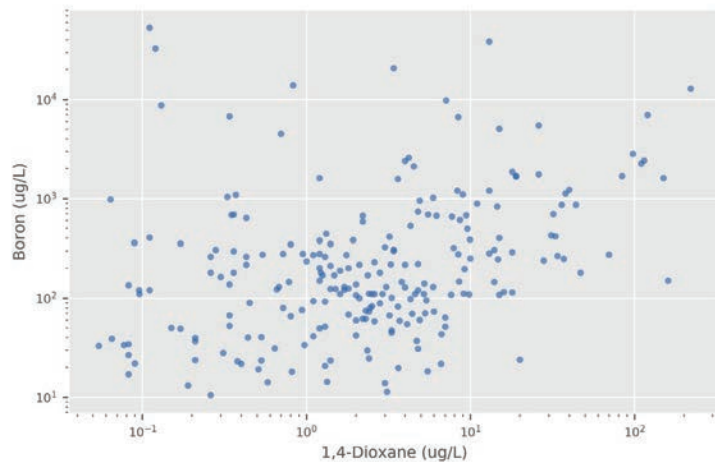
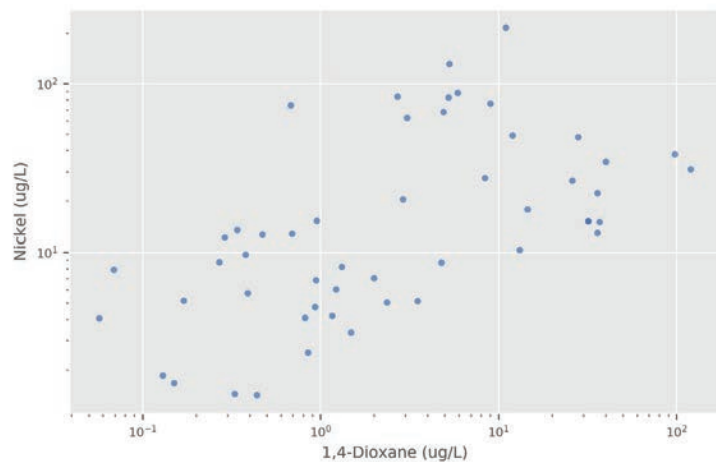
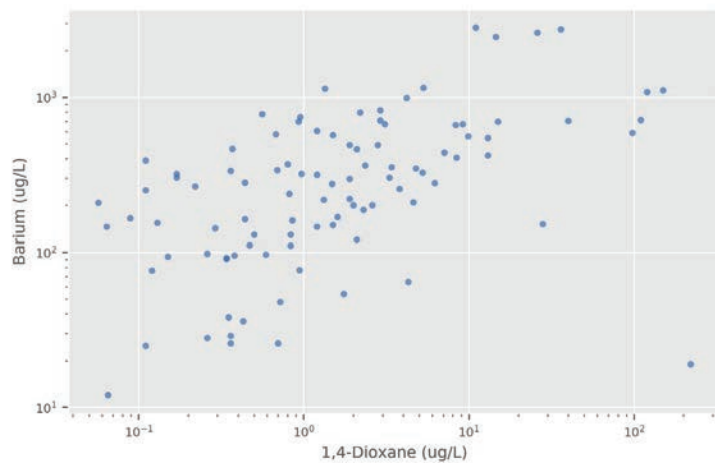
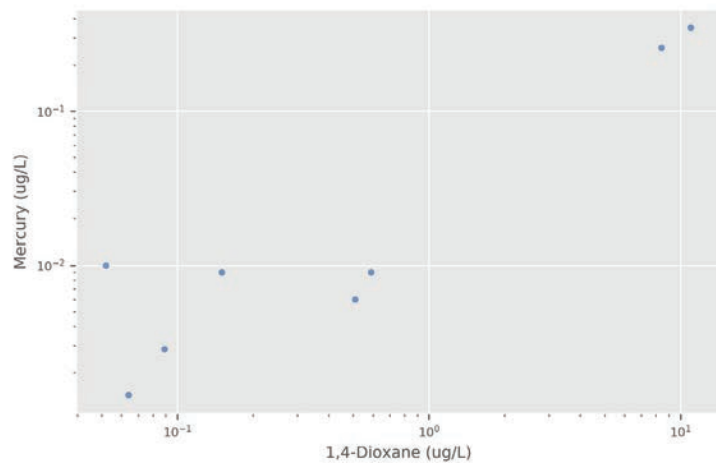
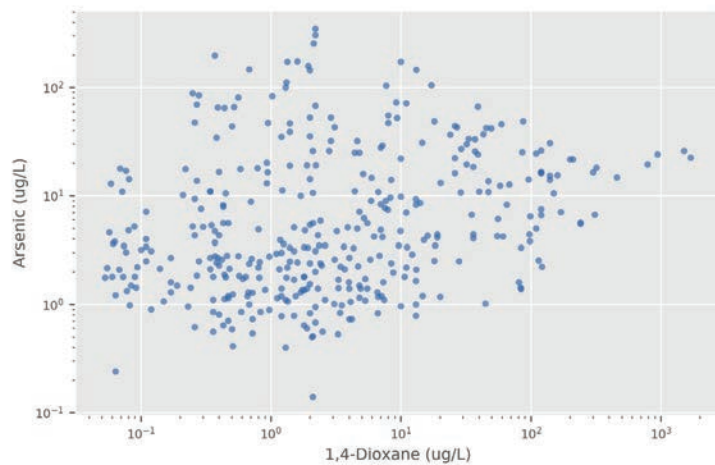
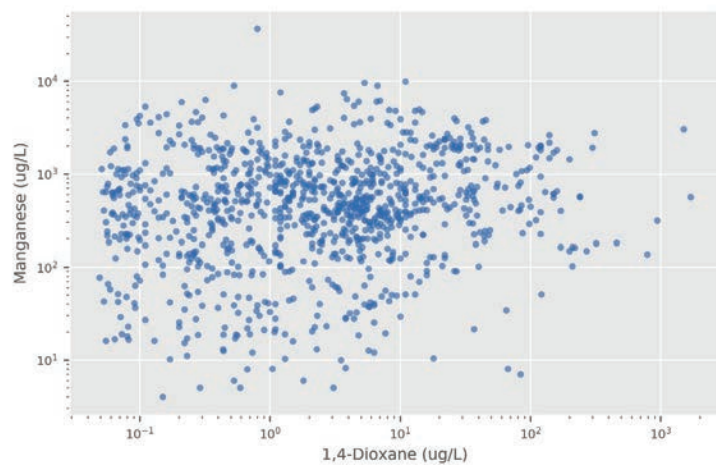




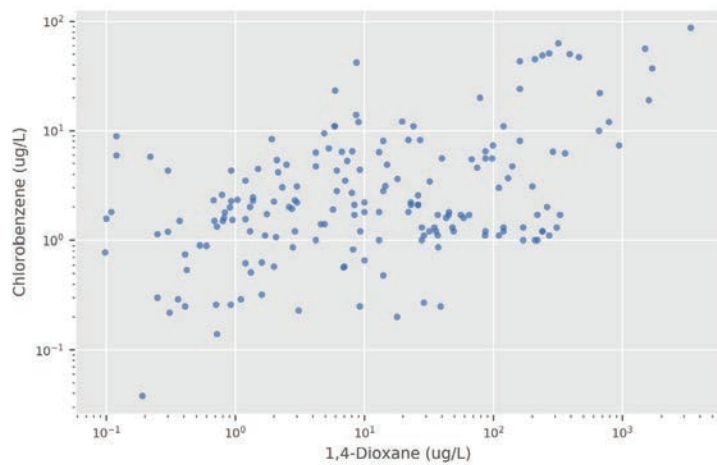
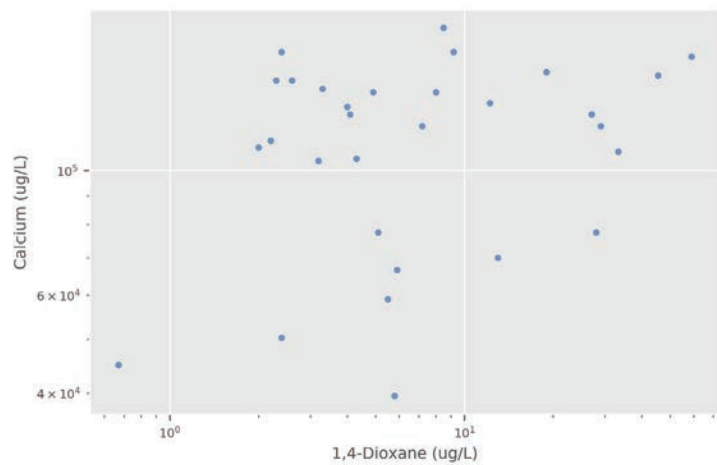
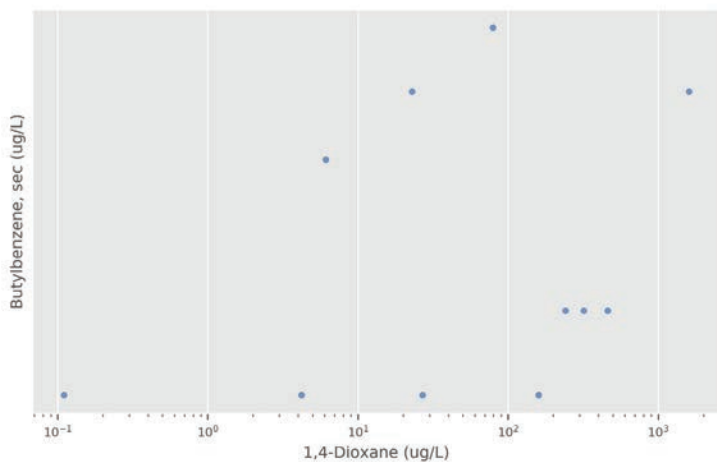
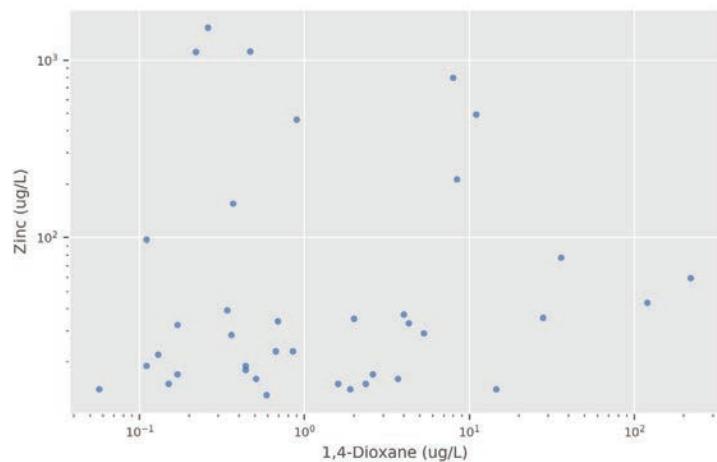
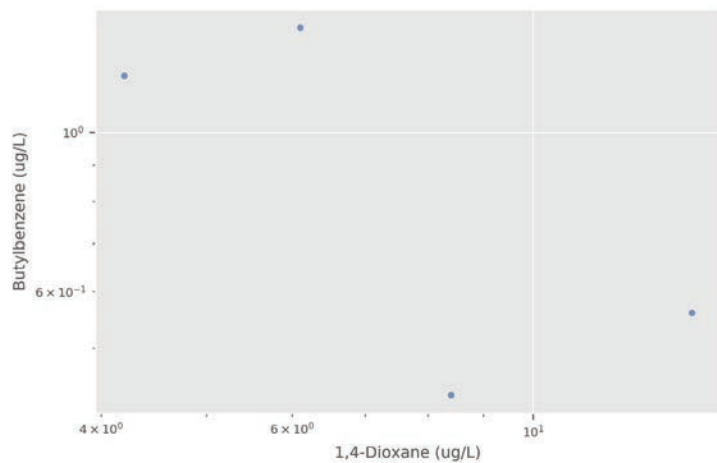
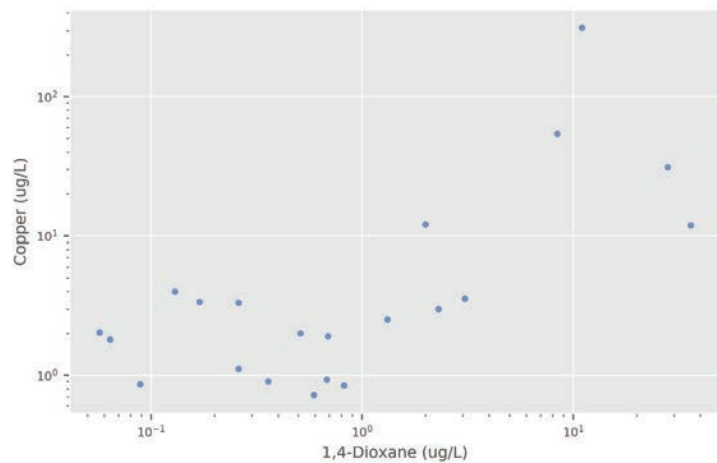
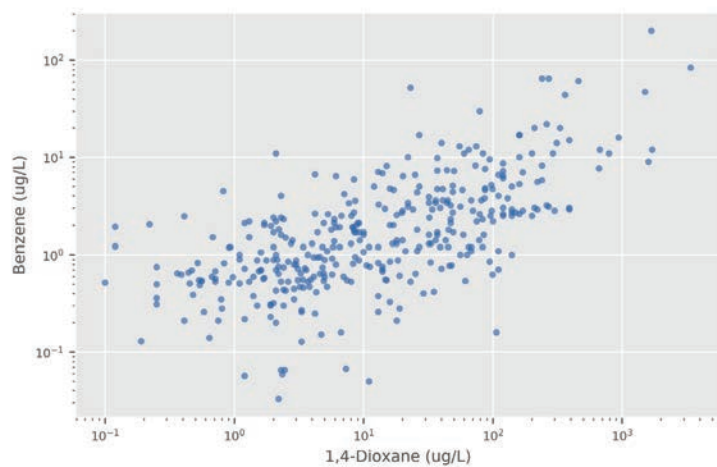
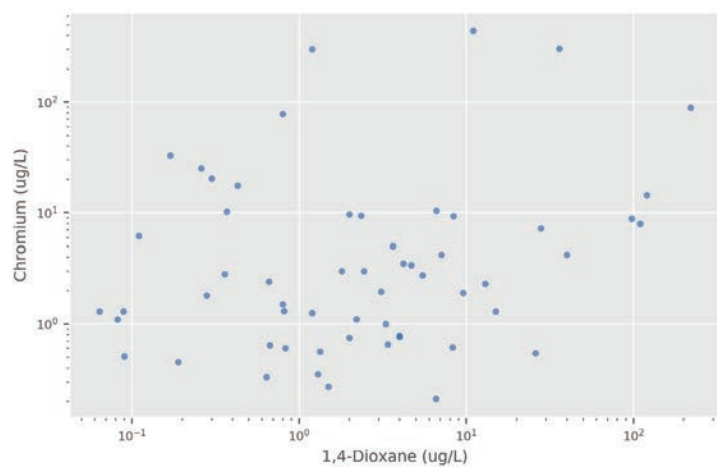


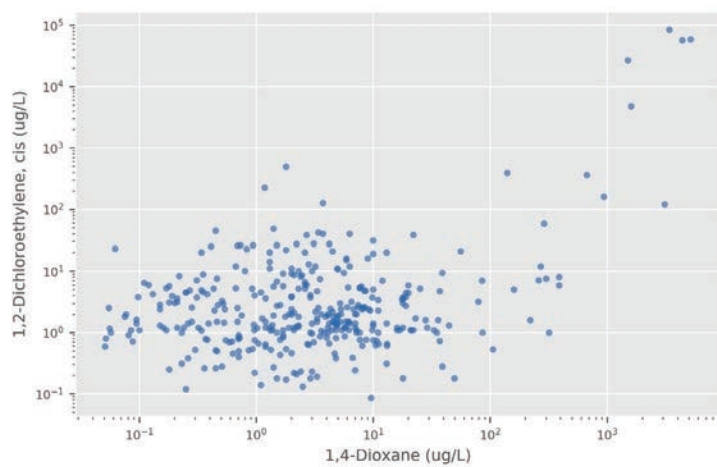
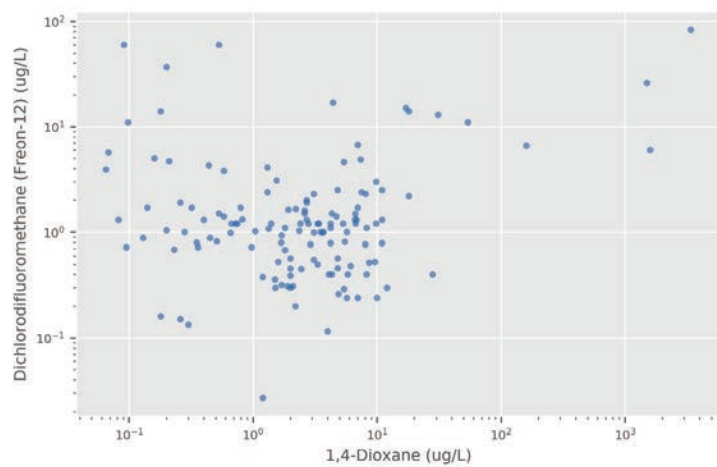
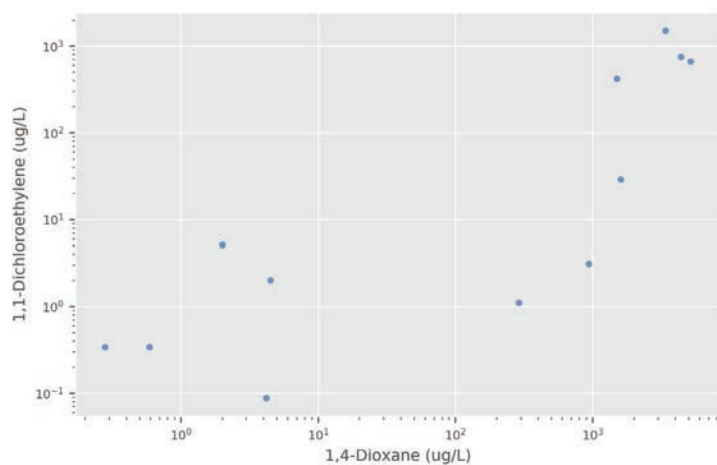
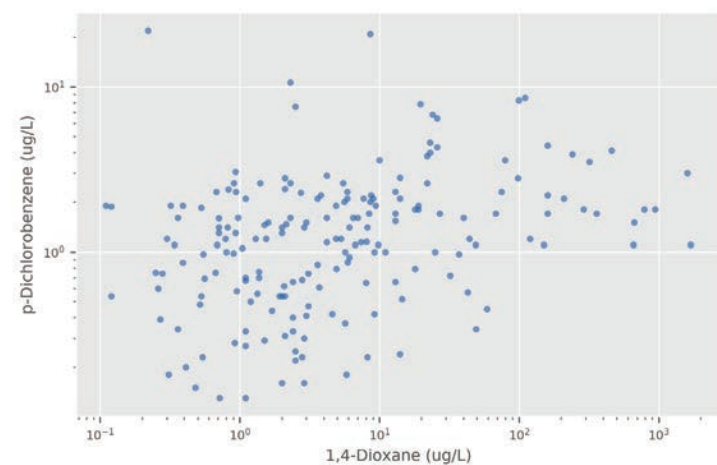
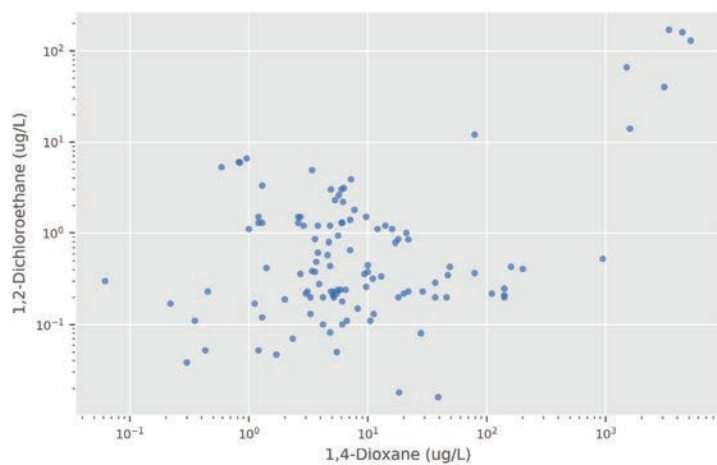
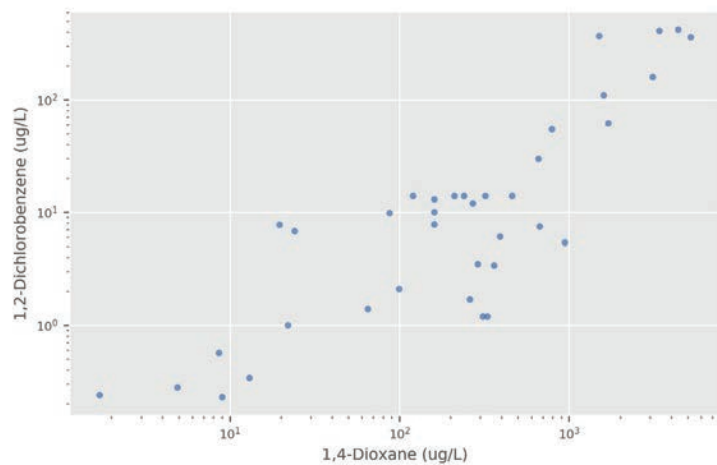
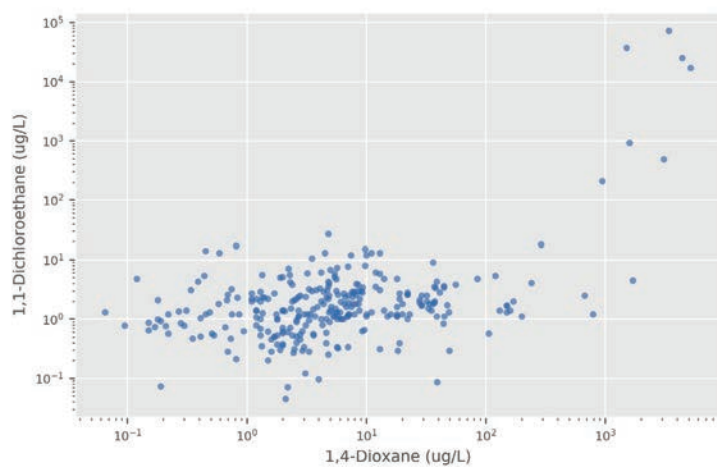
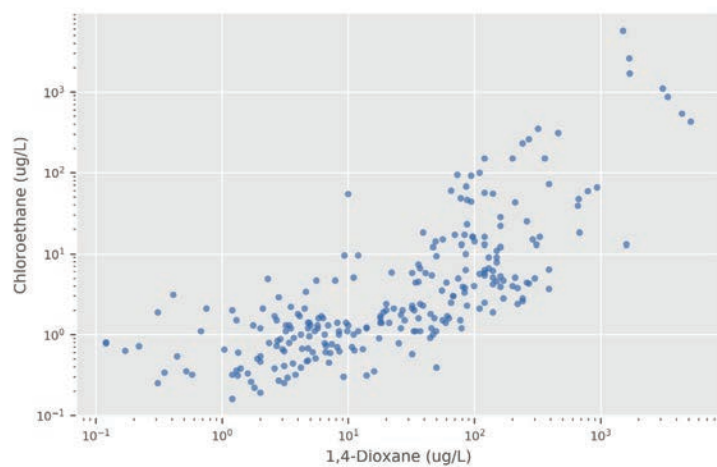


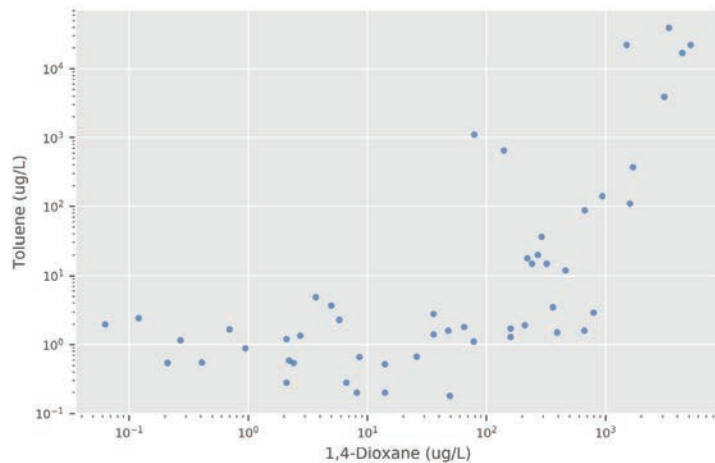
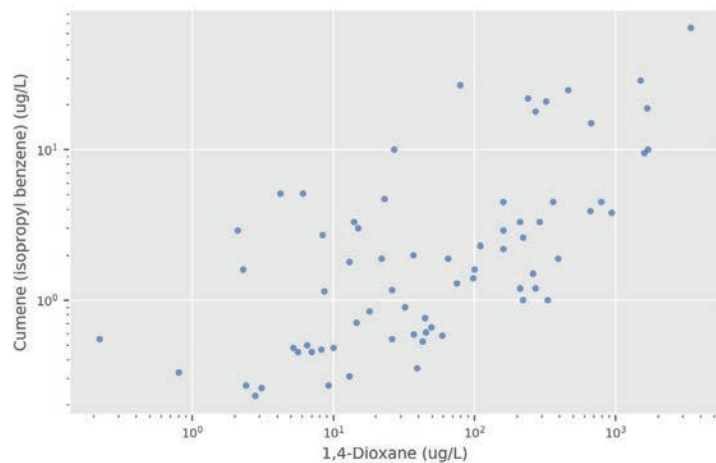
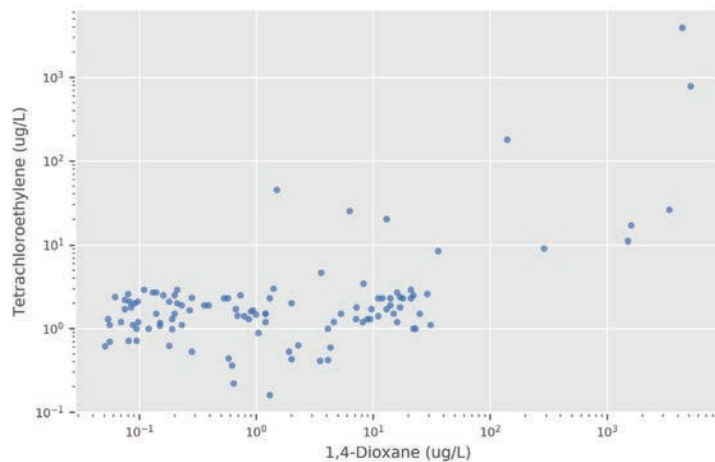
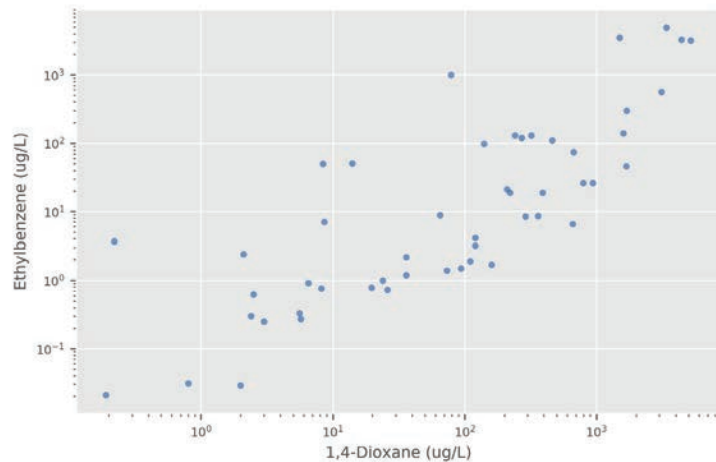
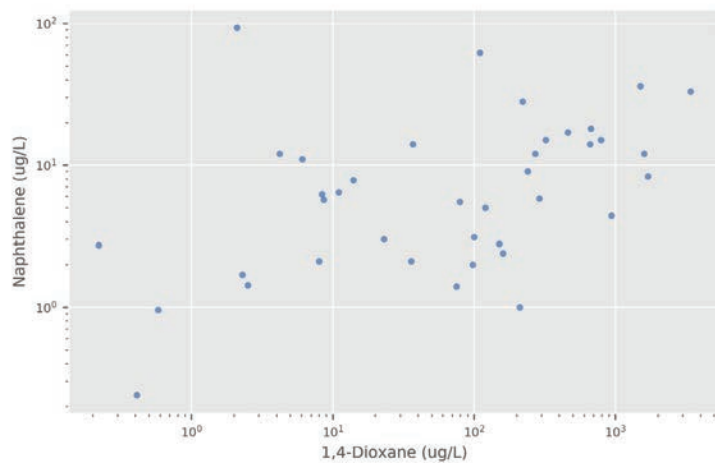
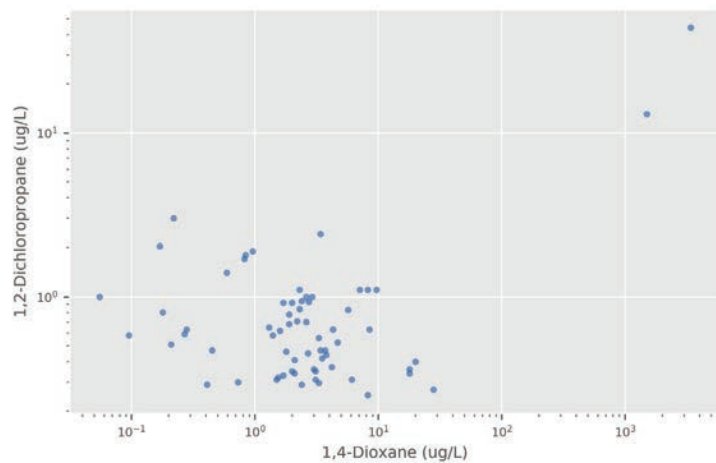
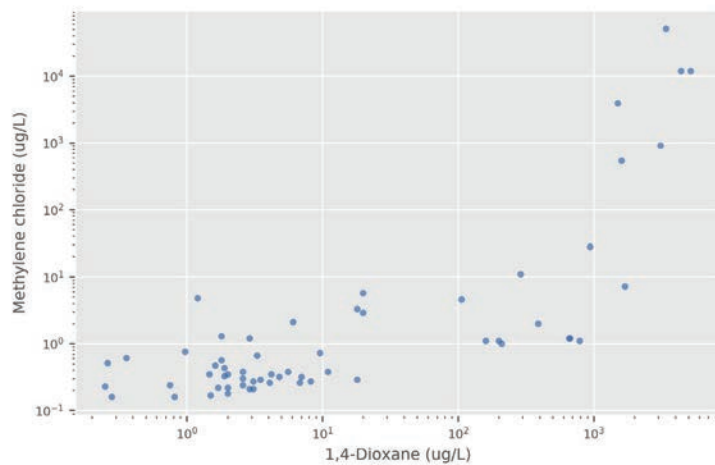
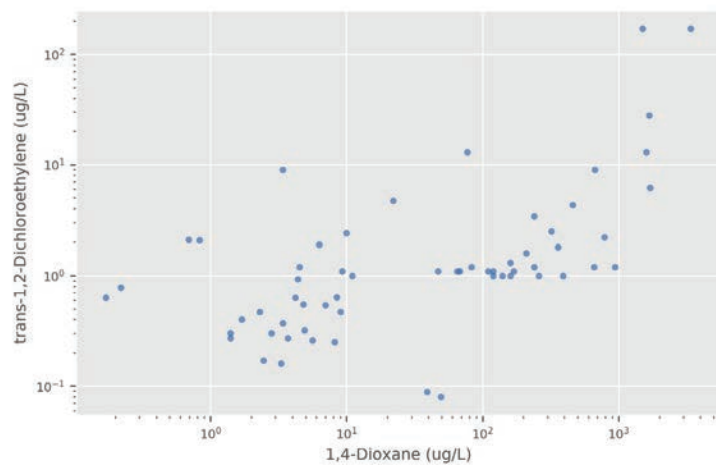


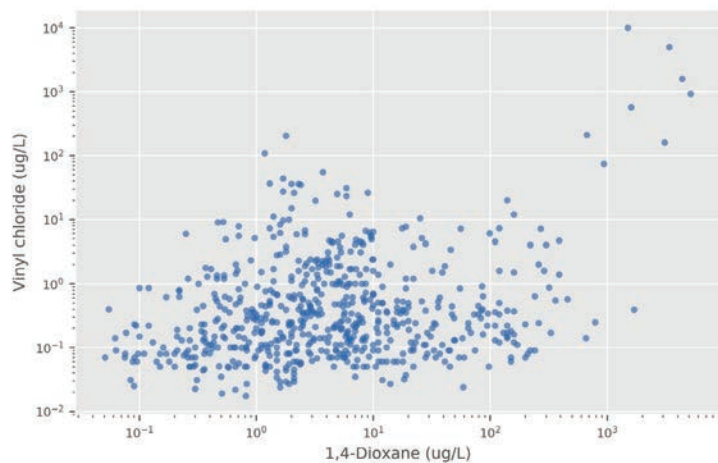
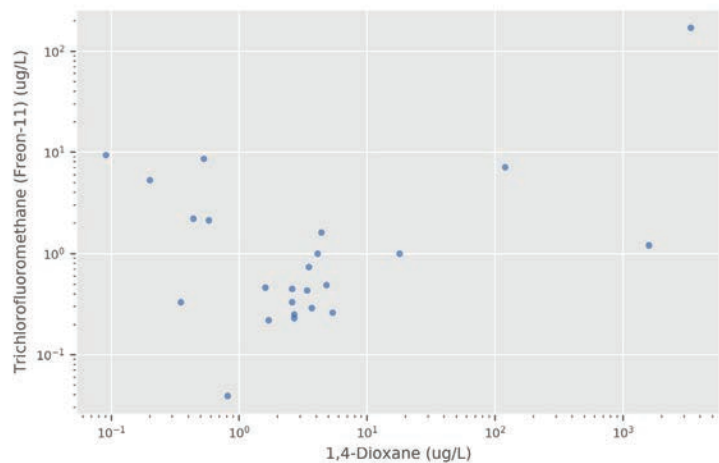
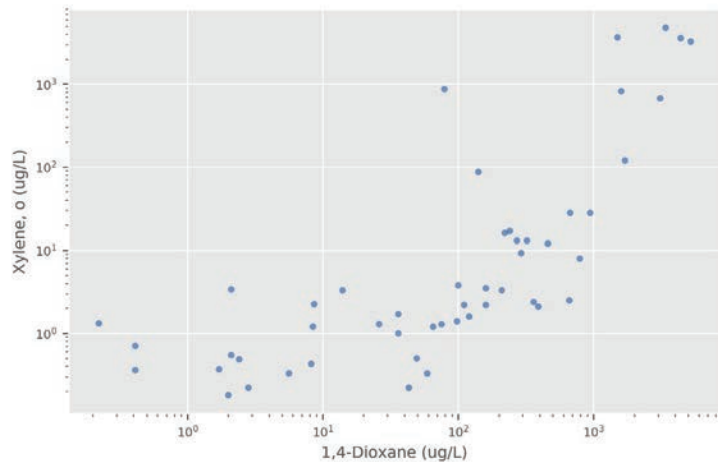
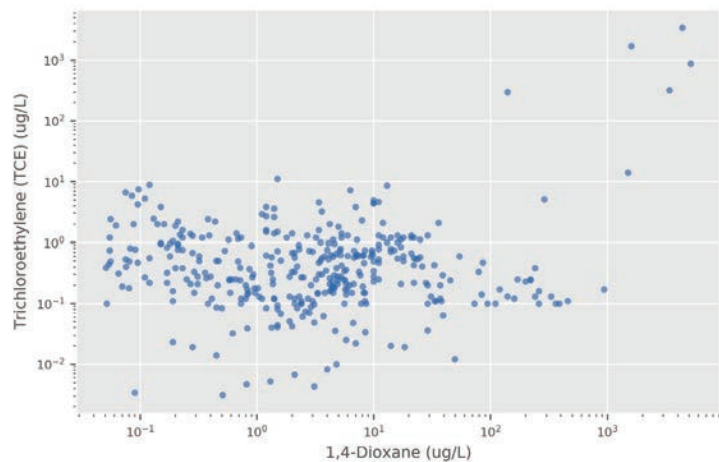
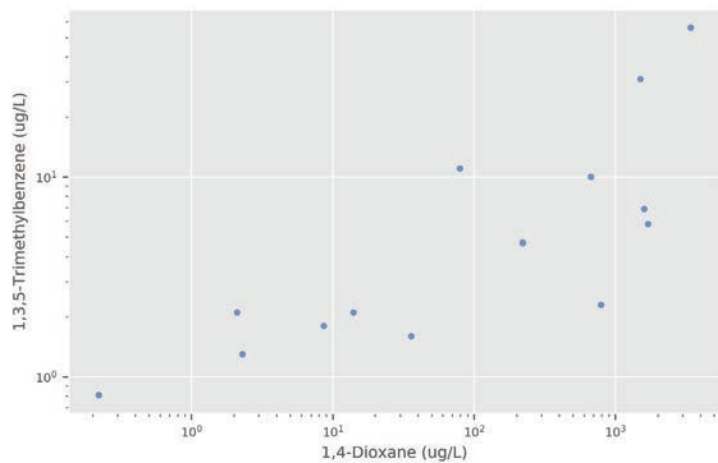
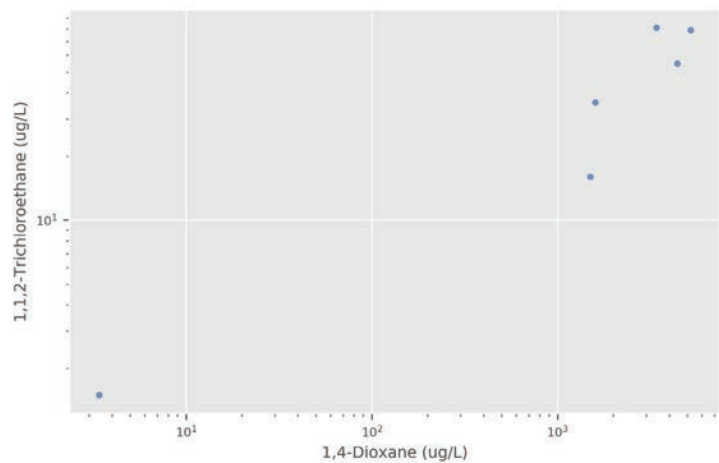
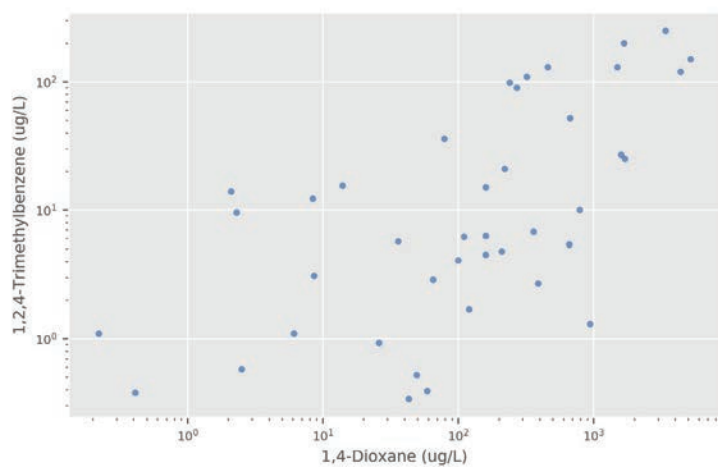
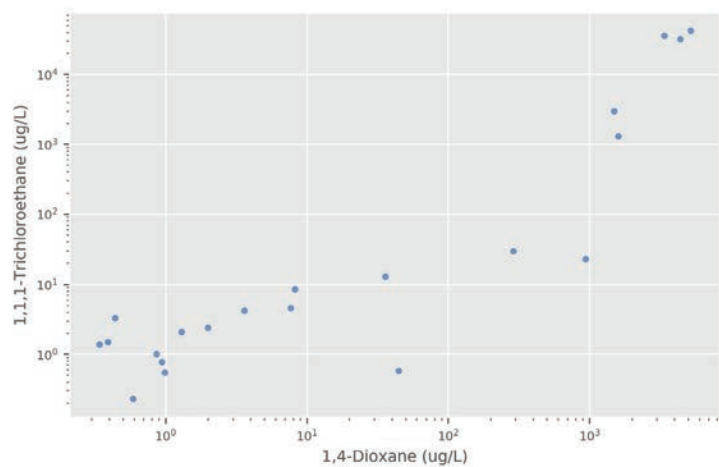




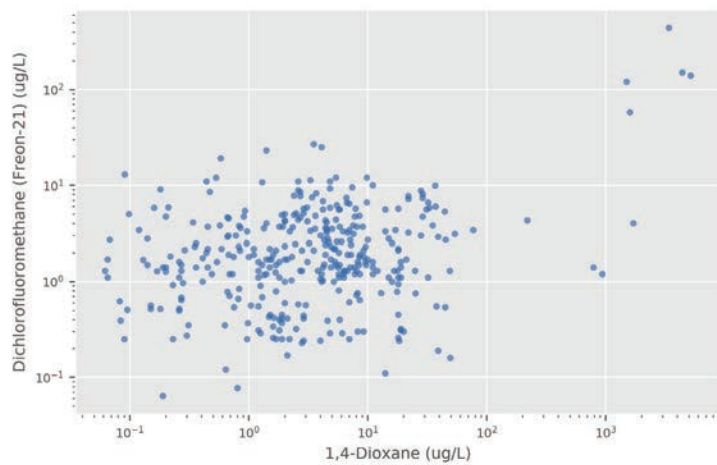
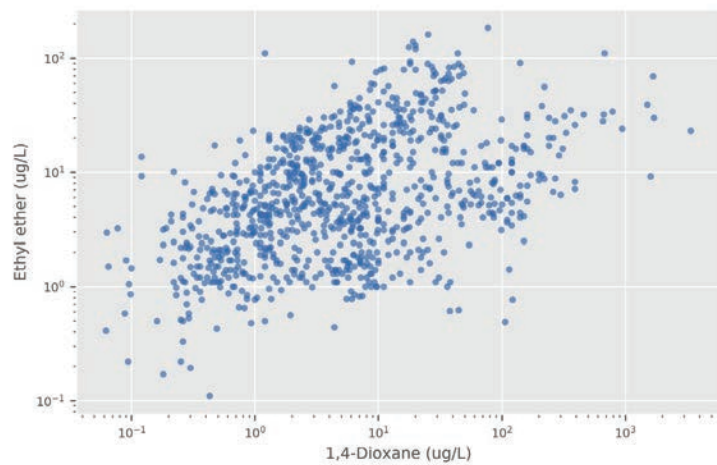
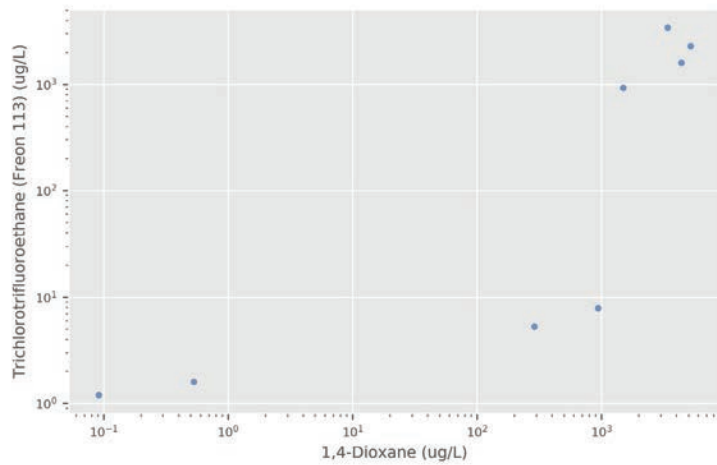
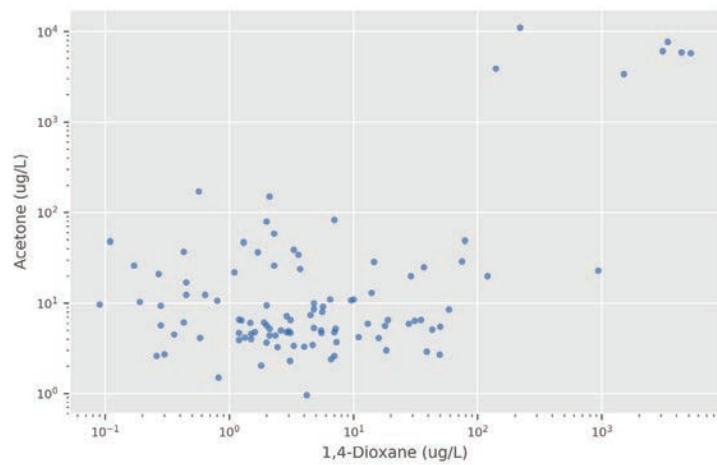
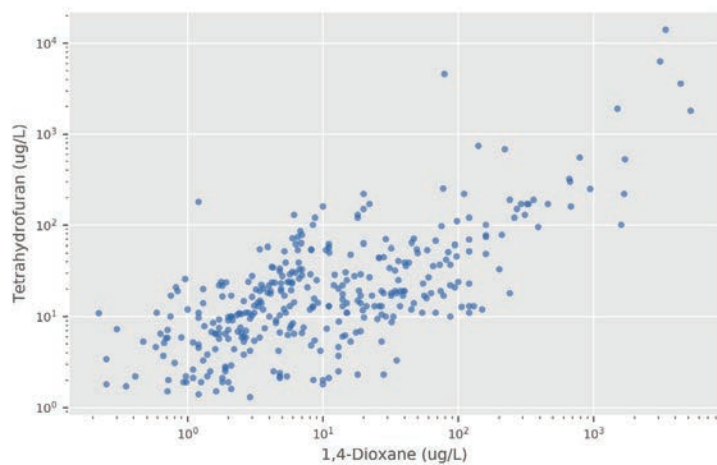
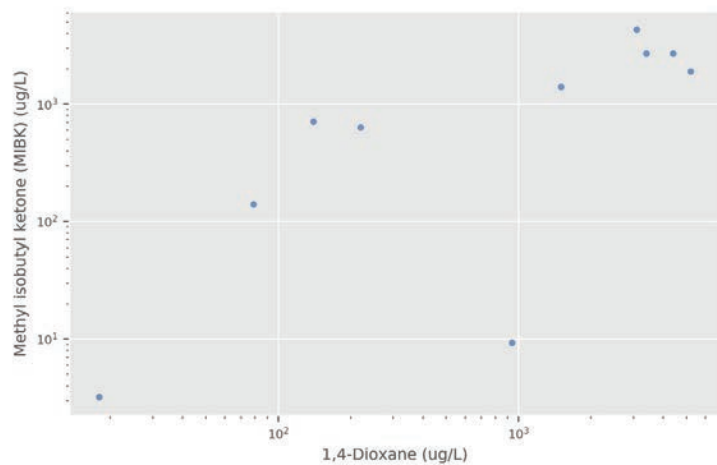
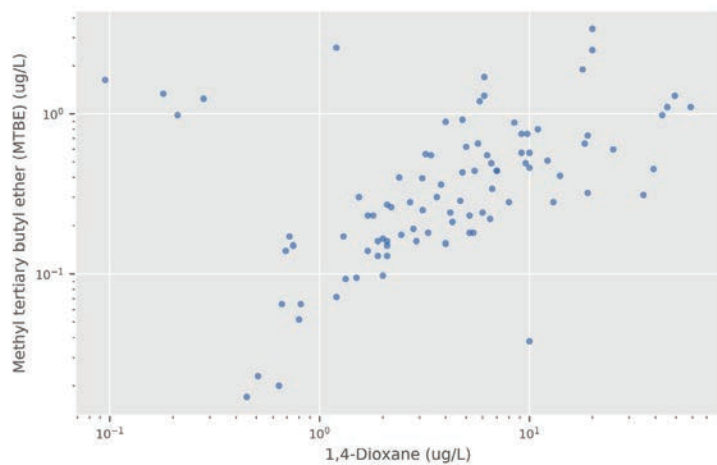
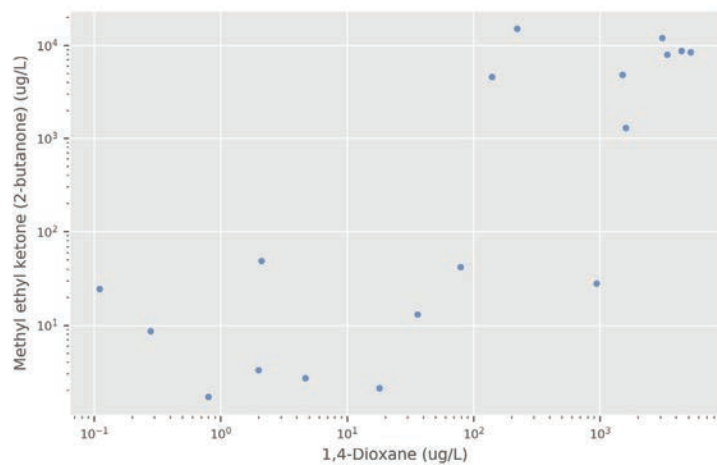




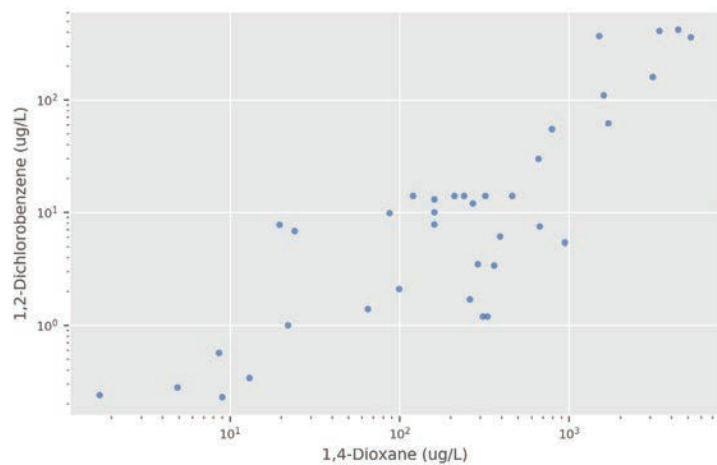
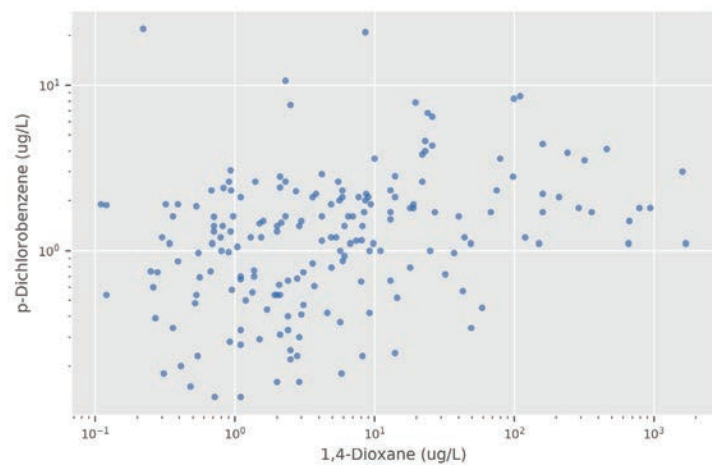












## **Appendix E**

### **Maximum PFAS HRI for Each Facility**

Table E-1  
Maximum Facility PFAS HRI Values

| Facility Code | Facility Name                              | Facility Type     | Maximum HRI |
|---------------|--------------------------------------------|-------------------|-------------|
| SR0000365     | 3M Woodbury                                | East Metro PFAS   | 1763998.33  |
| SR0000055     | Oakdale Dump Sites                         | East Metro PFAS   | 711114.90   |
| SR0000117     | Pigs Eye Landfill                          | East Metro PFAS   | 14727.15    |
| SW-1          | Washington County Sanitary Landfill        | East Metro PFAS   | 2402.86     |
| SW-76         | Gofer Sanitary Landfill                    | Closed Landfill   | 2381.37     |
| SW-45         | Pine Bend Sanitary Landfill                | Operating MSW     | 196.72      |
| SW-57         | Freeway Sanitary Landfill                  | Closed Landfill   | 45.18       |
| SW-31         | Kummer Sanitary Landfill                   | Closed Landfill   | 44.25       |
| SW-117        | Lindala Sanitary Landfill                  | Closed Landfill   | 44.22       |
| SW-47         | East Bethel Demolition/Sanitary Landfill   | Closed Landfill   | 44.22       |
| SW-32         | Louisville Landfill Inc.                   | Closed Landfill   | 40.34       |
| SW-28         | Waste Disposal Engineering Landfill        | Closed Landfill   | 30.40       |
| SW-35         | St. Augusta Sanitary Landfill              | Closed Landfill   | 27.20       |
| SW-353        | Vonco Demolition Debris Landfill           | Other Solid Waste | 23.93       |
| SW-63         | Minnesota Sanitation Services Landfill     | Closed Landfill   | 22.65       |
| SW-16         | Crosby American Properties Landfill        | Closed Landfill   | 21.57       |
| SW-67         | Tellijohn Sanitary Landfill                | Closed Landfill   | 18.80       |
| SW-43         | Oak Grove Sanitary Landfill                | Closed Landfill   | 14.40       |
| SW-61         | Woodlake Sanitary Landfill                 | Closed Landfill   | 11.91       |
| SW-134        | Begin Dump and Demolition Landfill         | Other Solid Waste | 10.56       |
| SW-406        | Douglas County Demolition Landfill         | Other Solid Waste | 10.54       |
| SW-387        | Summit Avenue Demolition Landfill          | Other Solid Waste | 9.59        |
| SW-101        | Jackson County Sanitary Landfill           | Closed Landfill   | 9.56        |
| SW-501        | Lyon County Demolition Landfill            | Other Solid Waste | 8.84        |
| SW-232        | Western Lake Superior Sanitary District Lf | Closed Landfill   | 8.65        |
| SW-58         | Hopkins Sanitary Landfill                  | Closed Landfill   | 8.29        |
| SW-126        | Houston County Sanitary Landfill           | Closed Landfill   | 7.51        |
| SW-175        | Cotton Area Sanitary Landfill              | Closed Landfill   | 7.33        |
| SW-120        | Pipestone County Sanitary Landfill         | Closed Landfill   | 7.24        |
| SW-56         | Burnsville Sanitary Landfill               | Operating MSW     | 5.96        |
| SW-262        | Hwy 77 Sanitary Landfill                   | Closed Landfill   | 5.90        |
| SW-405        | St Louis County Regional Landfill          | Operating MSW     | 5.72        |
| SW-94         | Anoka Municipal Regional Landfill          | Closed Landfill   | 5.72        |
| SW-91         | Sun Prairie Sanitary Landfill              | Closed Landfill   | 5.63        |
| SW-6          | Spruce Ridge Resource Management           | Operating MSW     | 5.30        |
| SW-303        | Dawnway Demolition Landfill                | Other Solid Waste | 5.21        |
| SW-102        | Carlton County 2 Sanitary Landfill         | Closed Landfill   | 5.12        |
| SW-2          | Sibley County Sanitary Landfill            | Closed Landfill   | 4.51        |
| SW-178        | Northeast Otter Tail Co. Landfill          | Closed Landfill   | 4.36        |
| SW-33         | Maple Landfill                             | Closed Landfill   | 4.30        |
| SW-68         | Northwoods Sanitary Landfill               | Closed Landfill   | 4.26        |
| SW-22         | Barnesville Sanitary Landfill              | Closed Landfill   | 3.89        |
| SW-70         | Meeker County Sanitary Landfill            | Closed Landfill   | 3.84        |
| SW-25         | Winona County Sanitary Landfill            | Closed Landfill   | 3.53        |
| SW-335        | Bueckers City Sanitation Services          | Other Solid Waste | 3.15        |
| SW-19         | Korf Brothers Sanitary Landfill            | Closed Landfill   | 2.86        |

Table E-1  
Maximum Facility PFAS HRI Values

|        |                                                     |                   |      |
|--------|-----------------------------------------------------|-------------------|------|
| SW-44  | Lindenfelser Demolition Landfill                    | Closed Landfill   | 2.64 |
| SW-62  | Red Rock Sanitary Landfill                          | Closed Landfill   | 2.58 |
| SW-42  | Yellow Medicine County Sanitary Landfill            | Closed Landfill   | 2.27 |
| SW-115 | Karlstad Sanitary Landfill                          | Closed Landfill   | 1.87 |
| SW-79  | Kandiyohi County Sanitary Landfill                  | Operating MSW     | 1.80 |
| SW-8   | Johnson Bros./Lochness Park Sanitary Landfill       | Closed Landfill   | 1.47 |
| SW-111 | Crow Wing County Landfill                           | Closed Landfill   | 1.45 |
| SW-49  | Ironwood Sanitary Landfill                          | Closed Landfill   | 1.42 |
| SW-14  | Flying Cloud Sanitary Landfill                      | Closed Landfill   | 1.42 |
| SW-536 | Vonco V - Duluth                                    | Other Solid Waste | 1.41 |
| SW-161 | Hibbing Sanitary Landfill                           | Closed Landfill   | 1.35 |
| SW-85  | Albert Lea Sanitary Landfill                        | Closed Landfill   | 1.21 |
| SW-64  | Mankato Sanitary Landfill                           | Closed Landfill   | 1.14 |
| SW-291 | Hengel Demolition Landfill                          | Other Solid Waste | 1.12 |
| SW-428 | Voyageur Disposal & Processing Inc                  | Other Solid Waste | 1.02 |
| SW-263 | Wanamingo Demolition Landfill                       | Other Solid Waste | 0.91 |
| SW-73  | Iron Range Sanitary Landfill                        | Closed Landfill   | 0.85 |
| SW-376 | Crow Wing County MMSW Landfill                      | Operating MSW     | 0.79 |
| SW-29  | Kluver Sanitary Landfill                            | Closed Landfill   | 0.75 |
| SW-7   | Wadena Sanitary Landfill                            | Closed Landfill   | 0.73 |
| SW-154 | Wabasha County Sanitary Landfill                    | Closed Landfill   | 0.68 |
| SW-114 | Anderson Sanitary Landfill                          | Closed Landfill   | 0.66 |
| SW-52  | Chippewa County Sanitary Landfill                   | Closed Landfill   | 0.63 |
| SW-74  | Elk River Landfill                                  | Operating MSW     | 0.62 |
| SW-486 | Meeker County Demolition Landfill                   | Other Solid Waste | 0.61 |
| SW-108 | Benson Sanitary Landfill                            | Closed Landfill   | 0.61 |
| SW-135 | Grand Rapids Area Sanitary Landfill                 | Closed Landfill   | 0.61 |
| SW-343 | SKB Rich Valley Demolition Waste Mgmt Facility      | Other Solid Waste | 0.60 |
| SW-137 | Salol Landfill                                      | Closed Landfill   | 0.53 |
| SW-253 | Carlton South Sanitary Landfill                     | Closed Landfill   | 0.51 |
| SW-60  | Advanced Disposal Services - Rolling Hills Landfill | Other Solid Waste | 0.50 |
| SW-383 | SKB Rosemount Industrial Waste Facility             | Other Solid Waste | 0.48 |
| SW-408 | Glenwood Demolition Disposal LLC                    | Other Solid Waste | 0.46 |
| SW-333 | TK Demolition Disposal LLC                          | Other Solid Waste | 0.38 |
| SW-318 | Hubbard Co So Transfer & Demo Landfill              | Other Solid Waste | 0.38 |
| SW-82  | Mille Lacs Sanitary Landfill                        | Closed Landfill   | 0.37 |
| SW-131 | Steele County Sanitary Landfill                     | Operating MSW     | 0.30 |
| SW-145 | Aitkin County Sanitary Landfill                     | Closed Landfill   | 0.29 |
| SW-50  | Dakhue Sanitary Landfill                            | Closed Landfill   | 0.27 |
| SW-83  | Redwood County Sanitary Landfill                    | Closed Landfill   | 0.27 |
| SW-113 | Hansen Sanitary Landfill                            | Closed Landfill   | 0.26 |
| SW-541 | Oak Ridge Demolition Landfill                       | Other Solid Waste | 0.25 |
| SW-72  | Pine Lane Sanitary Landfill                         | Closed Landfill   | 0.24 |
| SW-121 | Dodge County Sanitary Landfill                      | Closed Landfill   | 0.23 |
| SW-100 | Waseca County Sanitary Landfill                     | Closed Landfill   | 0.23 |
| SW-34  | Clay County Sanitary Landfill                       | Operating MSW     | 0.16 |
| SW-412 | Crosslake Construction Demolition Debris            | Other Solid Waste | 0.15 |

Table E-1  
Maximum Facility PFAS HRI Values

|        |                                            |                   |      |
|--------|--------------------------------------------|-------------------|------|
| SW-5   | Olmsted County - Oronoco Sanitary Landfill | Closed Landfill   | 0.10 |
| SW-306 | Beltrami County Demolition Landfill        | Other Solid Waste | 0.01 |
| SW-429 | DKV Demolition Landfill                    | Other Solid Waste | 0.01 |
| SW-157 | Goodhue Cooperative Landfill               | Closed Landfill   | 0.01 |
| SW-174 | Red Wing Land Disposal Facility            | Other Solid Waste | 0.01 |
| SW-191 | Koochiching County Sanitary Landfill       | Closed Landfill   | 0.01 |
| SW-141 | La Grand Sanitary Landfill                 | Closed Landfill   | 0.00 |
| SW-51  | Eighty Acres Sanitary Landfill             | Closed Landfill   | 0.00 |
| SW-407 | Lakes Area Demolition Landfill             | Other Solid Waste | 0.00 |
| SW-99  | Becker County Sanitary Landfill            | Closed Landfill   | 0.00 |
| SW-77  | Rock County Sanitary Landfill              | Closed Landfill   | 0.00 |
| SW-181 | Crosby Sanitary Landfill                   | Closed Landfill   | 0.00 |
| SW-59  | French Lake Sanitary Landfill              | Closed Landfill   | 0.00 |
| SW-548 | Waste Management Demolition Landfill       | Other Solid Waste | 0.00 |
| SW-542 | Vonco 4 - Austin Demolition Landfill       | Other Solid Waste | 0.00 |
| SW-104 | Murray County Sanitary Landfill            | Closed Landfill   | 0.00 |
| SW-129 | Isanti-Chisago County Sanitary Landfill    | Closed Landfill   | 0.00 |
| SW-179 | Walker-Hackensack Landfill                 | Closed Landfill   | 0.00 |
| SW-18  | Bueckers #1 Sanitary Landfill              | Closed Landfill   | 0.00 |
| SW-204 | Orr Sanitary Landfill                      | Closed Landfill   | 0.00 |
| SW-237 | Cook Area Sanitary Landfill                | Closed Landfill   | 0.00 |