R. Pitt
August 30, 2022
December 4, 2022

Puget Sound Naval Shipyard, Bremerton, WA, Metals Yard Stormwater Data Analyses and Preliminary Modeling Memo

Contents

Summary
The estimated drainage area of the Metals Yard at the Bremerton Puget Sound Naval Shipyard (PSNS) is 2.5 acres. The Metals Yard is used for laydown, supply and storage for large metal plating, steel and concrete pier blocks used for ship support in the dry docks. The stormwater was sampled at the inlet and outlet side of a 10 ft Vortech hydrodynamic separator. Five events were monitored at the site; available data for four of the rains indicated total rain depths of 0.14 to 3.97 inches, typical for the area.

Most of the inlet heavy metals (manganese, nickel, copper, zinc, and arsenic) were mostly associated with the filtered sample fraction, while chromium was mostly associated with the particulates and lead was about evenly divided between the particulate and filtered sample portions. After the hydrodynamic separator, there was a shift to greater abundance with the particulates for manganese, with smaller changes for the other metals. The calculated percentage concentration reductions were only based on four sets of paired samples, which is insufficient to calculate the statistical significance of the observed concentration changes. The apparent TSS reduction was about 44%. Other positive reductions ranged from about 40% (Cd) to 63% (Ni), while Mn, Cu, Zn, and As all indicated increases in concentrations. The associations with the different particle size categories did not show any consistent patterns. Most of the TSS mass was associated with particles between about 5 and 64 µm, with median sizes of about 15 µm for both influent and effluent samples.

Many influent PAHs were mostly in filtered forms, with 2-methylnaphthalene, 1-methylnaphthalene, 2.6-dimethylnaphthalene, 1.3-dimethylnaphthalene, and fluorene having more than 70% of their concentrations associated with filtered forms of the samples. Only acenaphthene, phenanthrene, and 2-ethylanthracene had more than 70% of their concentrations associated with filtered samples for effluent samples (these were not shown to be predominately filtered in the inlet samples). In contrast, only inlet samples for 2-ethylanthracene, benzo(a)anthracene, chrysene, and benzo(b)fluoranthene had >70% of their concentrations associated with particulate fractions of the samples, while no effluent PAHs had large particulate fractions. Most of the PAHs had apparent low to moderate concentration reductions associated with treatment by the hydrodynamic separator, although the few (4) sample pair sets were not sufficient to show if these were statistically significant reductions.

The particulate strengths for all of the PAHs were highest for the smallest particle size range (0.7 to 2.7 µm), with the exception of naphthalene that also had a high particulate strength value for an intermediate particle size range. Most (>70%) of outlet acenaphthene, fluorene, and benzo(a)anthracene would be widely dispersed upon discharge, while none of the outlet PAHs would be associated with near-field sedimentation.

There is total and filtered PFAS data reported for some locations and events. Analyses weren't done by particle size and most of the PFAS congeners were ND. Therefore, analyses of PFAS data were not performed due few detections and no particle size data.

These recent SERDP copper monitored average values were within the range as the prior NPDES non-dry dock study reported data for the closest location to the Metals Yard. The filtered lead recent average values were greater than the prior data, while the total lead average values were lower than the prior data. The recent monitored average zinc values were greater than the maximum values reported previously for both filtered and total zinc forms. The non-dry dock sampling study did not report TSS data for the monitoring location closest to the Metals Yard. However, they summarized the TSS data for 67 samples taken from the many locations at the site. The reported TSS overall concentrations had a mean of 19.5 mg/L (range of 2.7 to 60.3, and a COV of 0.6) and a median of 17.5 mg/L. The SERDP average TSS for the inlet samples was 10.3 mg/L, and the outlet TSS average concentration was 5.7 mg/L. While the SERDP average TSS values are lower than the overall site average TSS values, they are within the reported range of concentrations previously observed.

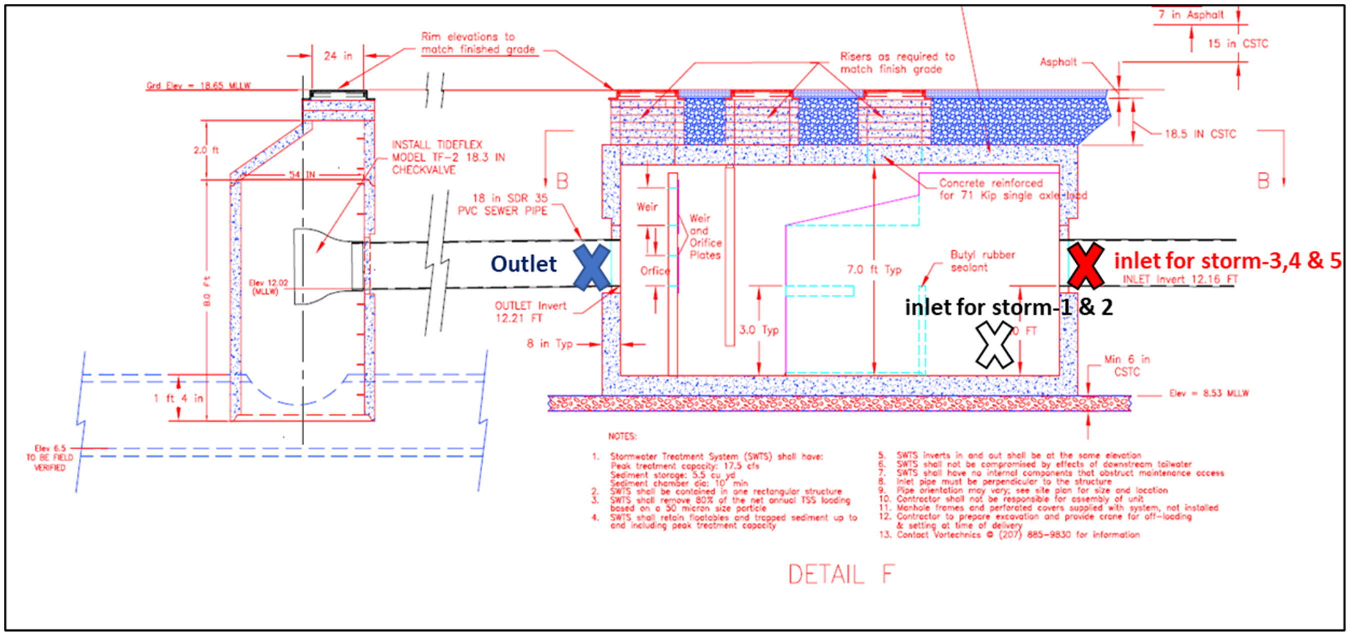
Preliminary WinSLAMM modeling used the previously calibrated Bremerton parameter files, using three special industrial source areas (galvanized metal roofs, moderate asphalt laydown areas, and areas having large amounts of galvanized material exposure). The SERDP monitored TSS values are quite low and less than the range of predicted values, for both influent and effluent conditions, although effluent TSS concentrations are close to the minimum modeled value. The SERDP monitored total and filtered copper and zinc values are within the range of the modeled concentrations.

Monitored Site Description

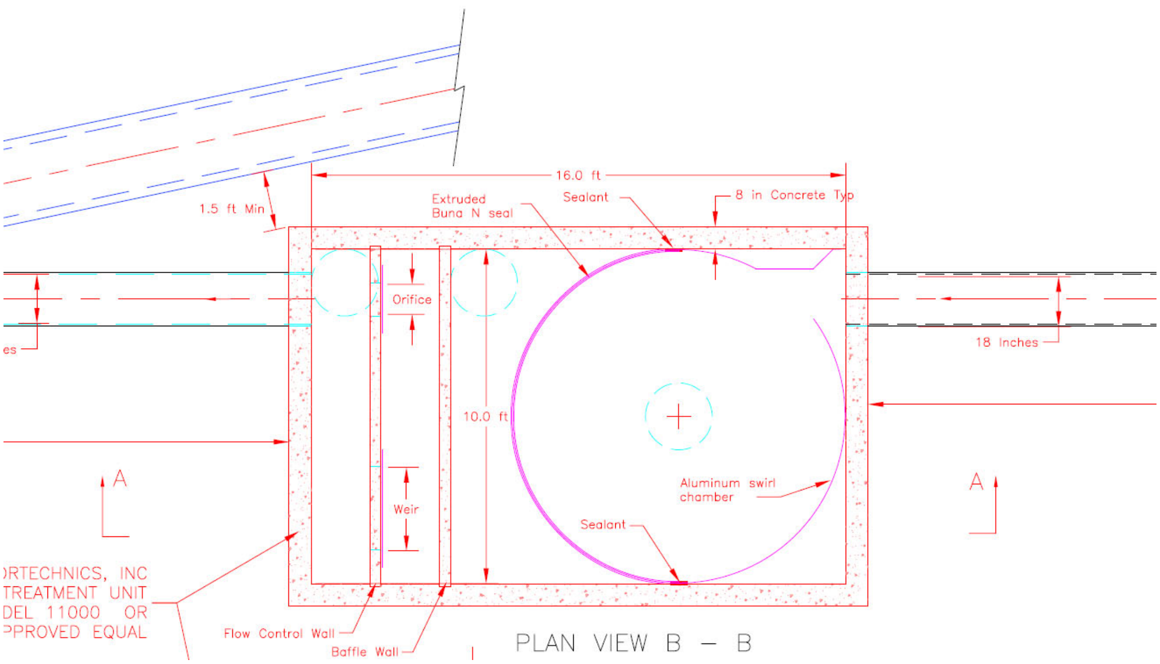
The following information is summarized from material provided by the Texas Tech research group describing the site and the monitoring activity at the Puget Sound Naval Shipyard Metal Yards site. The estimated drainage area is 2.5 acres based on the drainage system diagram shown below. The area is used for laydown, supply and storage for large metal plating, steel and concrete pier blocks used for ship support in the dry docks. The site is adjacent to Harborside Fountain Park on one side and the Bremerton Puget Sound Naval Shipyard on the other side. The site contains temporary material storage covering about 1/3 of the paved site. Much of the material stored appears to be galvanized (roofs of storage bins).

The stormwater was sampled at the inlet and outlet side of a hydrodynamic separator. The outlet of the ten-foot diameter Vortech system drains to a separate discharge to the bay. A total of five events were sampled for flow and TSS, heavy metals, and PAHs. Few data were available for PFAS compounds. For some events, only inlet or outlet samples were obtained due to sampler trigger problems. Maintenance cleaning of the hydrodynamic separator swirl chamber was performed after the second storm event and before the third storm event. Prior to the maintenance, the inlet sampler tube was located inside the swirl chamber due to lack of proper access to the inlet pipe. During maintenance, the inlet sampler tube was re-located to the inlet pipe entering the swirl chamber. Approximate locations of the inlet and outlet samplers are provided in the figure below the drainage map.

Drainage area of Metals Yard.



CDS hydrodynamic separator and sampling locations.

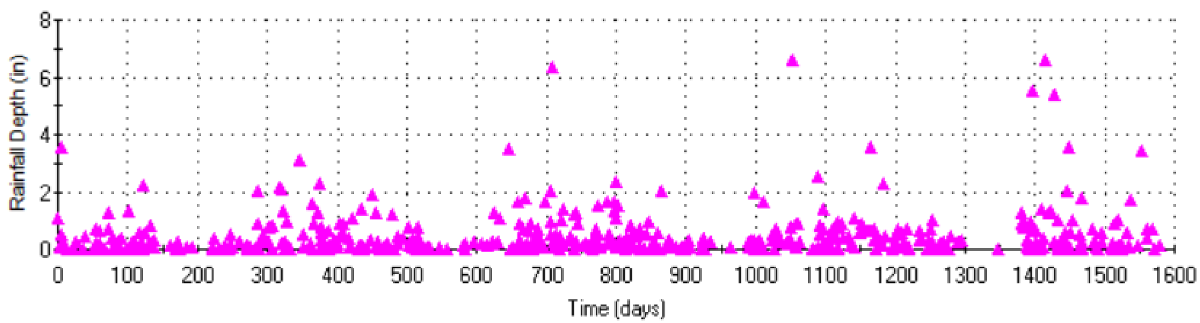


Monitored Events

Five events were monitored at the Metals Yards site. The first four events had the following rain depths, start and end dates, and average intensities (no rainfall data available for the fifth event):

Total rain (in)	start date and time	End date and time	Rain duration (hrs)	Average intensity (in/hr)
3.97	2/27/2022 1:15	3/1/2022 7:35	54.3	0.073
0.14	4/9/2022 15:25	4/11/2022 6:35	39.2	0.0036
0.33	4/29/2022 22:20	4/30/2022 5:30	7.2	0.046
0.58	5/5/2022 1:45	5/7/2022 4:20	50.6	0.011

The following plot shows the rainfall pattern for the four plus years from 2009 through 2013. These are the rain events used in the preliminary WinSLAMM modeling described later in this memo.



The average annual rainfall during this period was about 56 inches, with most of the rain occurring during October through March. During this period, five rains were also greater than 5 inches, about 15 were between 2 and 5 inches, while most rains were less than 1 inch in depth. The four monitored events are will within the overall range of these reported rains occurring at the site.

SERDP TSS, Heavy Metals, and PAH Monitoring Results at Bremerton Metals Yard

Appendix A contains summarized results for the heavy metals, and Appendix B contains summarized results for the PAH data for the Metals Yard site. No data are available for PFAS compounds at this location.

Most of the inlet heavy metals (manganese, nickel, copper, zinc, and arsenic) were mostly associated with the filtered sample fraction, while chromium was mostly associated with the particulates and lead was about evenly divided between the particulate and filtered sample portions. After the hydrodynamic separator treatment, there was a shift to greater abundance with the particulates for manganese, with smaller changes for the other metals. The calculated percentage concentration reductions are only based on four sets of paired samples, which is insufficient to calculate the statistical significance of the observed concentration changes. The apparent TSS reduction was about 44%. Other positive reductions ranged from about 40% (Cd) to 63% (Ni), while Mn, Cu, Zn, and As, all indicated increases in concentrations after the hydrodynamic separator.

The associations with the different particle size categories did not show any consistent patterns. Most of the TSS mass was associated with particles between about 5 and 64 µm, with median sizes of about 15 µm for both influent and effluent samples. Some of the metals had most of their masses associated with particles >63 µm (inlet chromium, outlet manganese, and outlet zinc), while the others were mostly associated with the intermediate particle sizes. Most of the effluent nickel, copper, and arsenic would be widely dispersed upon discharge, while the effluent manganese and zinc are expected to affect near field areas. Heavy metal particulate strengths were greatest for the largest particle size (>63 µm) for chromium, manganese, and lead, while nickel, zinc, arsenic, and cadmium had the largest particulate strengths associated with the smallest particle size range (0.45 to 5 µm).

PAH data are summarized in Appendix B for the PAHs that had few non-detected values. Many influent PAHs were mostly in filtered forms, with 2-methylnaphthalene, 1-methylnaphthalene, 2.6-dimethylnaphthalene, 1.3-dimethylnaphthalene, and fluorene having more than 70% of their concentrations associated with filtered forms of the samples. Only acenaphthene, phenanthrene, and 2-ethylanthracene had more than 70% of their concentrations associated with filtered samples for effluent samples (these were not shown to be predominately filtered in the inlet samples). In contrast, only inlet samples for 2-ethylanthracene, benzo(a)anthracene, chrysene, and benzo(b)fluoranthene had >70% of their concentrations associated with particulate fractions of the samples, and no effluent PAHs had large particulate fractions.

Inlet fluorene, inlet and outlet phenanthrene, inlet and outlet 2-methylphenathrene, outlet 2-ethylanthracene, inlet and outlet fluoranthene, inlet pyrene, inlet benzo(a)anthracene, inlet chrysene, inlet benzo(b)fluoranthene, and total inlet PAHs had most of their particulate bound concentrations associated with particles greater than 63 µm. Many of the other particulate bound PAHs were mostly associated with particles smaller than 10 µm. Most (>70%) of outlet acenaphthene, fluorene, and benzo(a)anthracene would be widely dispersed upon discharge, while none of the outlet PAHs would be associated with near-field sedimentation. In contrast, 2-methylphenanthrene, 2-ethylanthracenepyrene, benzo(a)anthracene, chrysene, and benzo(b)fluoranthene untreated inlet samples would be associated with near-field deposition.

Most of the PAHs had apparent low to moderate concentration reductions associated with treatment by the hydrodynamic separator, although the few (4) sample pair data sets were not sufficient to show if these were statistically significant reductions.

The particulate strengths for all of the PAHs were highest for the smallest particle size (0.7 to 2.7 µm), with the exception of naphthalene with also had a high particulate strength value for an intermediate particle size.

Metals Yard SERDP Stormwater Monitoring Data Compared to Historical Bremerton Stormwater Data

During the prior NPDES non-dry dock study, the PSNS collected 115 samples between April 29, 1994, and March 19, 2005, including 9 to 10 samples at a location adjacent to the metals yard during 1994 to 1996. The following figure shows the sampling locations, and the table compares the NPDES sampling results with the recent SERDP monitoring results for copper, lead, and zinc for the close location.

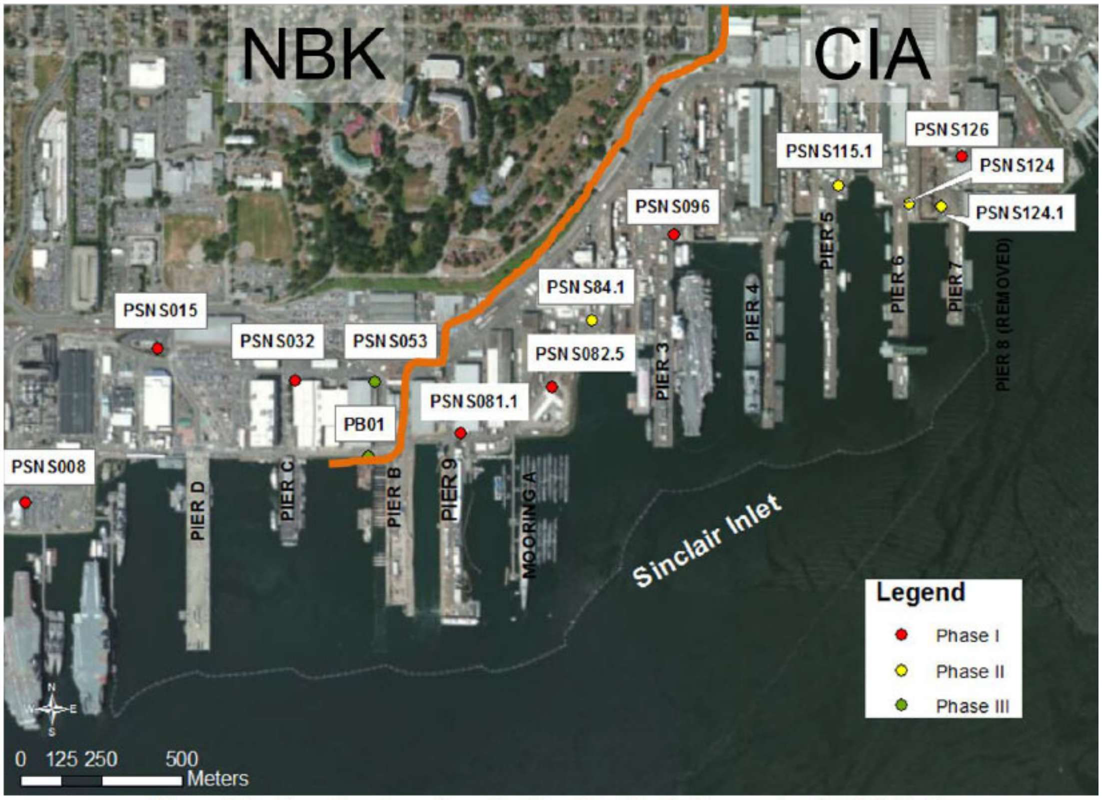


Figure 2-1. Sampling Locations for Non-Dry Dock Stormwater Outfall Study

CIA PSN S126 is the closest historical monitoring location (described as: CIA 126 East CIA, Southwest B460 along "C" Street, east of DD3, Materials storage (outdoor), 15.22 acres drainage area). The following table summarizes the copper, lead, and zinc total and filtered concentrations at this location, compared to the average SERDP monitored values at the Metals Yard.

µg/L	Cu filtered	Cu total	Pb filtered	Pb total	Zn filtered	Zn total
mean	12.8	18.7	0.314	4.32	52	73
Min	3.35	7.64	0.159	2.60	34.7	49
Max	29.3	42.8	0.546	7.89	62	108
COV	0.72	0.64	0.36	0.38	0.18	0.25
count	10	10	10	10	10	10
SERDP monitored average inlet Metals Yard	10.6	16.8	0.58	1.09	202	254
SERDP monitored average outlet Metals Yard	10.4	19.8	0.76	0.99	243	360

The recent SERDP copper monitored average values were within the range as the prior reported data for the close location. The filtered lead recent average values were greater than the prior data, while the total lead average values were lower than the prior data. The recent monitored average zinc values were greater than the maximum values reported previously for both filtered and total forms of zinc.

The non-dry dock sampling study report did not show TSS data for the monitoring location closest to the Metals Yard. However, they summarized the TSS data for 67 samples taken from the many locations at the PSNS Bremerton area. The reported TSS overall concentrations had a mean of 19.5 mg/L (range of 2.7 to 60.3, and a COV of 0.6) and a median of 17.5 mg/L. The SERDP average TSS for the inlet samples was 10.3 mg/L, and the outlet TSS average concentration was 5.7 mg/L. While the SERDP average TSS values are lower than the overall site average TSS values, they are within the reported range of concentrations previously observed.

Preliminary WinSLAMM Modeling

The preliminary WinSLAMM modeling used the previously calibrated Bremerton parameter files, using three special industrial source areas (galvanized metal roofs, moderate asphalt laydown areas, and areas having large amounts of galvanized material exposure). The following special source areas were used to describe these areas:

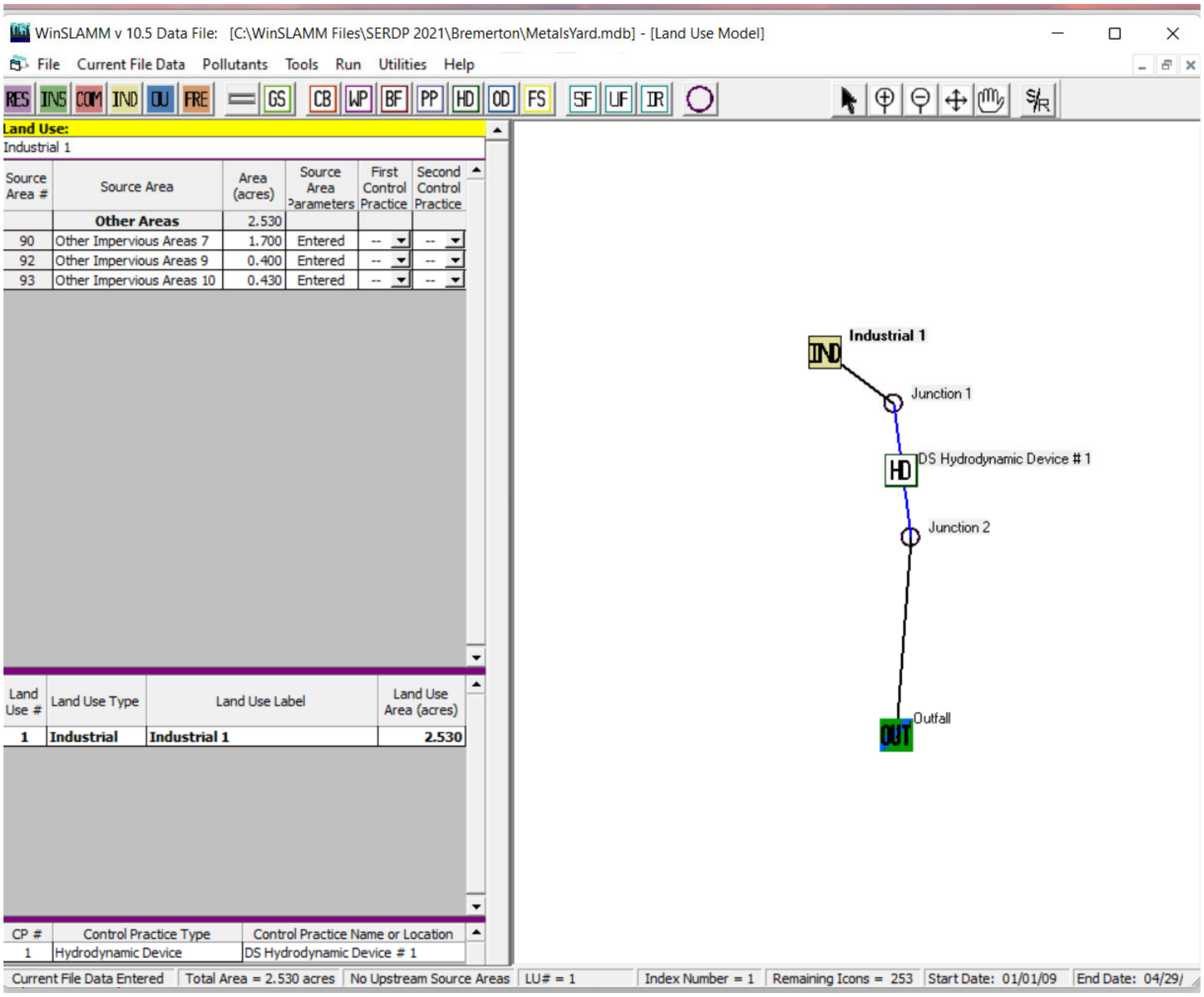
WinSLAMM other impervious areas

84	Other Imp Area 1	OIA1 - Airfield apron/runway paved areas	
85	Other Imp Area 2	OIA2 - Airfield other paved areas	
86	Other Imp Area 3	OIA3 - Light laydown concrete areas	
87	Other Imp Area 4	OIA4 - Moderate laydown concrete areas	
88	Other Imp Area 5	OIA5 - Heavy laydown concrete areas	
89	Other Imp Area 6	OIA6 - Light laydown asphalt areas	
90	Other Imp Area 7	OIA7 - Moderate laydown asphalt areas	1.70 acres
91	Other Imp Area 8	OIA8 - Heavy laydown asphalt areas	
92	Other Imp Area 9	OIA9 - Galvanized metal roofs	0.40 acres
93	Other Imp Area 10	OIA10 - Other galvanized materials	0.43 acres
94	Other Imp Area 11		
95	Other Imp Area 12		
96	Other Imp Area 13		
97	Other Imp Area 14		
98	Other Imp Area 15		

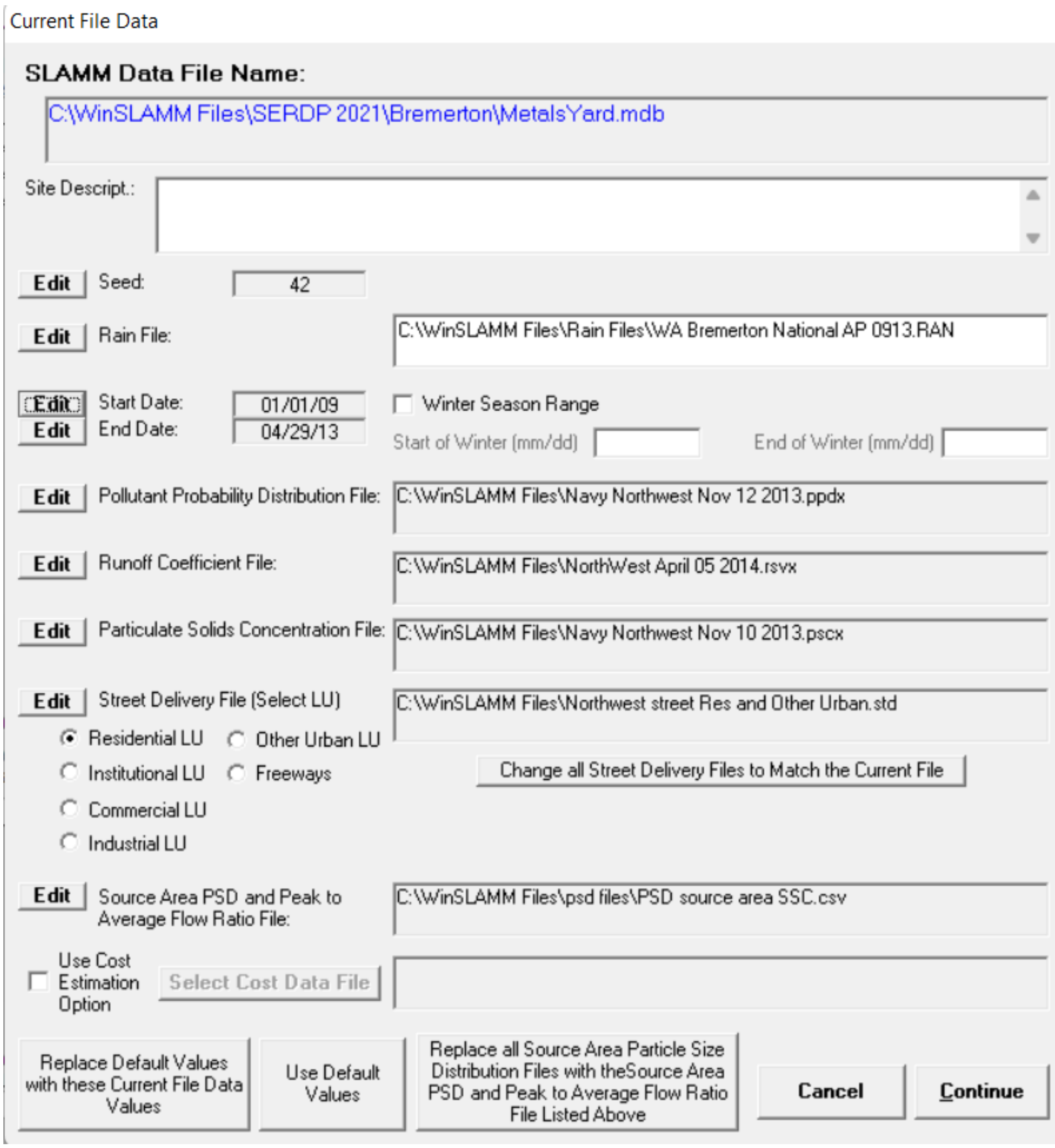
WinSLAMM other non-paved areas

99	Other Non-Paved Area 1	ONPA1 - Light laydown unpaved
100	Other Non-Paved Area 2	ONPA2 - Moderate laydown unpaved
101	Other Non-Paved Area 3	ONPA3 - Heavy laydown unpaved
102	Other Non-Paved Area 4	
103	Other Non-Paved Area 5	

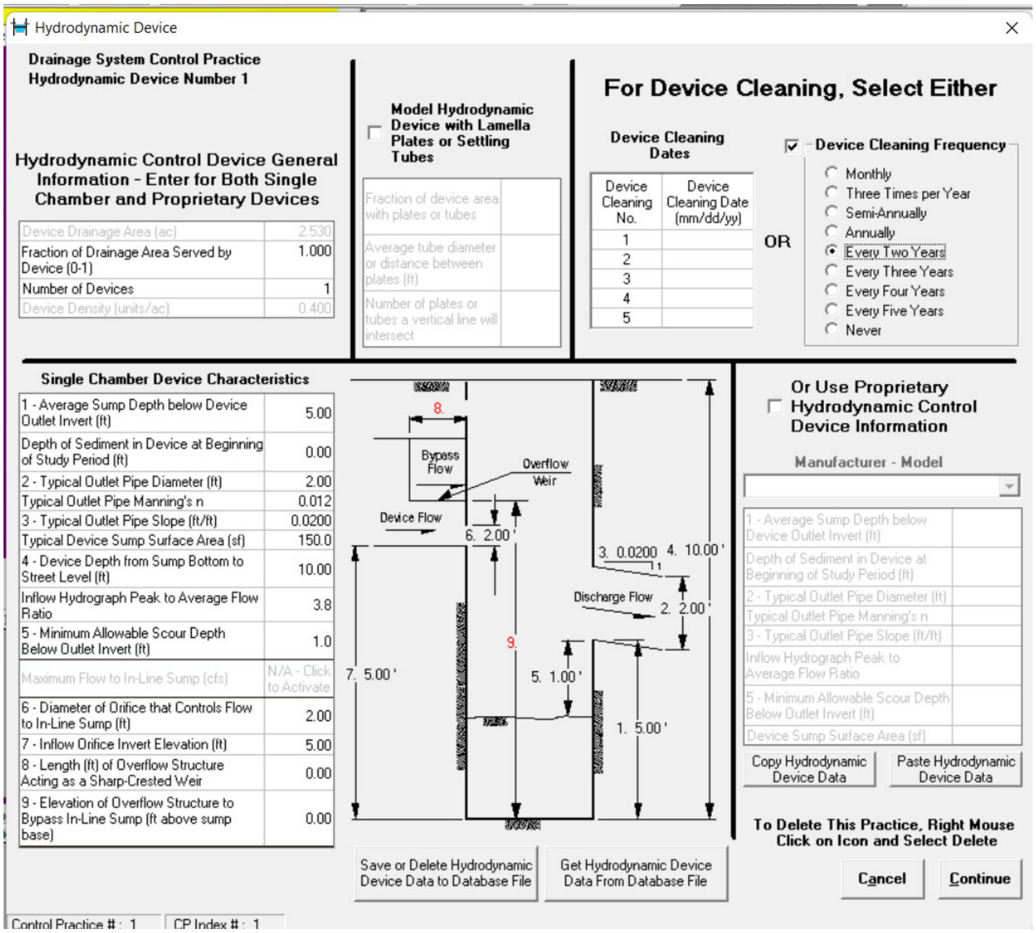
The following screen shows the layout of the modeled area, along with the Vortech hydrodynamic separator.



The following screen shows the parameter files used in the Metals Yard modeling analyses, including the previously calibrated files.



The following screen shows the dimensions of the Vortech hydrodynamic separator:



The model used the Bremerton rain file that includes 522 rains from 01/01/2009 to 04/29/2013, ranging from 0.01 to 6.61 inches, with an average of 0.46 inches. The following table summarizes the model calculated influent and effluent concentrations. In addition, the calculated weighted Rv was 0.79.

	Modeled influent	SERDP monitored influent data	Modeled after hydrodynamic separator	SERDP monitored effluent data
TSS (mg/L)	105 (103 to 124)	10	42 (16 to 60)	6
Cu, total (µg/L)	55 (11 to 203)	17	53 (9 to 200)	20
Cu, filtered (µg/L)	52 (7 to 199)	11	52 (7 to 199)	11
Zn, total (µg/L)	221 (46 to 1,620)	254	166 (15 to 1,550)	360
Zn, filtered (µg/L)	129 (3 to 1,530)	202	129 (3 to 1,530)	243

Note: the prior Bremerton calibration data did not contain lead data

The SERDP monitored TSS values were quite low and less than the range of predicted values, for both influent and effluent conditions, although effluent TSS concentrations were close to the minimum modeled value. The SERDP monitored total and filtered copper and zinc values were within the range of the modeled concentrations.

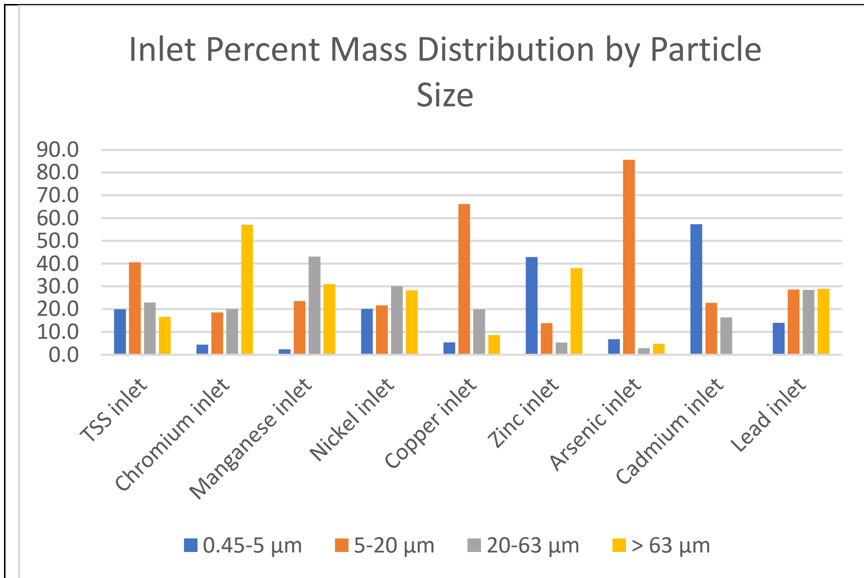
Appendix A: TSS and Heavy Metals Stormwater Monitoring Results at Metals Yard Site

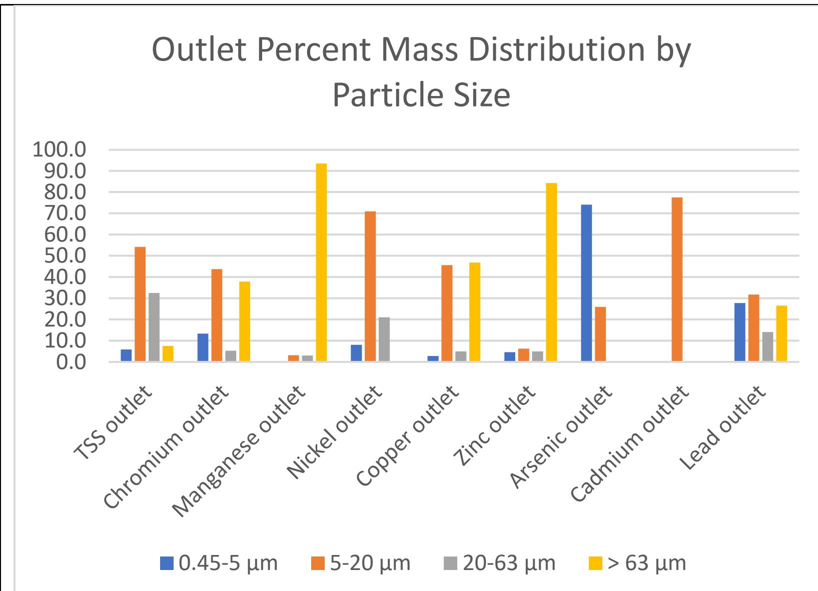
Heavy Metal Stormwater Concentrations at Metals Yard Site

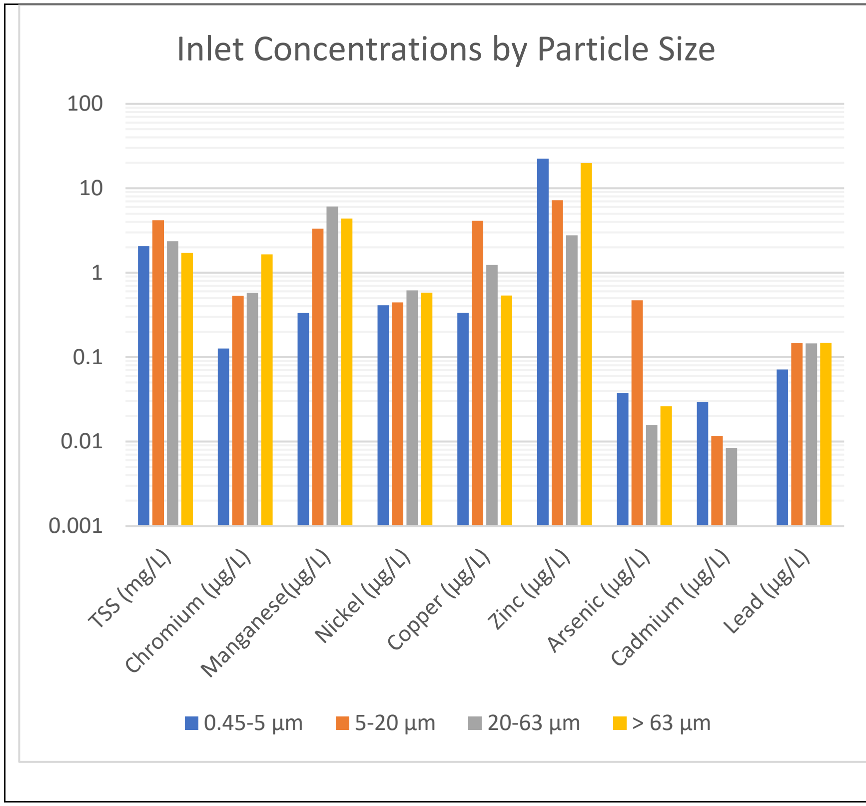
inlet average	**TSS (mg/L)**	**Chromium (µg/L)**	**Manganese (µg/L)**	**Nickel (µg/L)**	**Copper (µg/L)**	**Zinc (µg/L)**	**Arsenic (µg/L)**	**Cadmium (µg/L)**	**Lead (µg/L)**
total		3.96	152.3	11.8	16.8	253.7	3.13	0.17	1.09
particulate (>0.45 µm)	10.3	2.89	14.1	2.1	6.2	52.2	0.55	0.05	0.51
filtered (<0.45 µm)		1.07	138.2	9.8	10.6	201.5	2.58	0.12	0.58
% filtered		27.1	90.7	82.6	63.0	79.4	82.4	70.3	53.2
% particulate	100.0	72.9	9.3	17.4	37.0	20.6	17.6	29.7	46.8
outlet average	**TSS (mg/L)**	**Chromium (µg/L)**	**Manganese (µg/L)**	**Nickel (µg/L)**	**Copper (µg/L)**	**Zinc (µg/L)**	**Arsenic (µg/L)**	**Cadmium (µg/L)**	**Lead (µg/L)**
total		1.51	33.4	5.3	19.8	359.7	3.02	0.21	0.99
particulate (>0.45 µm)	5.7	0.90	17.6	0.8	9.4	116.7	0.90	0.03	0.22
filtered (<0.45 µm)		0.61	15.8	4.5	10.4	243.0	2.12	0.18	0.76
% filtered		40.4	47.2	85.6	52.6	67.6	70.2	85.2	77.2
% particulate	100.0	59.6	52.8	14.4	47.4	32.4	29.8	14.8	22.8
inlet average	**TSS (mg/L)**	**Chromium (µg/L)**	**Manganese (µg/L)**	**Nickel (µg/L)**	**Copper (µg/L)**	**Zinc (µg/L)**	**Arsenic (µg/L)**	**Cadmium (µg/L)**	**Lead (µg/L)**
0.45-5 µm	2.1	0.13	0.3	0.4	0.3	22.4	0.04	0.03	0.07
5-20 µm	4.2	0.54	3.3	0.4	4.1	7.2	0.47	0.01	0.15
20-63 µm	2.4	0.58	6.1	0.6	1.2	2.8	0.02	0.01	0.15
> 63 µm	1.7	1.65	4.4	0.6	0.5	19.8	0.03	nd	0.15
outlet average	**TSS (mg/L)**	**Chromium (µg/L)**	**Manganese (µg/L)**	**Nickel (µg/L)**	**Copper (µg/L)**	**Zinc (µg/L)**	**Arsenic (µg/L)**	**Cadmium (µg/L)**	**Lead (µg/L)**
0.45-5 µm	0.3	0.12	0.1	0.1	0.3	5.3	0.67	nd	0.06
5-20 µm	3.1	0.39	0.6	0.5	4.3	7.3	0.23	0.02	0.07
20-63 µm	1.9	0.05	0.5	0.2	0.5	5.8	nd	nd	0.03
> 63 µm	0.4	0.34	16.5	nd	4.4	98.3	nd	nd	0.06

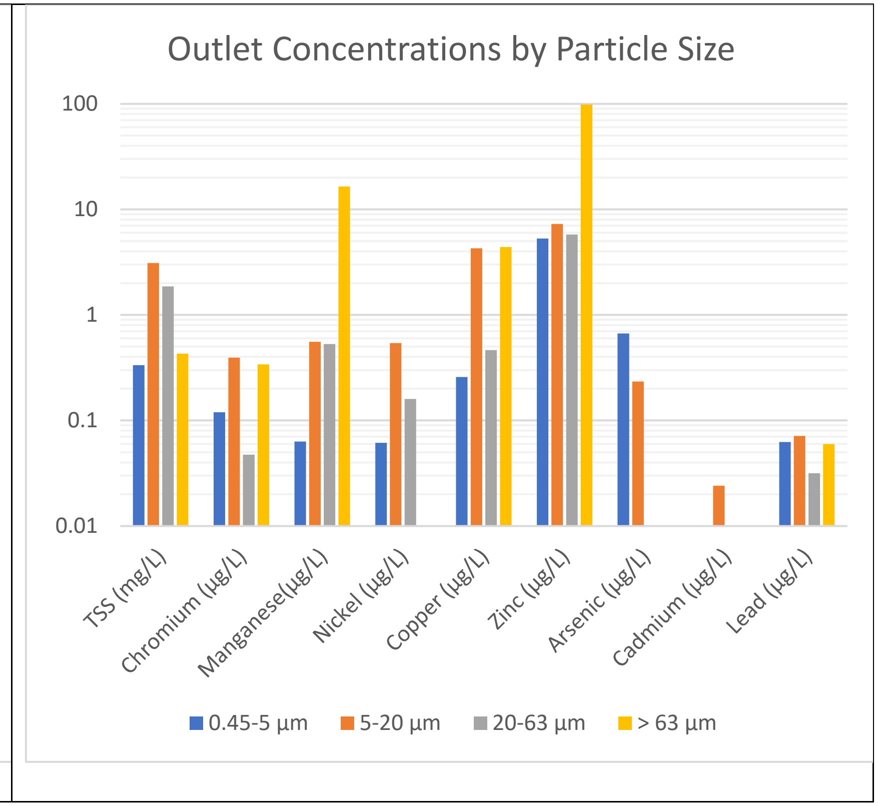
Apparent Percentage Reductions Associated with Stormwater Treatment at Metals Yard, by Particle Size (likely not statistically significant due to few samples)

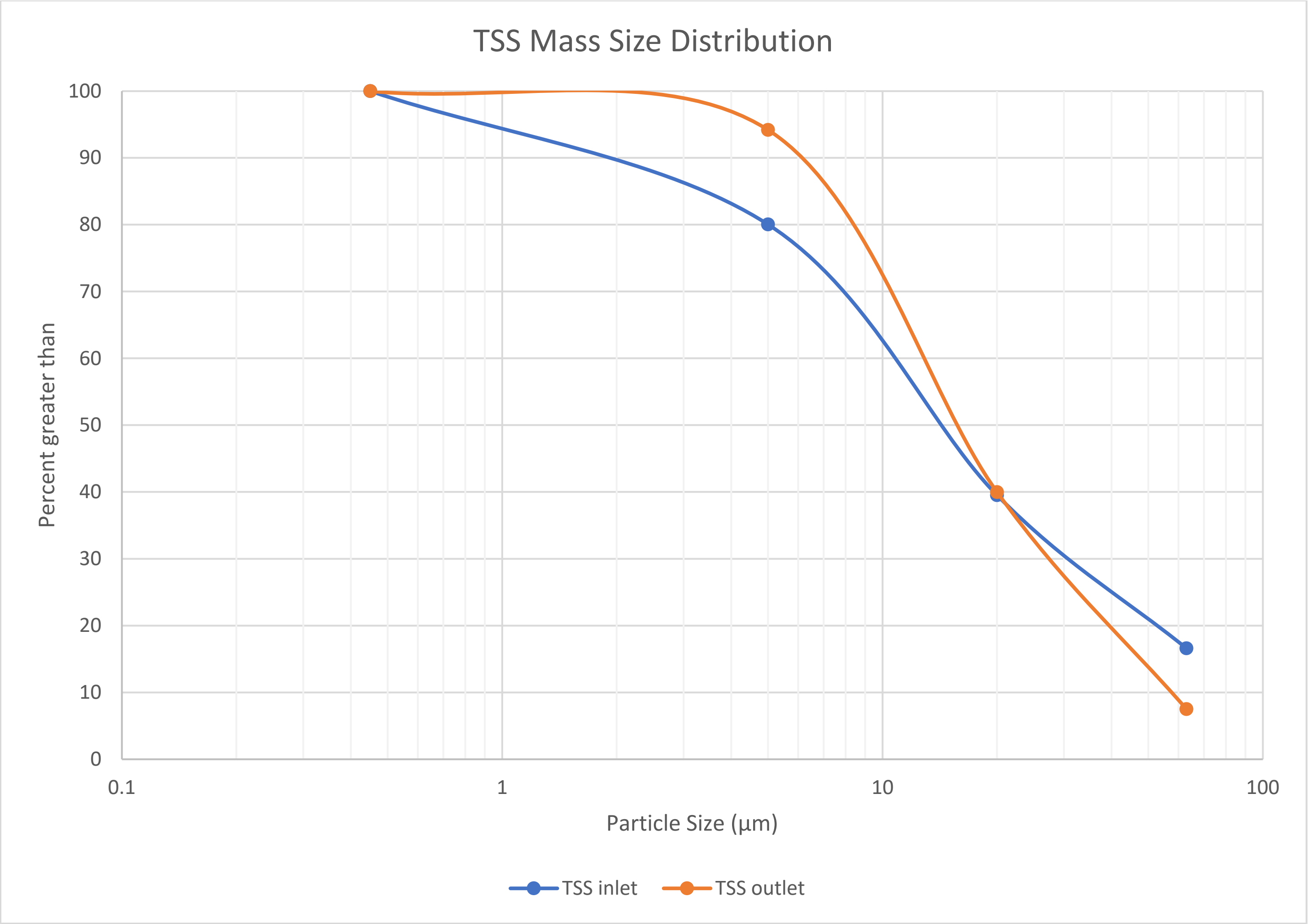
	TSS	Cr	Mn	Ni	Cu	Zn	As	Cd	Pb
Particulate (>0.45 µm)	44.4%	68.8%	-24.6%	62.9%	-50.9%	-123.5%	-63.5%	39.7%	55.9%
Filtered (<0.45 µm)	n/a	43.3	88.6	53.5	1.6	-20.6	18.0	-46.9	-31.2
0.45-5 µm	83.8	5.5	81.0	85.1	23.0	76.4	-1,680	n/a	12.5
5-20 µm	25.7	26.5	83.3	-21.9	-3.9	-1.1	50.5	-105	51.1
20-63 µm	21.2	91.8	91.3	74.1	62.4	-108.0	n/a	n/a	78.2
> 63 µm	74.9	79.4	-275.6	100.0	-717.9	-395.5	n/a	n/a	59.6

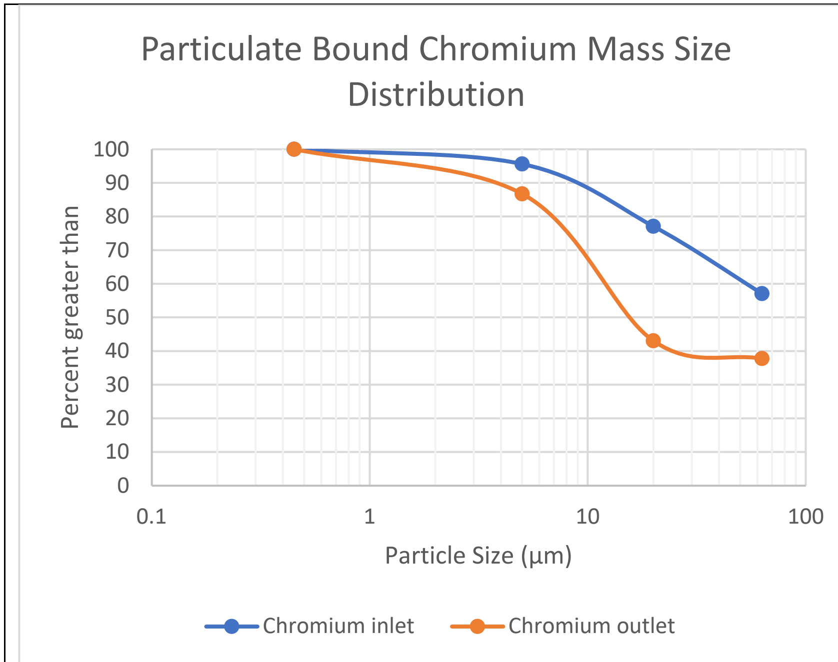


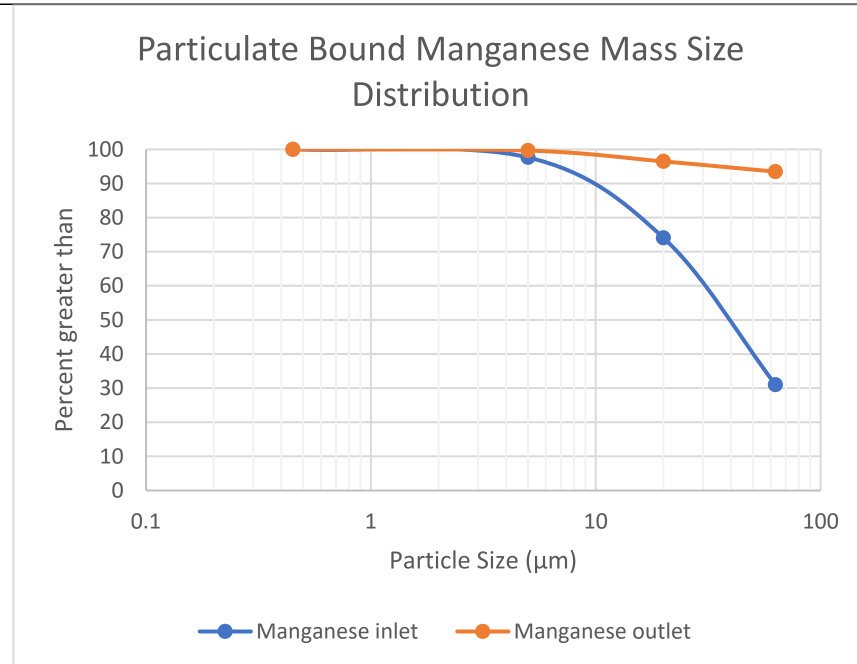


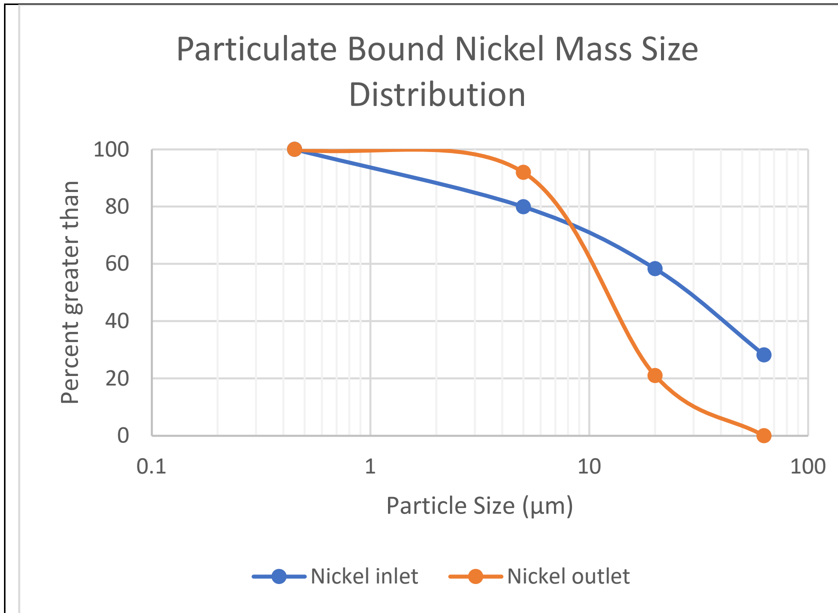

Inlet Concentrations by Particle Size
100
10
1
0.1
0.01
0.001
TSS (mg/L)
Chromium (µg/L)
Manganese(µg/L)
Nickel (µg/L)
Copper (µg/L)
Zinc (µg/L)
Arsenic (µg/L)
Cadmium (µg/L)
Lead (µg/L)
0.45-5 µm
5-20 µm
20-63 µm
> 63 µm

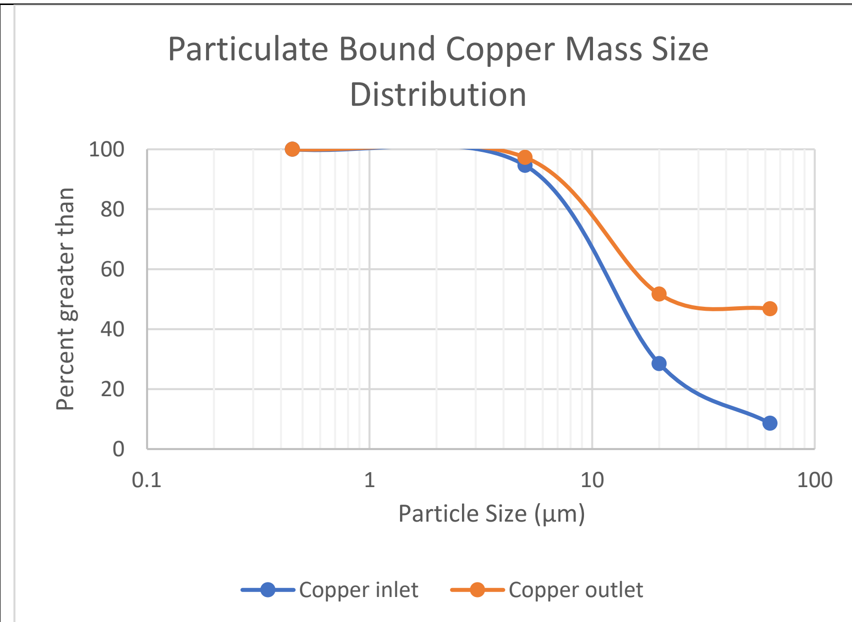

Outlet Concentrations by Particle Size
100
10
1
0.1
0.01
TSS (mg/L)
Chromium (µg/L)
Manganese(µg/L)
Nickel (µg/L)
Copper (µg/L)
Zinc (µg/L)
Arsenic (µg/L)
Cadmium (µg/L)
Lead (µg/L)
0.45-5 µm
5-20 µm
20-63 µm
> 63 µm

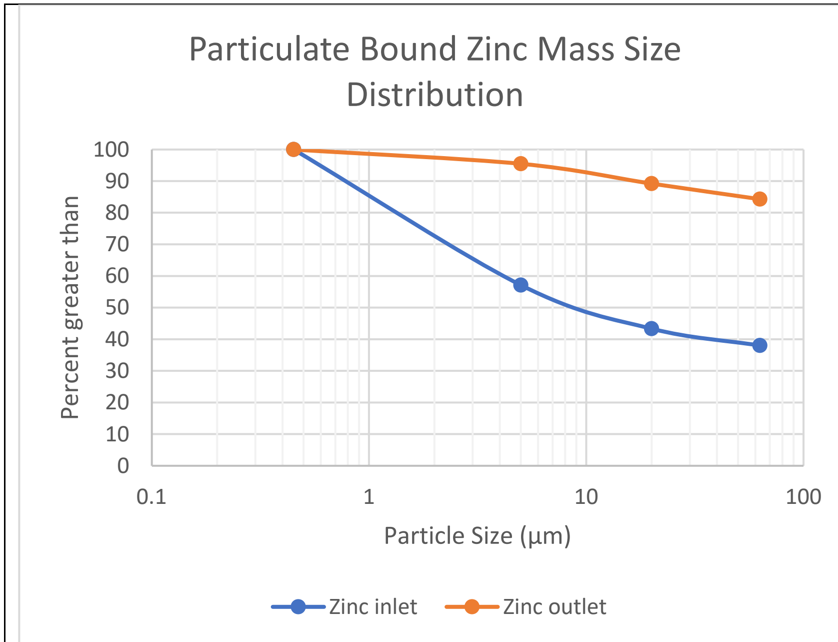

TSS Mass Size Distribution
100
90
80
70
60
50
40
30
20
10
0
Percent greater than
0.1
1
10
100
Particle Size (µm)
TSS inlet
TSS outlet

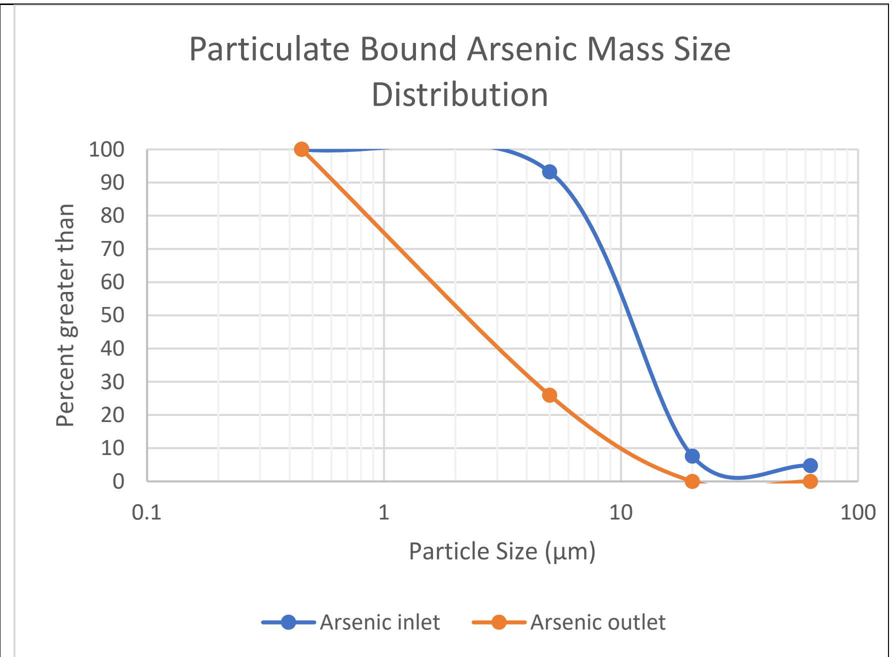

Particulate Bound Chromium Mass Size Distribution
Percent greater than
100
90
80
70
60
50
40
30
20
10
0
0.1
1
10
100
Particle Size (µm)
Chromium inlet
Chromium outlet

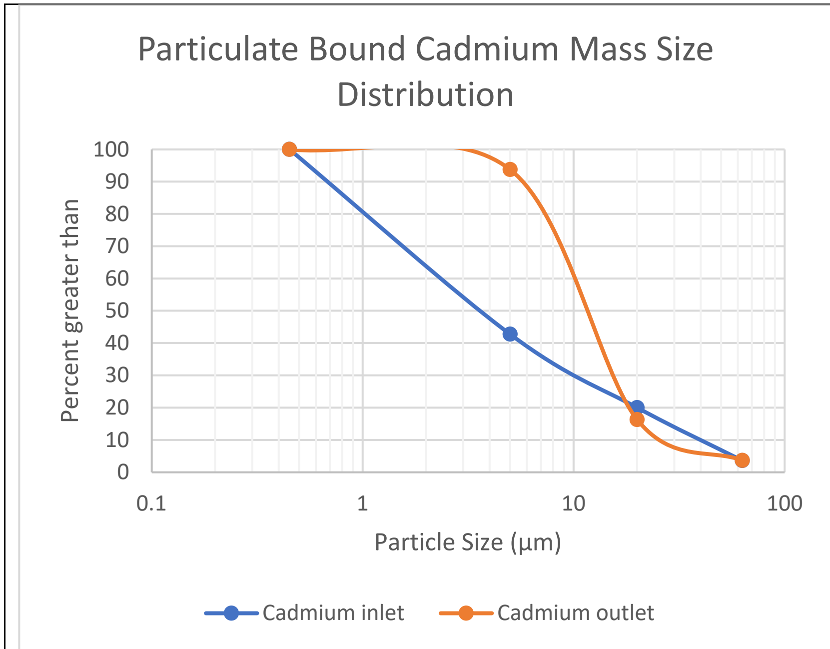

Particulate Bound Manganese Mass Size Distribution
Percent greater than
100
90
80
70
60
50
40
30
20
10
0
0.1
1
10
100
Particle Size (µm)
Manganese inlet
Manganese outlet

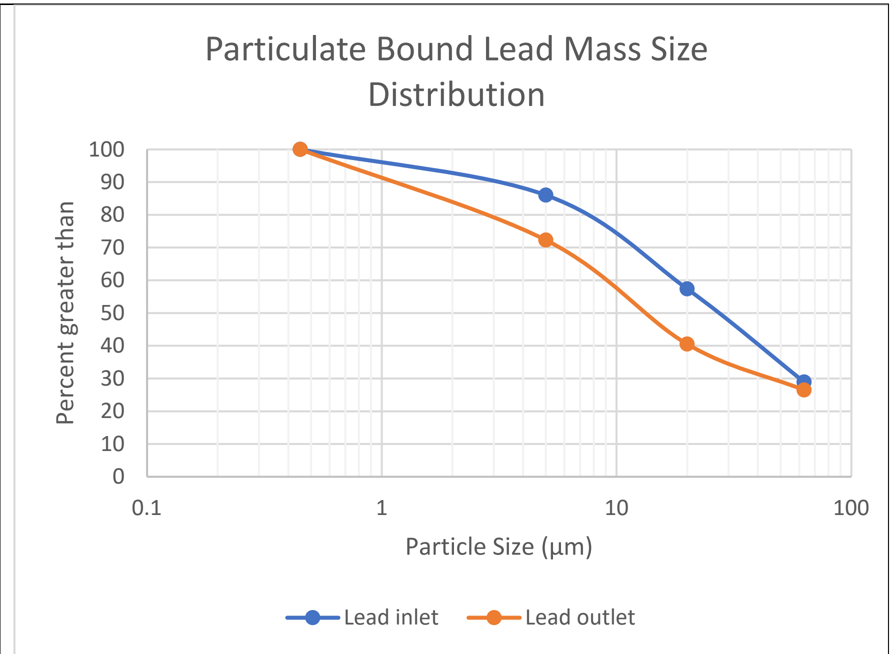

Particulate Bound Nickel Mass Size Distribution
Percent greater than
100
80
60
40
20
0
0.1
1
10
100
Particle Size (µm)
Nickel inlet
Nickel outlet


Particulate Bound Copper Mass Size Distribution
Percent greater than
100
80
60
40
20
0
0.1
1
10
100
Particle Size (µm)
Copper inlet
Copper outlet


Particulate Bound Zinc Mass Size Distribution
Percent greater than
100
90
80
70
60
50
40
30
20
10
0
0.1
1
10
100
Particle Size (µm)
Zinc inlet
Zinc outlet

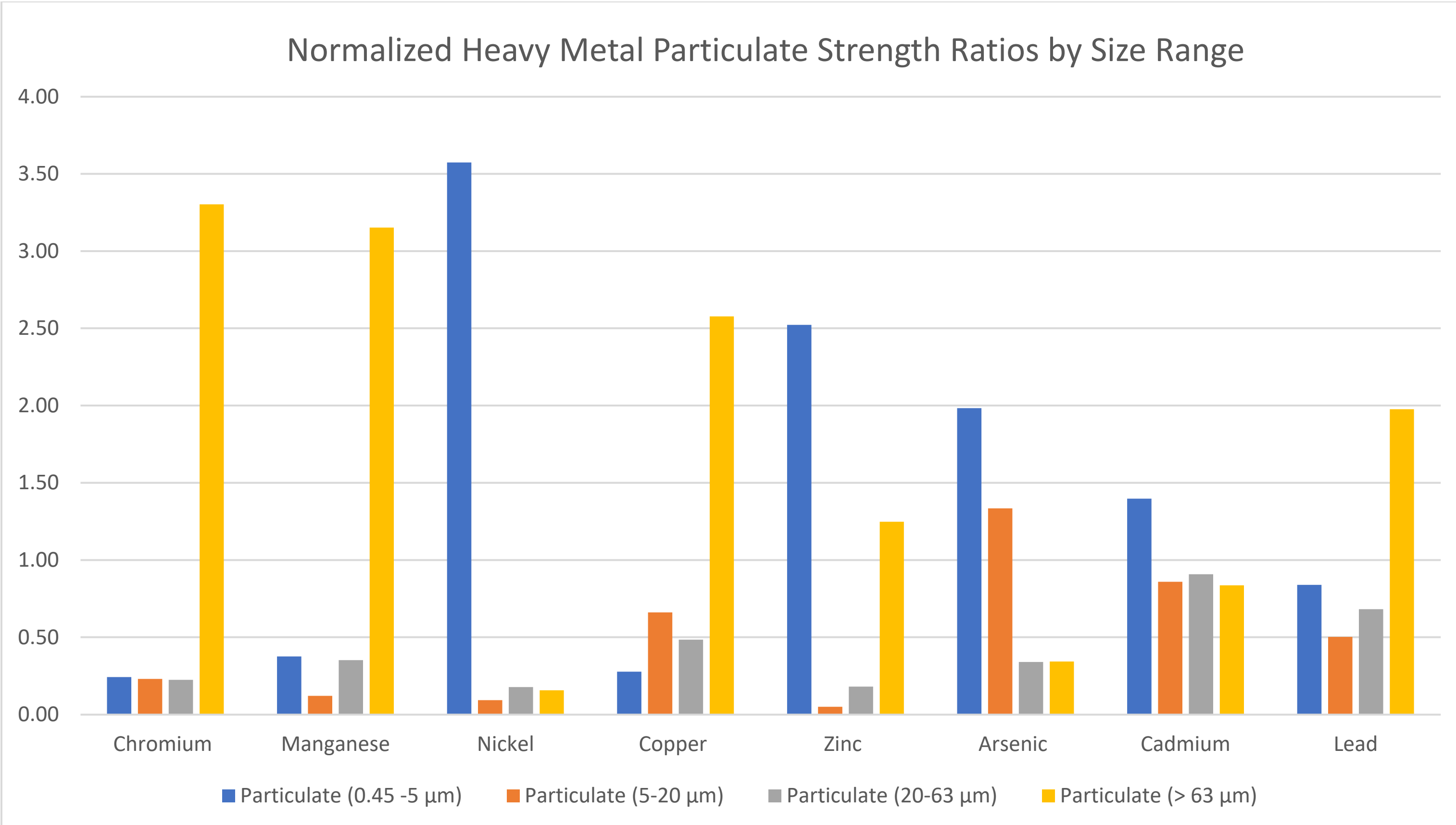

Particulate Bound Arsenic Mass Size Distribution
Percent greater than
100
90
80
70
60
50
40
30
20
10
0
0.1
1
10
100
Particle Size (µm)
Arsenic inlet
Arsenic outlet





Particulate Strengths of Heavy Metals (mg/kg)

average of all samples	Chromium	Manganese	Nickel	Copper	Zinc	Arsenic	Cadmium	Lead
Total Particulate (> 0.45 µm)	237	1,588	145	972	10,281	77	6	53
Particulate (0.45 -5 µm)	196	1,373	4,856	547	189,479	104	12	69
Particulate (5-20 µm)	186	441	126	1,306	3,726	70	7	41
Particulate (20-63 µm)	182	1,287	241	957	13,585	18	8	56
Particulate (> 63 µm)	2,667	11,531	213	5,088	93,703	18	7	163



Normalized Heavy Metal Particulate Strength Ratios by Size Range
4.00
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
Chromium
Manganese
Nickel
Copper
Zinc
Arsenic
Cadmium
Lead
Particulate (0.45 -5 µm)
Particulate (5-20 µm)
Particulate (20-63 µm)
Particulate (> 63 µm)

Mass Percentages Associated with Particulate Sedimentation at Near Field, Far Field, and Widely Dispersed

inlet	TSS	Chromium	Manganese	Nickel	Copper	Zinc	Arsenic	Cadmium	Lead
>63 µm (near field)	16.6	57.1	31.0	28.2	8.6	38.0	4.8	n/a	28.9
20 to 63 µm (far field)	22.9	20.0	43.1	30.1	19.8	5.3	2.9	16.4	28.5
<20 µm (widely dispersed)	60.5	22.9	25.9	41.7	71.5	56.7	92.4	80.0	42.6
outlet	TSS	Chromium	Manganese	Nickel	Copper	Zinc	Arsenic	Cadmium	Lead
>63 µm (near field)	7.5	37.8	93.5	0.0	46.8	84.3	n/a	n/a	26.5
20 to 63 µm (far field)	32.5	5.3	3.0	21.0	4.9	4.9	n/a	n/a	14.0
<20 µm (widely dispersed)	60.0	57.0	3.5	79.0	48.3	10.8	100.0	n/a	59.5

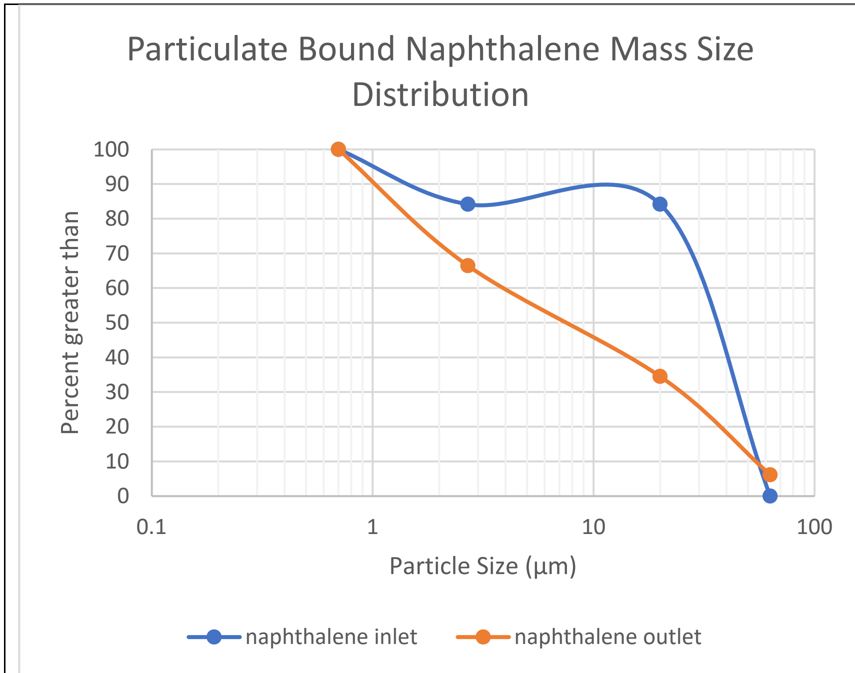
Appendix B: PAH Stormwater Monitoring Results at Metals Yard Site

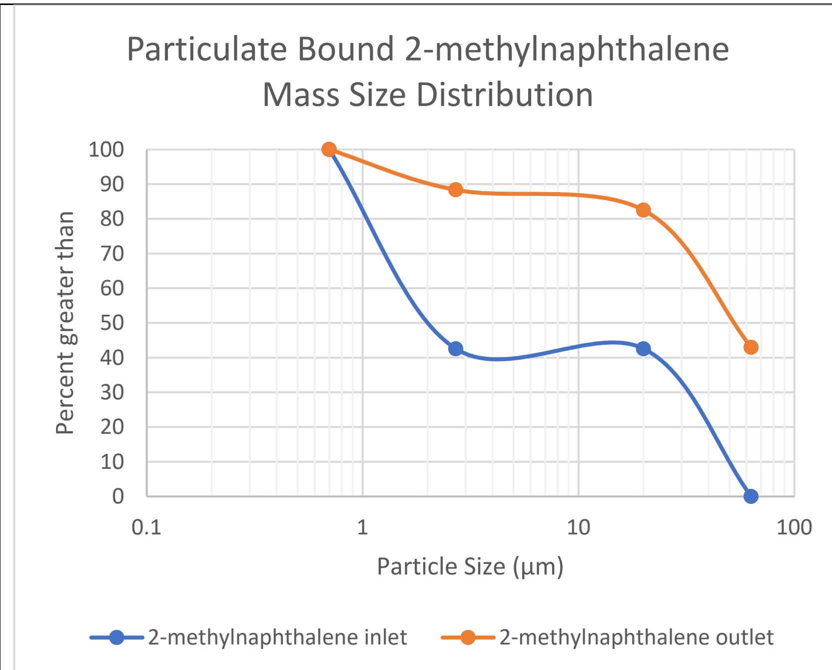
average inlet	naphthalene	2-methylnaphthalene	1-methylnaphthalene	2.6-dimethylnaphthalene	1.3-dimethylnaphthalene	acenaphthene	fluorene	phenanthrene
total sample	16.7	5.9	2.6	1.7	1.4	2.3	6.6	21.0
Total Particulate (>0.7 µm)	7.7	1.3	0.4	0.4	0.3	0.8	1.5	7.0
Filtered (<0.7µm)	9.0	4.6	2.3	1.3	1.1	1.5	5.1	14.0
% filtered	53.7	77.5	85.0	77.1	81.9	65.7	77.7	66.7
% particulate	46.3	22.5	15.0	22.9	18.1	34.3	22.3	33.3
0.7-2.7 µm	1.2	0.8	0.2	0.3	0.2	0.1	0.5	1.7
2.7-20 µm	nd	nd	nd	nd	nd	0.1	0.3	1.5
20-63 µm	6.5	0.6	0.1	nd	nd	0.2	nd	nd
>63 µm	nd	nd	nd	0.1	0.1	nd	0.2	1.7
average outlet	naphthalene	2-methylnaphthalene	1-methylnaphthalene	2.6-dimethylnaphthalene	1.3-dimethylnaphthalene	acenaphthene	fluorene	phenanthrene
total sample	8.7	5.5	2.1	1.7	1.3	1.2	3.5	15.0
Total Particulate (>0.7 µm)	4.7	3.2	1.0	1.0	0.6	0.4	1.1	4.5
Filtered (<0.7µm)	4.0	2.2	1.1	0.7	0.7	0.9	2.4	10.6
% filtered	45.7	40.7	52.5	42.9	52.2	70.8	68.2	70.4
% particulate	54.3	59.3	47.5	57.1	47.8	29.2	31.8	29.6
0.7-2.7 µm	1.6	0.4	0.2	0.1	0.1	0.3	0.3	1.4
2.7-20 µm	1.5	0.2	nd	0.2	0.1	0.1	0.5	0.9
20-63 µm	1.3	1.3	0.4	0.2	0.1	nd	nd	nd
>63 µm	0.3	1.4	0.4	0.5	0.3	nd	0.3	2.2
average inlet, ug/L	naphthalene	2-methylnaphthalene	1-methylnaphthalene	2.6-dimethylnaphthalene	1.3-dimethylnaphthalene	acenaphthene	fluorene	phenanthrene
0.7-2.7 µm	1.23	0.77	0.25	0.29	0.18	0.12	0.46	1.67
2.7-20 µm	nd	nd	nd	0.02	nd	0.13	0.25	1.48
20-63 µm	6.51	0.57	0.15	0.02	nd	0.25	nd	nd
>63 µm	nd	nd	nd	0.07	0.08	nd	0.18	1.71
average outlet, ug/L	naphthalene	2-methylnaphthalene	1-methylnaphthalene	2.6-dimethylnaphthalene	1.3-dimethylnaphthalene	acenaphthene	fluorene	phenanthrene
0.7-2.7 µm	1.58	0.38	0.18	0.06	0.11	0.26	0.32	1.35
2.7-20 µm	1.50	0.19	0.01	0.16	0.12	0.10	0.47	0.87
20-63 µm	1.34	1.28	0.44	0.18	0.14	nd	nd	nd
>63 µm	0.29	1.38	0.38	0.55	0.26	nd	0.33	2.23

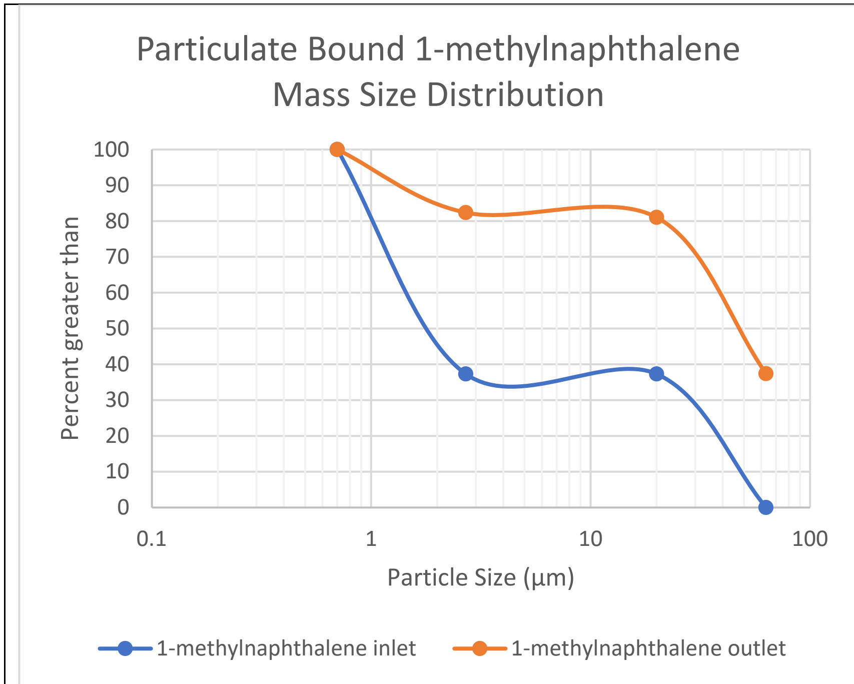
average inlet	2-methylphenanthrene	2-ethylanthracene	fluoranthene	pyrene	benzo(a)anthracene	chrysene	benzo(b)fluoranthene	Total PAH
total sample	3.4	2.5	10.8	10.1	2.0	6.1	2.2	108.2
Total Particulate (>0.7 µm)	1.4	1.7	6.1	6.2	1.7	4.6	1.9	50.3
Filtered (<0.7µm)	2.0	0.7	4.7	3.9	0.3	1.5	0.3	57.9
% filtered	59.9	29.3	43.3	38.6	13.5	25.2	14.3	53.6
% particulate	40.1	70.7	56.7	61.4	86.5	74.8	85.7	46.4
0.7-2.7 µm	0.2	0.3	1.0	0.2	0.1	0.4	0.3	8.3
2.7-20 µm	0.1	0.1	1.0	1.0	0.1	0.3	0.1	5.5
20-63 µm	nd	nd	nd	nd	nd	0.4	0.2	8.4
>63 µm	0.9	1.7	3.3	4.9	1.6	3.6	1.4	24.4
average outlet	2-methylphenanthrene	2-ethylanthracene	fluoranthene	pyrene	benzo(a)anthracene	chrysene	benzo(b)fluoranthene	
total sample	1.9	0.5	7.0	6.1	0.6	3.5	1.3	67.5
Total Particulate (>0.7 µm)	0.6	0.1	3.3	3.2	0.4	2.0	0.9	30.0
Filtered (<0.7µm)	1.4	0.4	3.7	2.9	0.2	1.5	0.4	37.4
% filtered	69.8	72.3	53.3	47.1	33.6	42.9	32.8	55.5
% particulate	30.2	25.3	46.7	52.9	66.4	56.7	67.2	44.5
0.7-2.7 µm	0.2	0.1	1.1	0.8	0.1	0.4	0.2	7.7
2.7-20 µm	0.1	0.0	0.2	1.0	0.3	0.5	0.2	5.4
20-63 µm	nd	nd	nd	0.2	nd	0.4	0.2	4.7
>63 µm	0.3	0.1	2.0	1.7	0.2	0.9	0.4	12.3
average inlet, ug/L	2-methylphenanthrene	2-ethylanthracene	fluoranthene	pyrene	benz(a)anthracene	chrysene	benzo(b)fluoranthene	Total PAH
0.7-2.7 µm	0.22	0.27	0.95	0.19	0.11	0.41	0.25	8.26
2.7-20 µm	0.14	0.06	0.98	1.02	0.11	0.30	0.09	5.48
20-63 µm	nd	nd	nd	nd	nd	0.42	0.18	8.41
>63 µm	0.93	1.69	3.33	4.92	1.58	3.64	1.41	24.44
average outlet, ug/L	2-methylphenanthrene	2-ethylanthracene	fluoranthene	pyrene	benz(a)anthracene	chrysene	benzo(b)fluoranthene	Total PAH
0.7-2.7 µm	0.21	0.06	1.09	0.77	0.11	0.39	0.20	7.70
2.7-20 µm	0.07	nd	0.19	0.97	0.31	0.55	0.18	5.38
20-63 µm	nd	0.02	0.04	0.16	0.02	0.44	0.19	4.67
>63 µm	0.30	0.05	1.99	1.70	0.16	0.95	0.38	12.27

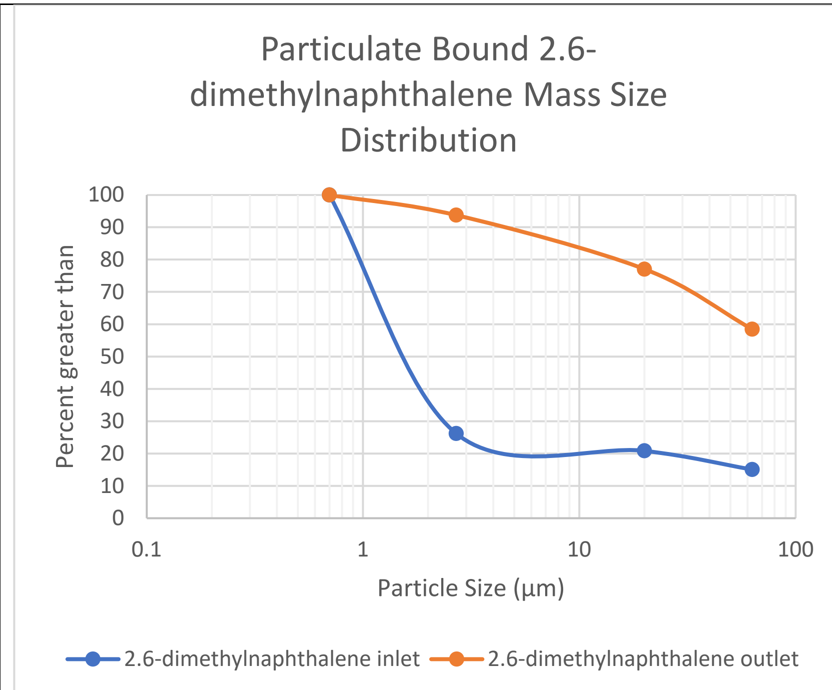
apparent % reduction	naphthalene	2-methylnaphthalene	1-methylnaphthalene	2.6-dimethylnaphthalene	1.3-dimethylnaphthalene	acenaphthene	fluorene	phenanthrene
total sample	48.2	7.9	19.6	-0.6	7.5	45.6	46.6	28.5
Total Particulate (>0.7 µm)	39.2	-142.2	-155.0	-150.8	-144.5	53.7	23.7	36.3
Filtered (<0.7µm)	56.0	51.5	50.3	44.0	41.1	41.3	53.2	24.5
0.7-2.7 µm	-28.6	50.9	28.3	78.7	38.2	-116.6	31.7	19.2
2.7-20 µm	na	na	na	-686.5	na	22.4	-86.1	41.2
20-63 µm	79.5	-125.0	-198.2	-701.2	na	na	na	na
>63 µm	na	na	na	-716.2	-221.8	na	-85.2	-30.4

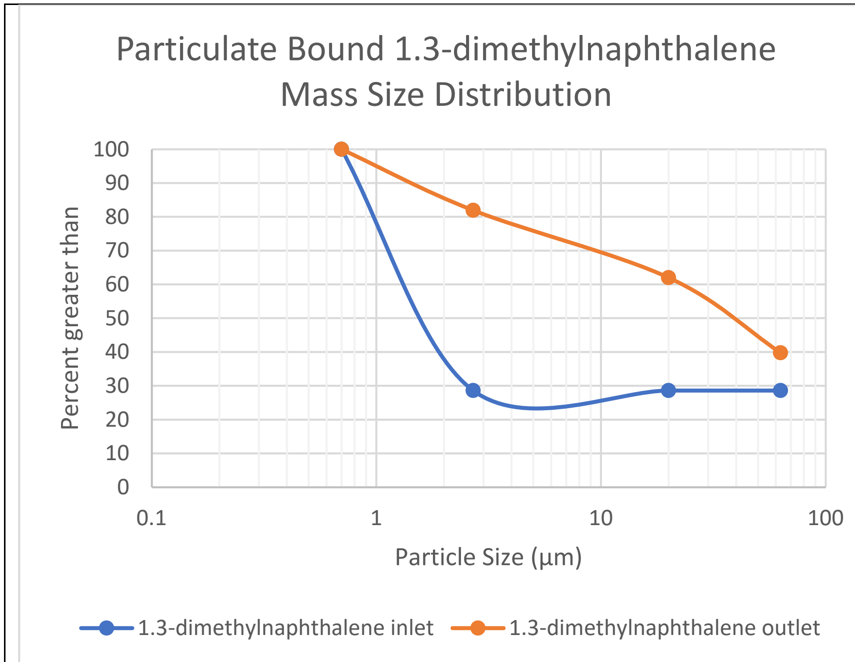
apparent % reduction	2-methylphenanthrene	2-ethylanthracene	fluoranthene	pyrene	benzo(a)anthracene	chrysene	benzo(b)fluoranthene	Total PAH
total sample	43.0	79.4	35.3	39.8	70.3	43.6	38.9	37.7
Total Particulate (>0.7 µm)	57.1	92.6	46.7	48.2	77.2	57.2	52.0	40.3
Filtered (<0.7µm)	33.5	49.1	20.3	26.5	26.0	4.1	-39.8	35.4
0.7-2.7 µm	4.9	77.5	-14.7	-304.7	-3.5	4.2	22.7	6.7
2.7-20 µm	47.8	na	80.6	4.8	-186.7	-80.7	-96.0	1.7
20-63 µm	na	na	na	na	na	-4.1	-7.4	44.5
>63 µm	67.6	96.7	40.4	65.4	89.8	74.0	73.2	49.8


Particulate Bound Naphthalene Mass Size Distribution
Percent greater than
100
90
80
70
60
50
40
30
20
10
0
0.1
1
10
100
Particle Size (μm)
naphthalene inlet
naphthalene outlet

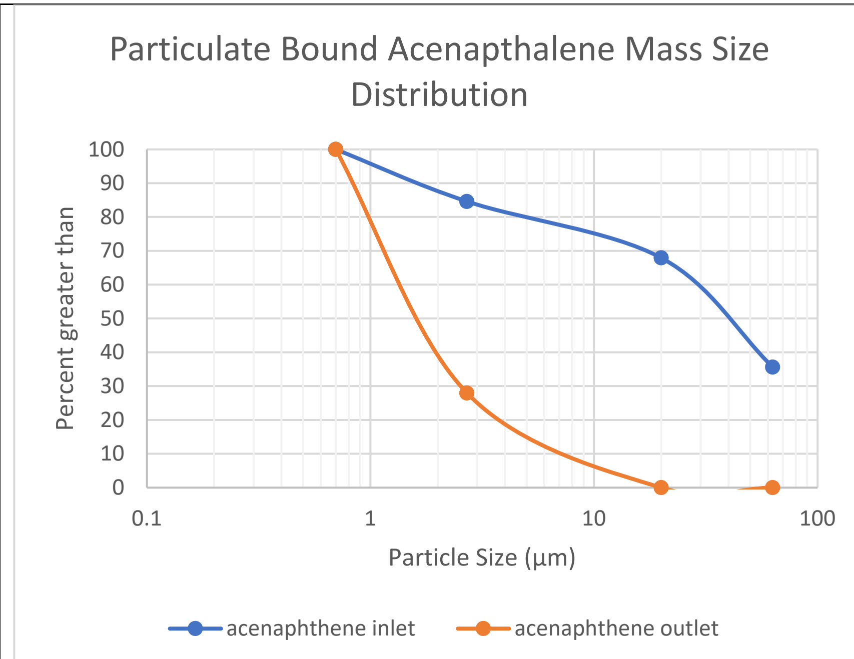

Particulate Bound 2-methylnaphthalene Mass Size Distribution
Percent greater than
100
90
80
70
60
50
40
30
20
10
0
0.1
1
10
100
Particle Size (μm)
2-methylnaphthalene inlet
2-methylnaphthalene outlet


Particulate Bound 1-methylnaphthalene Mass Size Distribution
Percent greater than
100
90
80
70
60
50
40
30
20
10
0
0.1
1
10
100
Particle Size (µm)
1-methylnaphthalene inlet
1-methylnaphthalene outlet

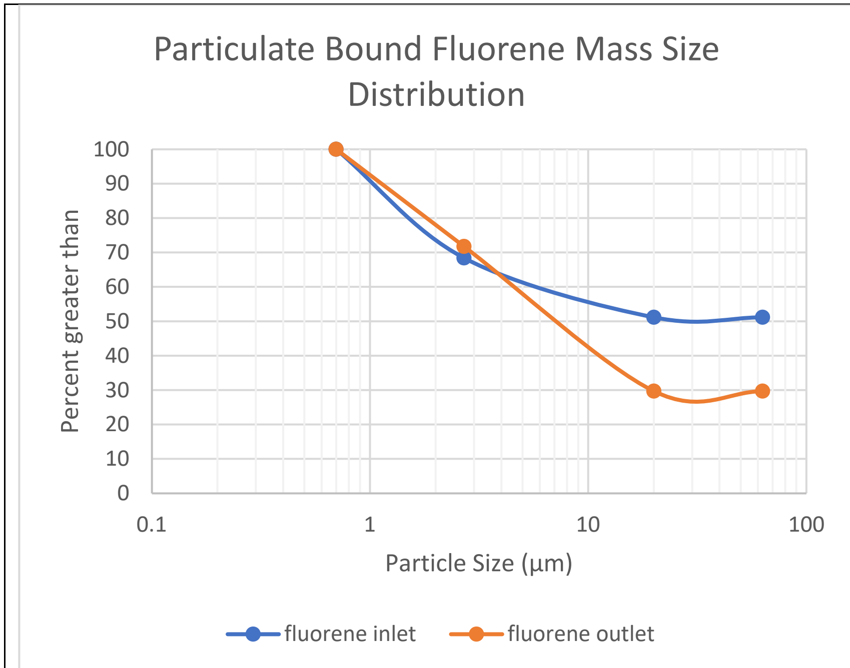

Particulate Bound 2.6-dimethylnaphthalene Mass Size Distribution
Percent greater than
100
90
80
70
60
50
40
30
20
10
0
0.1
1
10
100
Particle Size (µm)
2.6-dimethylnaphthalene inlet
2.6-dimethylnaphthalene outlet

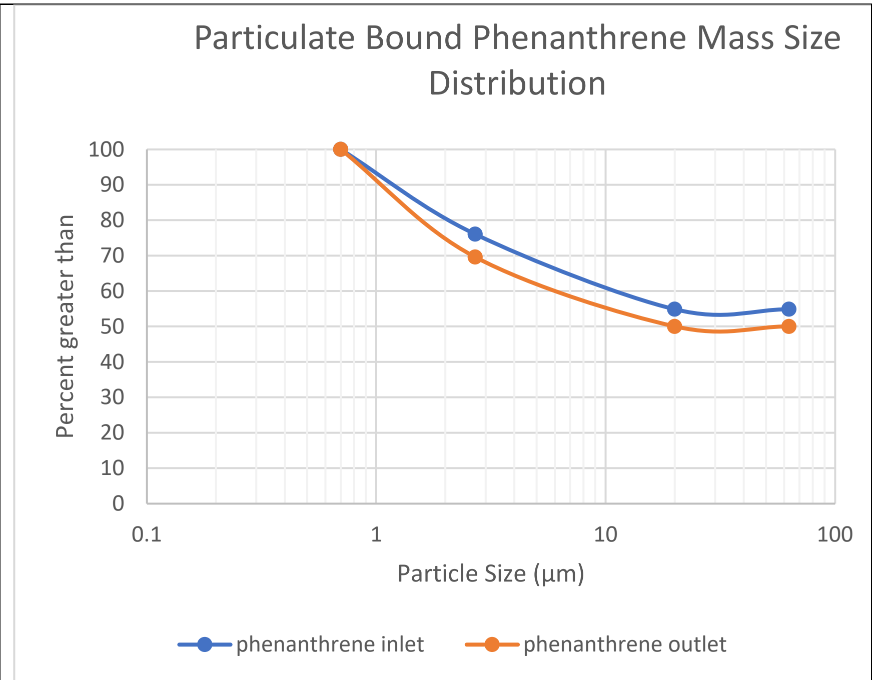


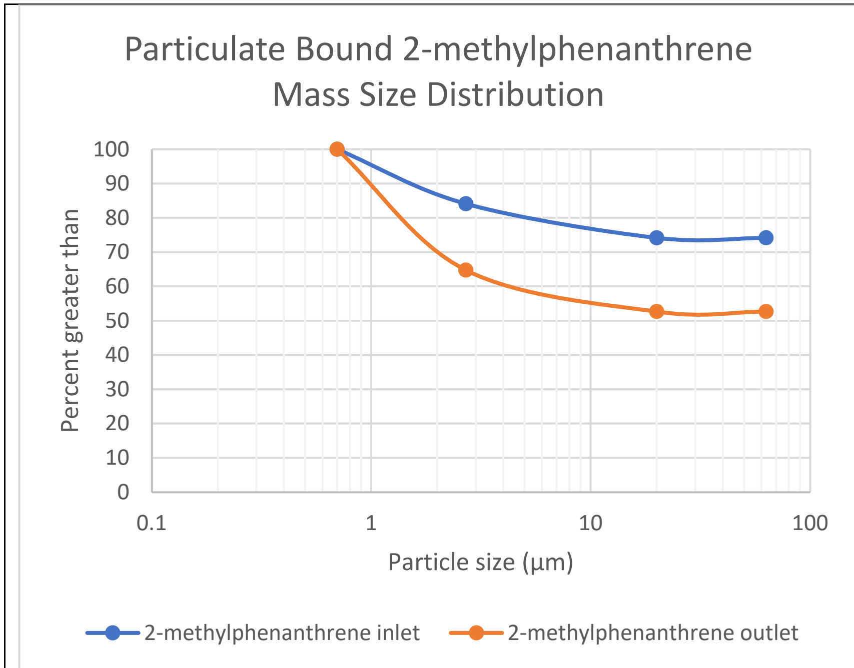
Particulate Bound 1.3-dimethylnaphthalene Mass Size Distribution
Percent greater than
100
90
80
70
60
50
40
30
20
10
0
0.1
1
10
100
Particle Size (µm)
1.3-dimethylnaphthalene inlet
1.3-dimethylnaphthalene outlet



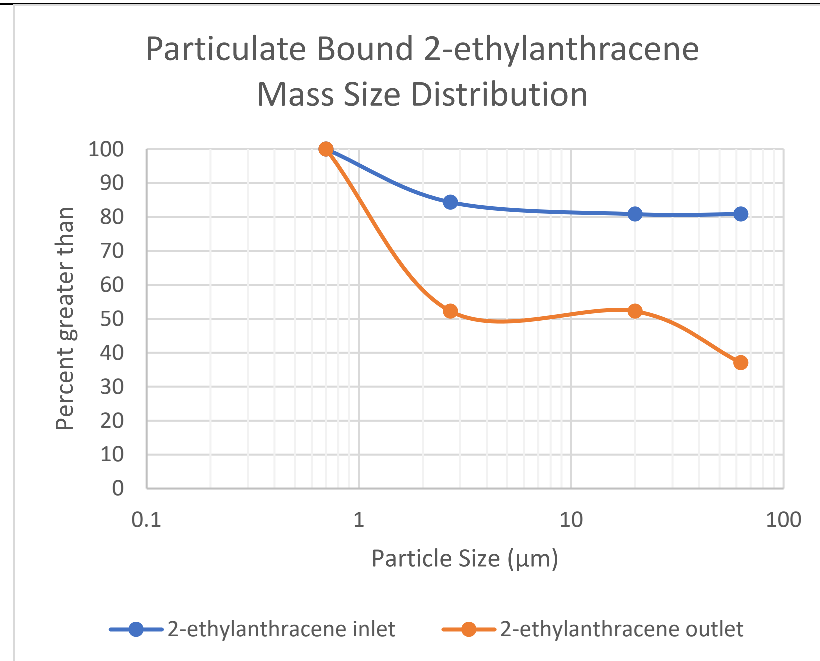
Particulate Bound Acenapthalene Mass Size Distribution
Percent greater than
100
90
80
70
60
50
40
30
20
10
0
0.1
1
10
100
Particle Size (µm)
acenaphthene inlet
acenaphthene outlet


Particulate Bound Fluorene Mass Size Distribution
Percent greater than
100
90
80
70
60
50
40
30
20
10
0
0.1
1
10
100
Particle Size (µm)
fluorene inlet
fluorene outlet

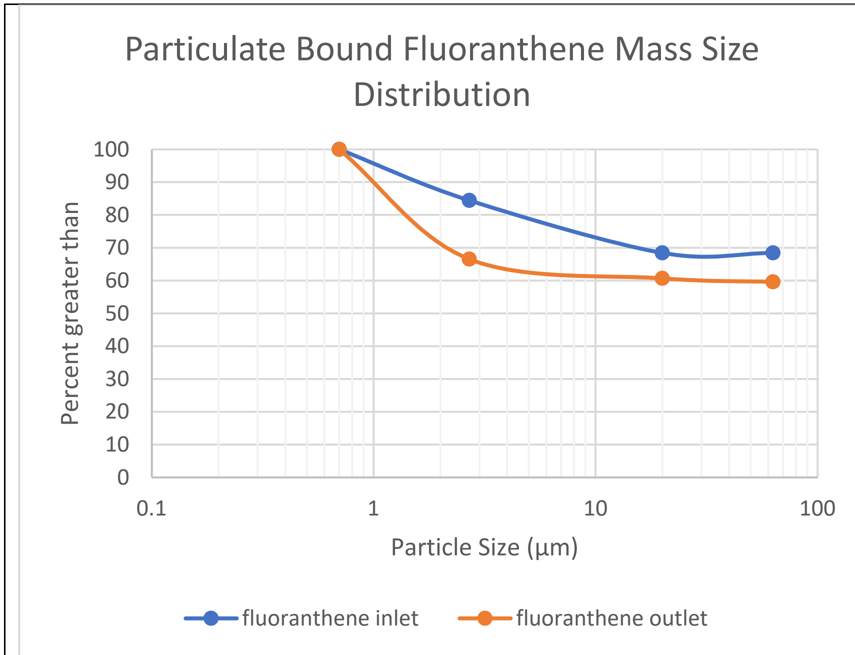

Particulate Bound Phenanthrene Mass Size Distribution
Percent greater than
100
90
80
70
60
50
40
30
20
10
0
0.1
1
10
100
Particle Size (µm)
phenanthrene inlet
phenanthrene outlet



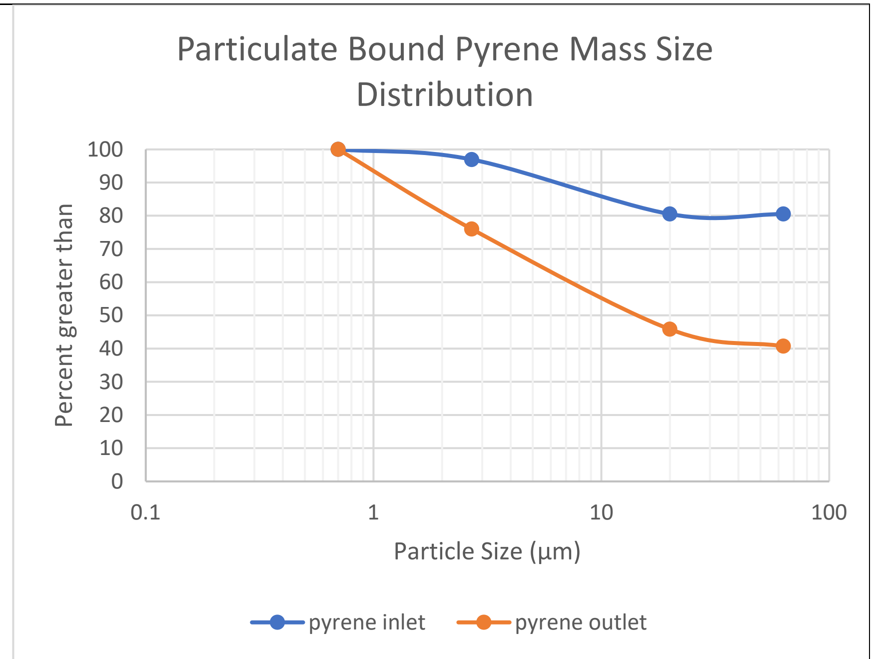
Particulate Bound 2-methylphenanthrene
Mass Size Distribution
Percent greater than
100
90
80
70
60
50
40
30
20
10
0
0.1
1
10
100
Particle size (µm)
2-methylphenanthrene inlet
2-methylphenanthrene outlet



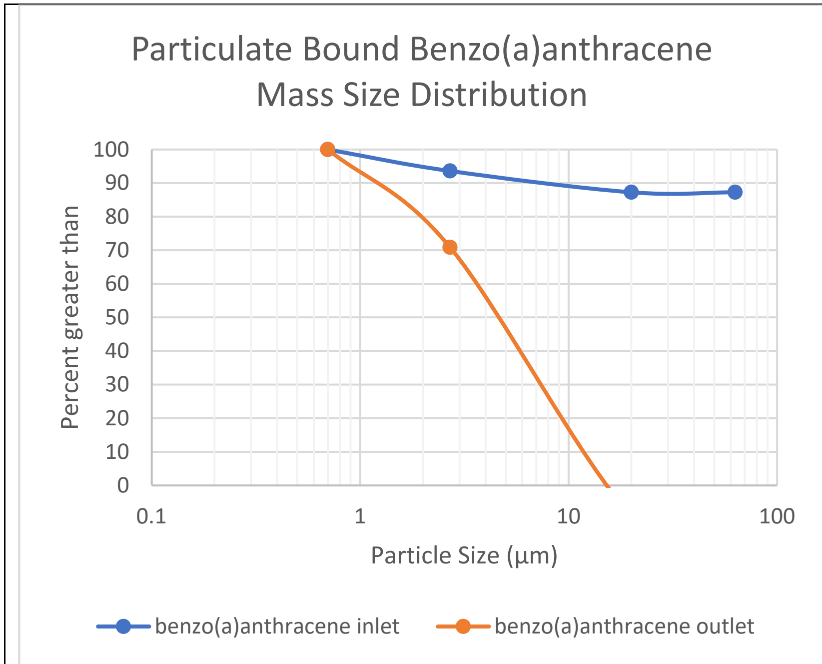
Particulate Bound 2-ethylanthracene
Mass Size Distribution
Percent greater than
100
90
80
70
60
50
40
30
20
10
0
0.1
1
10
100
Particle Size (µm)
2-ethylanthracene inlet
2-ethylanthracene outlet



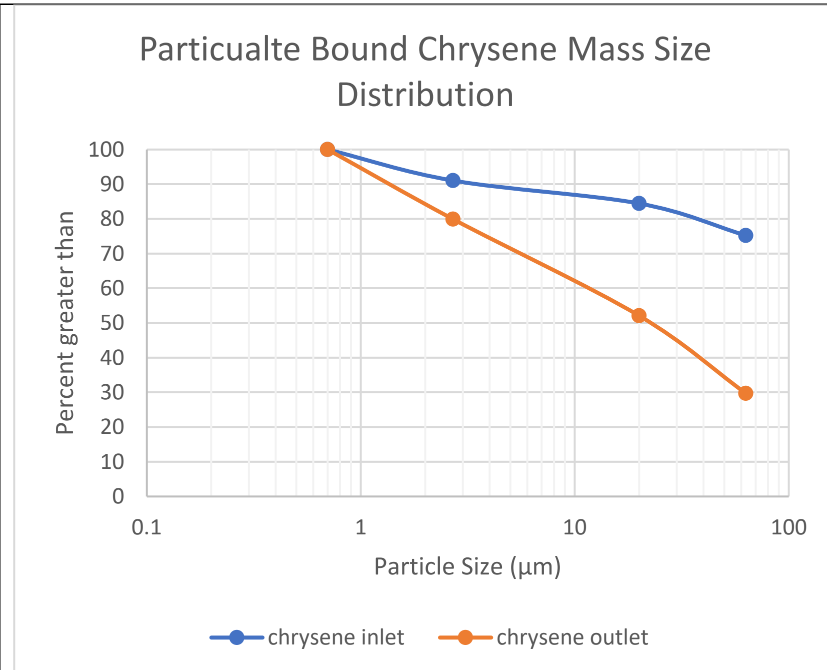
Particulate Bound Fluoranthene Mass Size Distribution
Percent greater than
100
90
80
70
60
50
40
30
20
10
0
0.1
1
10
100
Particle Size (µm)
fluoranthene inlet
fluoranthene outlet



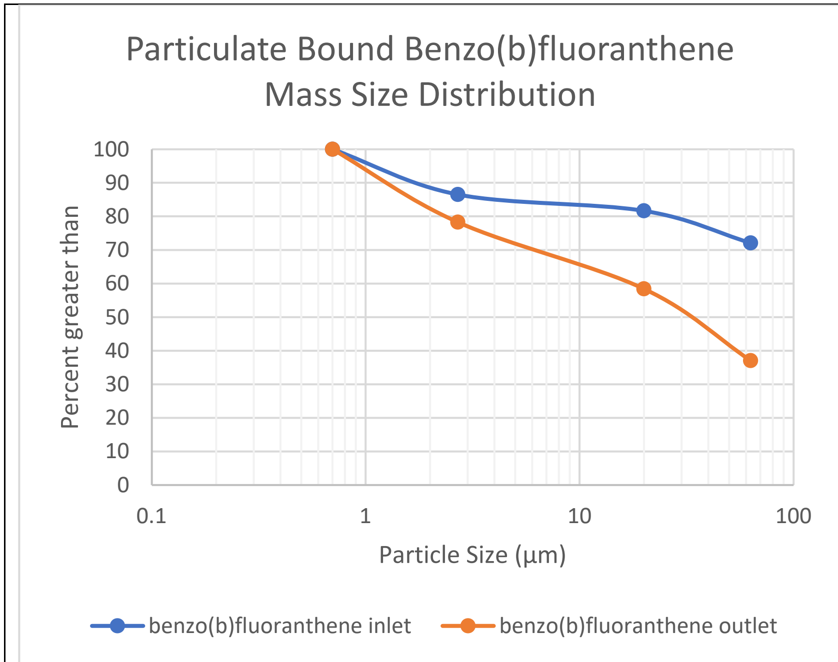
Particulate Bound Pyrene Mass Size Distribution
Percent greater than
100
90
80
70
60
50
40
30
20
10
0
0.1
1
10
100
Particle Size (µm)
pyrene inlet
pyrene outlet

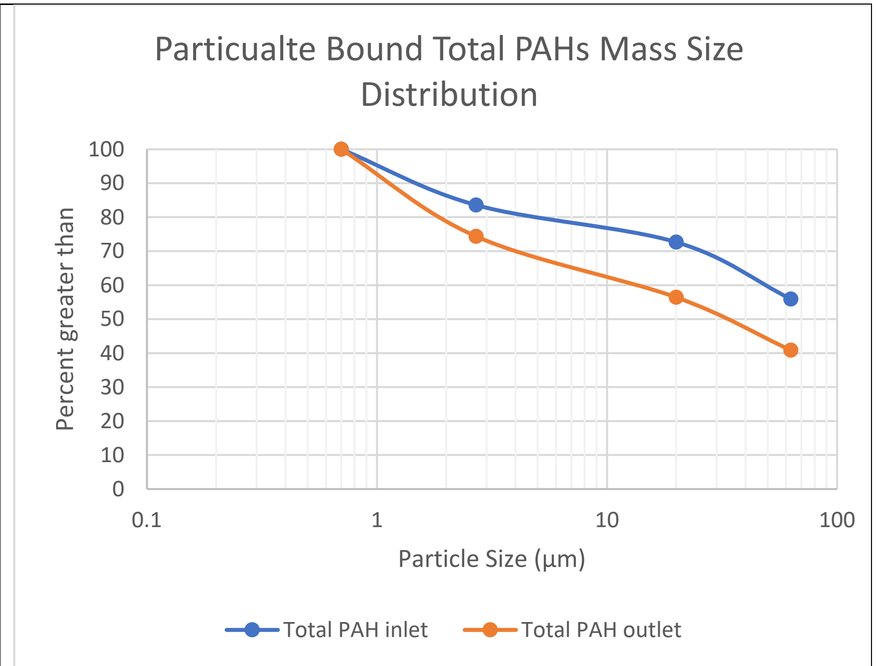


Particulate Bound Benzo(a)anthracene Mass Size Distribution
Percent greater than
100
90
80
70
60
50
40
30
20
10
0
0.1
1
10
100
Particle Size (µm)
benzo(a)anthracene inlet
benzo(a)anthracene outlet



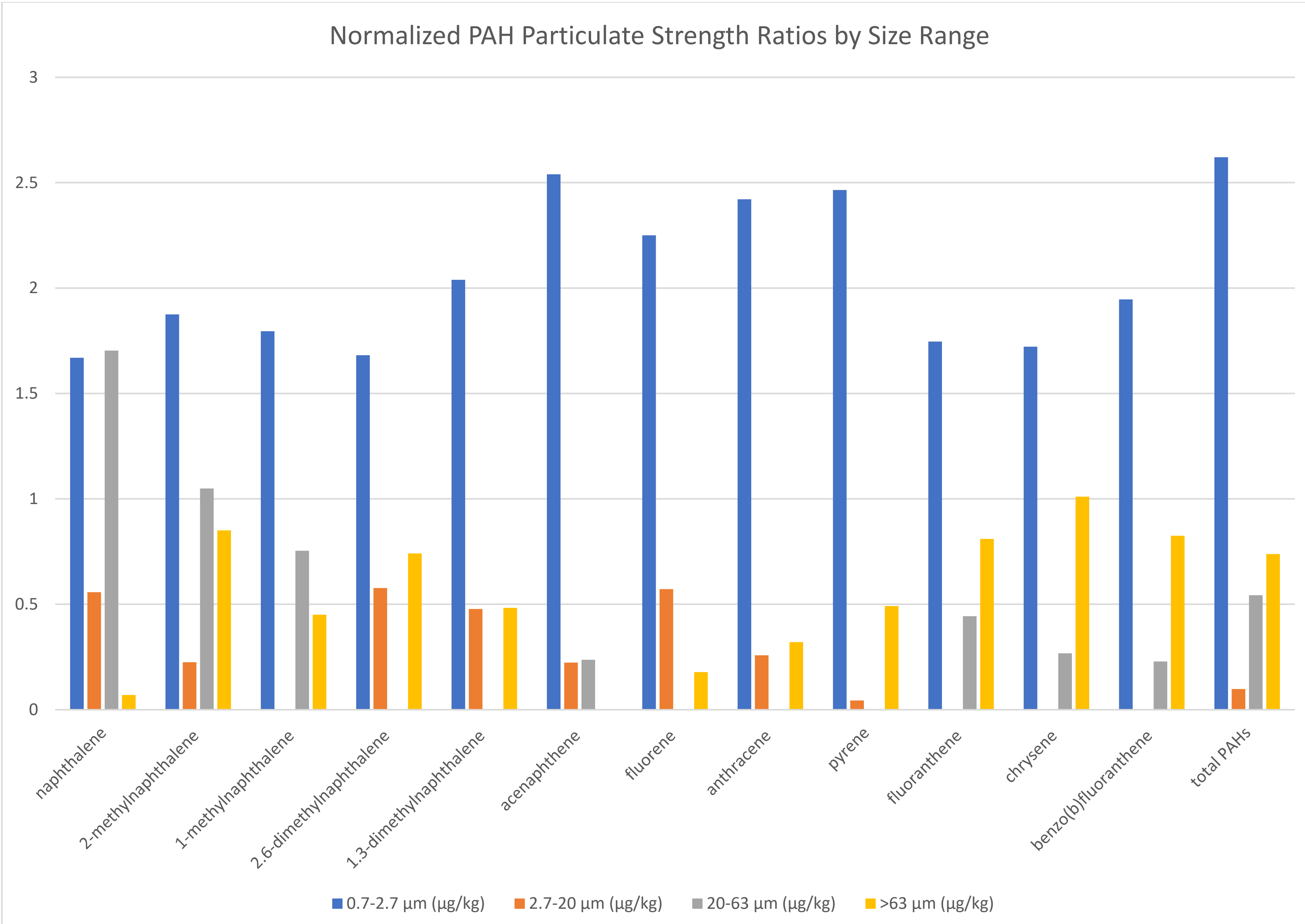
Particualte Bound Chrysene Mass Size Distribution
Percent greater than
100
90
80
70
60
50
40
30
20
10
0
0.1
1
10
100
Particle Size (µm)
chrysene inlet
chrysene outlet


Particulate Bound Benzo(b)fluoranthene Mass Size Distribution
Percent greater than
100
90
80
70
60
50
40
30
20
10
0
0.1
1
10
100
Particle Size (µm)
benzo(b)fluoranthene inlet
benzo(b)fluoranthene outlet


Particualte Bound Total PAHs Mass Size Distribution
Percent greater than
100
90
80
70
60
50
40
30
20
10
0
0.1
1
10
100
Particle Size (µm)
Total PAH inlet
Total PAH outlet

overall average	naphthalene	2-methylnaphthalene	1-methylnaphthalene	2.6-dimethylnaphthalene	1.3-dimethylnaphthalene	acenaphthene	fluorene	anthracene
Total Particulate (>0.7 µm) (µg/kg)	1.10	0.48	0.14	0.15	0.09	0.09	0.22	0.91
0.7-2.7 µm (µg/kg)	1.96	0.69	0.34	0.26	0.23	0.58	0.88	4.11
2.7-20 µm (µg/kg)	0.66	0.08	na	0.09	0.05	0.05	0.22	0.44
20-63 µm (µg/kg)	2.00	0.38	0.14	na	na	0.05	na	na
>63 µm (µg/kg)	0.08	0.31	0.09	0.11	0.05	na	0.07	0.54

overall average	2-methylphenanthrene	2-ethylanthracene	pyrene	fluoranthene	benzo(a)anthracene	chrysene	benzo(b)fluoranthene	total PAHs
Total Particulate (>0.7 µm) (µg/kg)	0.14	0.13	0.64	0.73	0.16	0.50	0.22	6.54
0.7-2.7 µm (µg/kg)	0.57	0.23	3.42	1.71	0.27	0.93	0.52	16.76
2.7-20 µm (µg/kg)	na	na	0.06	na	na	na	na	0.63
20-63 µm (µg/kg)	na	na	na	0.43	na	0.14	0.06	3.47
>63 µm (µg/kg)	0.14	0.17	0.68	0.79	0.19	0.55	0.22	4.72


Normalized PAH Particulate Strength Ratios by Size Range
3
2.5
2
1.5
1
0.5
0
naphthalene
2-methylnaphthalene
1-methylnaphthalene
2.6-dimethylnaphthalene
1.3-dimethylnaphthalene
acenaphthene
fluorene
anthracene
pyrene
fluoranthene
chrysene
benzo(b)fluoranthene
total PAHs
0.7-2.7 µm (µg/kg)
2.7-20 µm (µg/kg)
20-63 µm (µg/kg)
>63 µm (µg/kg)

inlet samples	naphthalene	2-methylnaphthalene	1-methylnaphthalene	2.6-dimethylnaphthalene	1.3-dimethylnaphthalene	acenaphthene	fluorene	phenanthrene
>63 µm (near field)	0.0	0.0	0.0	17.3	31.7	0.0	12.2	24.4
20 to 63 µm (far field)	84.1	42.6	37.3	5.8	0.0	32.3	0.0	0.0
<20 µm (widely dispersed)	15.9	57.4	62.7	79.1	71.4	32.1	48.8	45.1

inlet samples	2-methylphenanthrene	2-ethylanthracene	fluoranthene	pyrene	benzo(a)anthracene	chrysene	benzo(b)fluoranthene	Total PAH
>63 µm (near field)	68.2	97.3	54.5	78.9	93.5	79.5	74.6	48.6
20 to 63 µm (far field)	0.0	0.0	0.0	0.0	0.0	9.2	9.6	16.7
<20 µm (widely dispersed)	25.8	19.2	31.5	19.5	12.8	15.6	18.3	27.3

outlet samples	naphthalene	2-methylnaphthalene	1-methylnaphthalene	2.6-dimethylnaphthalene	1.3-dimethylnaphthalene	acenaphthene	fluorene	phenanthrene
>63 µm (near field)	6.1	42.6	37.4	56.3	41.7	0.0	29.7	50.0
20 to 63 µm (far field)	28.4	39.5	43.6	18.6	22.3	0.0	0.0	0.0
<20 µm (widely dispersed)	65.5	17.5	19.0	23.0	38.0	100.0	70.3	50.0

outlet samples	2-methylphenanthrene	2-ethylanthracene	fluoranthene	pyrene	benzo(a)anthracene	chrysene	benzo(b)fluoranthene	Total PAH
>63 µm (near field)	51.6	42.8	61.0	52.7	41.9	48.3	41.7	40.9
20 to 63 µm (far field)	0.0	15.2	1.1	5.1	5.9	22.4	21.4	15.6
<20 µm (widely dispersed)	47.4	47.8	39.3	54.2	108.9	47.9	41.5	43.6