Partitioning of Mercury into Several Size Fractions in Highway Runoff

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Abstract: Due to their large impervious coverage, highways are ideal sites for the transport of pollutants to either treatment units or direct discharge to waterways. Mercury, a highly toxic and ubiquitous environmental contaminant, is rarely studied in stormwater runoff. Removal of particulate-bound mercury in a dry detention basin was analyzed for the five size fractions: <0.45 μm, 0.45–8 μm, 8–20 μm, 20–100 μm, and >100 μm. The highest concentration of mercury for both influent and effluent is observed in the 8–20 μm size fraction. Treatment units are often characterized by suspended solids removal efficiency and particle-bound pollutants correlated to suspended solids removal; however, different suspended solids removal efficiency may occur in specific particle size fractions. Therefore, the benefits of treatment units may be different than originally anticipated, especially if the particle-bound concentrations are greater in fractions more efficiently removed. For sedimentation-based treatment units, the removal is dependent on size fraction, and when one size fraction is captured more efficiently, the removal rate calculated using the entire sample might indicate particle-bound pollutant removal quite different than actually occurring.
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Introduction

Mercury is a rarely studied contaminant in stormwater runoff. In fact, out of approximately 500 studies reported to the International Stormwater Best Management Practice [BMP Database (Jones and Strecker 2020)], only two studies reported mercury concentration in dry detention basins. Furthermore, neither of them makes a distinction between concentrations in dissolved and particulate phases, which is necessary when dealing with sedimentation-based treatment units, such as dry detention basins. The absence of mercury studies in stormwater is surprising, since mercury in its inorganic form is present in every ecosystem due to long-range atmospheric transport (Ullrich et al. 2001). The sources of atmospheric mercury range from volcanic eruptions to combustion processes, such as burning of coal and wildfires (Mason et al. 1995; Schroeder and Munthe 1998; Biswas et al. 2008; Burke et al. 2010; Pirrone et al. 2010).

Even though volcanic eruptions are responsible for about 20%–40% of all the mercury (Hg) released into the atmosphere by natural emissions (Pyle and Mather 2003), the contribution from natural sources to the global atmospheric Hg pool is decreasing. Until the 1970s, chlor-alkali plants were the largest anthropogenic source of atmospheric Hg, but their impact has been reduced due to stricter regulations (Schroeder and Munthe 1998). Currently, burning of fossil fuels, artisanal gold mining, nonferrous metals manufacturing, cement production, waste disposal, and caustic soda production are the major sources of atmospheric Hg (Pirrone et al. 2010).

Locations with a Mediterranean climate, such as southern California, are prone to wildfires due to their long dry summers and the occurrences of high-speed warm dry winds during the Fall (Mensing et al. 1999). In the year 2006, the state of California saw 4,805 fires burn 222,896 acres (State of California 2020), which is below the 5-year average (2002–2006) for the number of fires (average number of fires is 5,674 fires) but above the average for the burned area at 688 km^2 (170,126 acres). The past seasons (2017 and 2018) saw the largest wildfire in California history. These wildfires release contaminants into the atmosphere, which can either travel across the globe or settle nearby via ash deposition. Rothenberg et al. (2010) have shown that for two relatively close lakes (40 km apart), the accumulation of Hg in the lakes' sediment was greater on the lake affected more frequently with wildfires. Thus, besides long-range atmospheric transport, an important source of mercury to watersheds might be wildfires (Burke et al. 2010; Rothenberg et al. 2010).

Mercury is often found in stormwater runoff from urban watersheds (Lawson and Mason 2001; Eckley and Branfireun 2008; McKee and Gilbreath 2015), and land uses with no obvious local mercury sources such as highways may have elevated mercury concentrations because it is a global pollutant. Typical concentration of mercury in urban runoff was found to be 200 ng/L, and the range

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of concentration from highway runoff was 0–322 ng/L (Shaver et al. 2007; Clary et al. 2011). Total mercury concentrations, measured in dry and wet weather stormwater runoff from an urban watershed near San Francisco in Northern California, showed a range between 1.4 and 150 ng/L with a flow weighted mean concentration of 29 ng/L, and on average, 92% of total mercury was particulate (McKee and Gilbreath 2015). During 1996–2005, total mercury concentrations in precipitation did not significantly change in the US except the Northeast region where the concentrations decreased, which was consistent with mercury emission reductions from medical and municipal incinerators (Wentz et al. 2014). Stormwater runoff is, however, likely to increase mercury loads to receiving waters with increased precipitation intensity and extreme storm events (Krabbenhoft and Sunderland 2013). The largest problem with inorganic mercury in stormwater runoff occurs when it enters aquatic systems. It may be transformed into methylmercury (MeHg), which is a potent neurotoxin that has a tendency to biomagnify in food chains and has been implicated as a developmental toxicant for both humans and wildlife (Mason et al. 1995; Morel et al. 1998; USEPA 2001).

Previous studies investigated particle size distributions from road runoff (Furumai et al. 2002; Li et al. 2005; Kim and Sansalone 2008) or urban runoff (Brodie and Dunn 2009; Selbig et al. 2013; Charters et al. 2015; Selbig et al. 2016; Ermolin et al. 2018) because knowledge of particle size fraction can be used to select stormwater control measures for pollution removal and predict treatment unit removal efficiency (Ferreira et al. 2013). Studies focused on particle size distribution for heavy metals in stormwater runoff (Sansalone and Buchberger 1997; Roger et al. 1998; German and Svensson 2002; Deletics and Orr 2005; Lau and Stenstrom 2005; Zanders 2005; Ferreira et al. 2013; Hilliges et al. 2016; Wang et al. 2018) found that particulate metals in road runoff were associated with fine particles. However, little attention has been paid to particle size distribution for mercury in urban or road runoff.

The goal of this study is to provide mercury data in highway runoff and its removal in a dry detention basin, which is one of the most common stormwater control measures (SCMs) employed by the Caltrans (Geosyntec 2018). The dry detention basin, often used for flood control, showed highly variable removal of suspended solids and metals (Hossain et al. 2005; Starzec et al. 2005). A previous study showed good removal of metals attached to larger and medium size particles with little removal of metals in dissolved phase (Ferreira and Stenstrom 2013). Since detention basins remove pollutants based primarily on simple sedimentation, the samples were analyzed in five size fractions (<0.45 μm, 0.45–8 μm, 8–20 μm, 20–100 μm, and >100 μm) allowing for a comparison between theoretical and observed removal in the dry detention basin. In addition, this study aims to reinforce the use of particle size distribution to characterize pollutant removal efficiency versus an overall estimate of contaminant based on a simple suspended balance.

Materials and Methods

Study Area

The presence of mercury in stormwater and its removal by sedimentation was investigated using data collected from a 100 m^2 dry extended detention basin (identified in this study as detention basin) located in southern California next to the junction of the Interstate 605 (I-605) and State Route 91 (SR-91) highways (Kayhanian et al. 2006). This site was constructed as a prototype to evaluate the benefits of widespread application of highway stormwater control measures or BMPs (Caltrans 2004; Han et al. 2006). The accumulated sediments are periodically removed and disposed according to the Department of Toxic Substance Control (DTSC). Jang et al. (2010) provides additional information on options for disposing roadway residuals. The two highways host very heavy traffic (approximately 220,000 annual average daily traffic) and transport runoff from a catchment area of 4,000 m^2 into the dry detention basin. This detention basin was 30 m long, 3.3 m inside width, and sides with a slope of 1:2.8 (approximately 19.6°), without a permanent pool. The detention basin discharges overflow through an orifice at the base of an outlet riser (Kayhanian et al. 2006). The accumulated runoff was usually discharged within 72 h after collection, due in part to avoid vector (e.g., mosquitoes) growth.

Since rain is concentrated in the winter months in Southern California, samples for four rain events were collected in the 2005–2006 winter. Sampling procedure for the influent to the detention basin involved frequent (every 15 min) grab samples during the first hour to capture the first flush, and then hourly for the duration of the storm (Kayhanian et al. 2006). The first effluent grab sample was collected when water started flowing out of the basin, which was generally 1–3 h after the beginning of the rainfall. Subsequent grab samples of the effluent were collected after 3, 6, 12, and 24 h, and if there was still outflow, at 48 and 72 h. The number of samples varied depending on the total duration of the storm.

Laboratory Analyses

Samples were transported to the laboratory at the University of California, Los Angeles (UCLA) and prepared for analyses within 6 h of collection. This was done to preserve particle size characteristics, since an earlier study (Li et al. 2005) noted that a natural aggregation of particles quickly occurs. This natural aggregation of particles will increase the suspended solids fraction of the samples as holding time increases. The brief holding time (less than 6 h) may be partly responsible for generally lower particulate-phase metals concentrations (Lau and Stenstrom 2005; Lau et al. 2009).

Samples were analyzed for common water quality constituents such as total suspended solids (TSS), volatile suspended solids (VSS), chemical oxygen demand (COD), dissolved organic carbon (DOC), oil and grease (O&G), turbidity, and conductivity. All analytical methods followed Standard Methods (APHA 1999) including QA/QC procedures unless otherwise noted. Whatman GF/C filters (Sigma Aldrich, Darmstadt, Germany) specified by Standard Methods were used for TSS analysis and were prewashed before TSS analysis. Duplicate samples were sequentially filtered into five selected fractions (F1 = <0.45 μm, F2 = 0.45–8 μm, F3 = 8–20 μm, F4 = 20–100 μm, and F5 = >100 μm). For size differentiation, we used Millipore (Sigma Aldrich, Darmstadt, Germany) Nylon 100 μm and 20 μm for the two larger fractions and 8 μm and 0.45 μm mixed cellulose ester for the smaller fractions. Filters were prerinsed with distilled water, and blanks showed no contamination. Duplicate samples were no more than 20% different, and all duplicates were used; none were excluded. The suspended solids retained in each filter were digested using nitric acid and microwave extraction following EPA Method 3051A, and then diluted to 50 mL. The size-fractionated samples (the filtrate for the F1 fraction and the extraction fluid for the other size fractions) were analyzed for total mercury (THg) using a CETAC Tech. M-6000A Cold Vapor Atomic Absorption Mercury Analyzer (Teledyne CETAC Technologies, Omaha, Nebraska) with standard Hg solutions prepared immediately prior to analysis. The final concentration is a concentration (ng/L) that represents the mass of THg by volume of runoff filtered. In this study, the terms mercury and THg are used interchangeably and refer to all the species of mercury

Table 1. Rainfall characteristics

Storm date	Rainfall (mm)	Runoff volume (m^3)	Storm duration (h)	Antecedent dry days (days)	Influent samples	Effluent samples
02/27/2006	47.5	190.0	22	8	12	12
03/17/2006	4.8	19.3	5	18	5	5
03/28/2006	16.8	67.1	16	7	12	6
04/14/2006	10.9	43.7	7	9	9	6

Note: Volume calculated assuming drainage area of 4,000 m^2.

present in each size fraction sample, and not particulate plus dissolved phases. Implications for toxicity are not clear from the concentrations of THg, since THg concentrations cannot always predict MeHg concentrations (Kelly et al. 1995), Also, in the detention basins we do not observe high concentrations of sulfate or anaerobic zones, which are ideal conditions for the biotic transformation of inorganic Hg into MeHg.

Statistical Analyses

Statistical analyses were performed using the means of the sample duplicates. The data sets were tested for normality using probability plots and log-transformed when necessary prior to the statistical tests using the freely available "R" statistical software (Version 3.6.1, R Foundation 2020). The comparison among the several size fractions for either the group of influent or effluent samples was done using analysis of variance (ANOVA) with $\alpha = 0.05$. A calculated p-value of 0.01 or less was taken as evidence of a significant difference in the mean results for each group (influent or effluent). In order to determine which size fractions were different with statistical significance, the Tukey's honest significant difference (THSD) test with 95% family-wise confidence level (similar to Fisher's least significant test for pair-comparison) was used as a follow-up. The THSD test highlights the pair-wise comparisons exposing which pairs in each group have statistically significant differences.

Comparisons between influent and effluent concentrations for each size fraction were performed using Welch's t-test, which is a modification of the traditional Student's t-test for groups with different variances. Correlation analysis among water quality constituents and mercury concentration were made using the Spearman method. This method was preferred over the Pearson's method as being less sensitive to outliers and for indicating a monotonic increasing/decreasing correlation and not necessarily a linear relationship between the constituents.

Particle strength is metal concentration in a particulate form (F2-F5) divided by the TSS concentration, giving a mass/mass concentration (Ferreira et al. 2013). Particle strength, especially in different particle fraction, indicates the ability to remove the metal by removing suspended solids.

Results and Discussion

A total of 38 influent grab samples and 29 effluent grab samples for four storm events were collected at the inlet and the outlet of the detention basin (Table 1). After 72 h, the detention basin was usually empty. A total of eight conventional water quality constituents were analyzed (Table 2). As discussed elsewhere (Ferreira et al. 2013; Ferreira and Stenstrom 2013), the calculated mean of influent TSS is 127 mg/L, whereas mean of effluent TSS is 25.2 mg/L. Applying statistical analysis with the Welch t-test comparing the influent and effluent for each of the eight constituents, the result shows that there is a statistically significant difference between the two groups ($p < 0.05$) for TSS, VSS, turbidity, COD, and Oil and Grease (Fam et al. 1987). For conductivity, hardness, and DOC, there is no statistically significant difference between influent and effluent samples.

The influent data show a first flush effect for mercury particle size fraction for F3 and F4 (8–20 μm and 20–100 μm, respectively) for Storm events 1–3 during the first hour of the storm while the other mercury particle size fractions show no significant first flush effect (Fig. 1). Mercury concentrations were generally at peak in an hour (between 45 and 165 min) after the beginning of rainfall and decreased over time. The highest values of mercury concentrations usually occurred in F3 and F4, and each storm tended to have one high concentration during this period. The majority of the mercury-containing particles were 8–20 μm (F3) for most of the storm events with one exception for Storm event 4. The dissolved mercury (less than 0.45 μm, F1) showed lowest concentrations except

Table 2. Summary of conventional water quality parameters for combined storms

	TSS (mg/L)	VSS (mg/L)	Turbidity (NTU)	Conductivity (μmho/cm)	Hardness (mg/L)	COD (mg/L)	DOC (mg/L)	Oil and grease (mg/L)
Influent								
Minimum	15.1	5.18	27.0	62.0	22.0	6.49	6.60	2.54
Median	75.4	24.5	53.6	157	54.0	104	13.3	7.00
Mean	127	38.1	62.9	164	57.3	125	17.4	8.33
SD	142	41.6	37.3	56.4	18.5	81.9	12.6	5.33
Maximum	607	190	230	319	108	289	62.3	23.1
Effluent								
Minimum	5.18	1.97	9.0	41.0	18.0	17.02	3.16	1.52
Median	21.9	7.79	26.0	163	54.0	59.6	13.2	5.27
Mean	25.2	8.57	28.3	168	57.3	58.8	13.1	5.06
SD	16.5	4.78	12.5	50.9	19.2	29.5	3.93	1.71
Maximum	79.2	24.7	70.0	252	104	128	20.5	9.21

Note: TSS = total suspended solids; VSS = volatile suspended solids; COD = chemical oxygen demand; DOC = dissolved organic carbon; and SD = standard deviation.

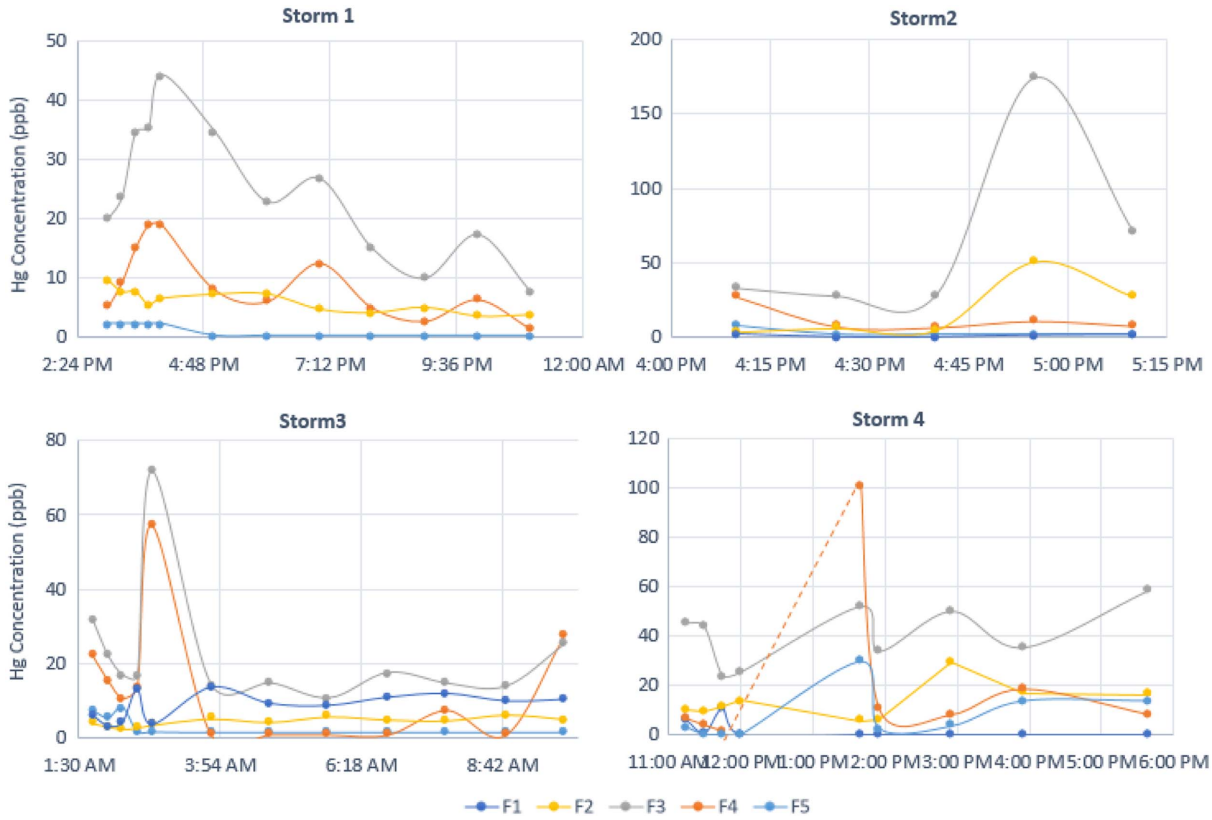

Fig. 1. Pollutograph of total mercury concentration in each size fraction in influent (size fractions: F1 =< 0.45 μm, F2 = 0.45–8 μm, F3 = 8–20 μm, F4 = 20–100 μm, and F5 = >100 μm).

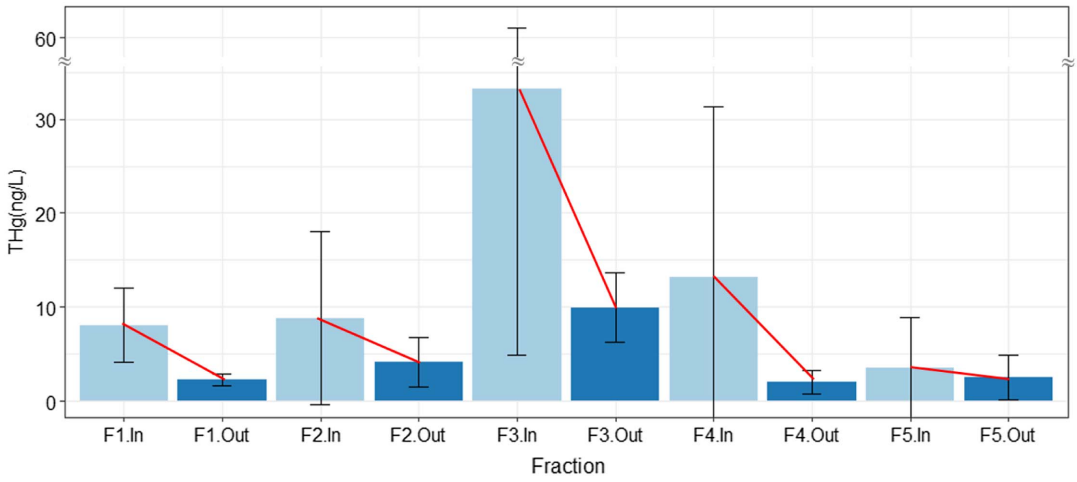

Fig. 2. Distribution of total mercury concentration in each size fraction.

in Storm event 3. Particles did not show aggregation as there was no increase in large particles (F5). The influent mercury concentration was 93% particulate.

Fig. 2 shows plots for mercury concentrations (mass of mercury per volume of filtered runoff) in all size fractions, both for the influent and effluent samples. The bars indicate the mean value for that size fraction, and the error bars show the standard deviations from each mean. Comparison of the influent samples in all size fractions (F1, F2, F3, F4, and F5) indicates that the highest mean concentration is in Size fraction F3. Contrary to the size fraction of metals in the previous study (Ferreira and Stenstrom 2013) where many of metal species (e.g., copper, nickel, zinc, arsenic, selenium, and strontium) showed highest median concentration in the dissolved fraction (<0.45 μm, F1) in both influent and effluent, the result of mercury analysis showed lower median concentration for the dissolved fraction (F1) and high median concentration for 8–20 μm (F3) size particles in both influent and effluent. A similar size fraction pattern was found with lead, aluminum, and iron (Ferreira and Stenstrom 2013).

ANOVA with $\alpha = 0.05$ was performed on the log-transformed influent data and showed statistically significant differences among groups (the influent samples were compared against the other

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Table 3. Summary of statistical analyses involving influent and effluent samples in size fractions

	Influent					Effluent				
	F1	F2	F3	F4	F5	F1	F2	F3	F4	F5
Influent										
F1	—	NO	YES	NO	YES	[a]	—	—	—	—
F2	—	—	YES	NO	YES	—	YES	—	—	—
F3	—	—	—	YES	YES	—	—	YES	—	—
F4	—	—	—	—	YES	—	—	—	YES	—
F5	—	—	—	—	—	—	—	—	—	[a]

Note: F1 = <0.45 μm; F2 = 0.45–8 μm; F3 = 8–20 μm; F4 = 20–100 μm; and F5 = >100 μm. "YES" means that the difference between the fractions compared is statistically significant; and "NO" means that the difference between the fractions compared is not statistically significant.
[a]Indicates insufficient data in effluents for statistical analysis.

Table 4. Removal rate of mercury in each size fraction

	THg					TSS			
Storm event	F2 (%)	F3 (%)	F4 (%)	F5 (%)	Total (%)	F2[a] (%)	F3[a] (%)	F4[a] (%)	Total (%)
Storm1	25	60	93	91	63	75	89	84	72
Storm2	86	86	91	63	86	57	84	87	76
Storm3	76	81	98	97	86	57	84	84	92
Storm4	71	81	99	98	85	71	91	95	93

Note: F2 = 0.45–8 μm; F3 = 8–20 μm; F4 = 20–100 μm; and F5 = >100 μm.
[a]Data from Ferreira and Stenstrom (2013).

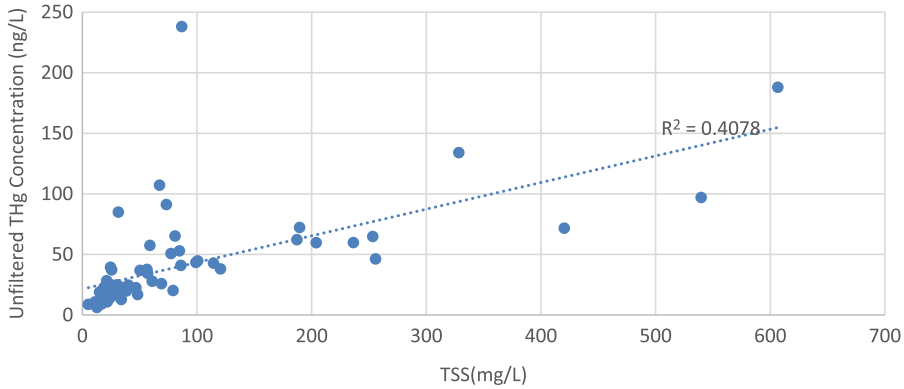

Fig. 3. Scatterplot of total suspended solids (TSS) versus the total amount of mercury (THg) in the samples (referred to as "Unfiltered").

influent samples, as well as the effluent samples compared to the other effluent samples). Tukey's honest significant difference (THSD) test with 95% family-wise confidence level was used as a follow-up and showed that the only influent pairs of size fractions that did not have statistically significant difference were F1-F2, F1-F4, and F2-F4 (Table 3). For the effluent, the highest mean concentration is also on Size fraction F3. ANOVA testing also showed difference among groups, which is only statistically significant for the effluent pairs: F2-F3, F3-F4. No comparison was made using Size fraction F5 due to the low number of samples.

Comparisons between influent and effluent concentrations used Welch's t-test and showed that there is statistically significant removal of THg in Size fractions F2, F3, and F4 (Table 3). High removal of THg on the largest size fraction (F5) was observed (Table 4) because of the theoretical removal of particles of that size by gravity. However, since 25 out of 29 effluent F5 samples were nondetects (generally less than 1 ng/L), it was not possible to perform a statistically valid comparison between influent and effluent for the F1 and F5 size fractions.

Fig. 3 shows a scatterplot of TSS for all the influent and effluent samples and the total amount of mercury in the samples, identified as *unfiltered* samples (numerically equals to the sum of the concentration of THg in all size fractions for a particular sample). Due to the presence of outliers, the correlation between THg and TSS is poor (r = 0.41). The extreme outlier with the highest concentration of THg (237 ng/L) is from an influent sample during the first hour of the second storm event (March 17, 2006). If the extreme outlier is removed, the correlation improves to r = 0.64; however, the authors see no strong reason to discard this sample. An earlier study (Eckley and Branfireun 2008) showed good agreement between TSS and unfiltered THg samples (r = 0.77), which was not observed in the current study. This lack of correlation is a good indication that the use of only one constituent such as TSS to estimate the removal of specific pollutants might not be the best estimate. The same poor correlation is observed if TSS is plotted against only particulate THg concentrations (r = 0.40) because the measured concentration in the dissolved fraction is at least one order of magnitude smaller than the particulate fraction. However, the large fractions (F4 and F5) of particulate mercury showed a high correlation with the TSS (r = 0.75 and 0.74, respectively).

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Table 5. Correlation analysis results among influent concentration values for water quality parameters and Hg concentration

Storm event	Hg dissolved[a]	Hg particulate[b]	THg[c]	TSS	VSS	Turbidity	Conductivity	Hardness	COD	DOC	Oil and grease
Hg dissolved		−0.233	−0.067	−0.225	−0.294	−0.231	0.174	0.171	0.163	−0.163	−0.192
Hg particulate			**0.975**	0.733	0.764	0.768	0.051	−0.037	0.413	0.436	0.512
THg		**		0.691	0.719	0.728	0.063	−0.035	0.44	0.414	0.474
TSS		**	**		**0.97**	**0.826**	−0.168	−0.223	0.437	0.198	0.346
VSS		**	**	**		**0.81**	−0.087	−0.158	0.505	0.352	0.468
Turbidity		**	**	**	**		−0.062	−0.187	0.386	0.284	0.373
Conductivity								**0.939**	0.355	0.655	0.518
Hardness							**		0.211	0.52	0.398
COD		*	**	**	**	*	**			0.691	**0.82**
DOC		**	*		**	**	**	**	**		**0.899**
O&G		**	**	**	**	**	**	*	**	**	

Note: Values above diagonal are Spearman rank-order coefficients, values in bold show correlation >0.8. Values below diagonal show the significant level using p-values, blank: $p > 0.05$, *: $p < 0.05$, **: $p < 0.01$.
[a]Mercury in dissolved form (passing through a 0.45 μm filter).
[b]Mercury in particulate form.
[c]Total Mercury (dissolved plus particulate phases).

As indicated previously, there are several outliers in the data set; thus, the Spearman rank-order technique was used to determine correlations among influent water quality constituents and mercury concentrations (Table 5). The results indicate high correlation ($r > 0.95$) for the concentration of Hg in the particulate phase and the unfiltered sample. Also, the correlation between Hg in the particulate phase and TSS is good ($r > 0.7$), as shown previously by other researchers. Both Hg in the particulate phase and unfiltered sample were well correlated with VSS and turbidity ($r > 0.7$). Note that the Spearman rank-order technique gives a relationship r which is not equivalent to the Pearson's correlation coefficient r that is the square root of r^2 obtained by simple linear regression (see preceding discussion concerning Fig. 3).

A similar analysis was performed for the samples in the effluent. The correlation between Hg Particulate-THg and VSS-TSS both decreased to 0.74, VSS-Turbidity decreased to 0.4, and Oil&Grease-COD and Oil&Grease-DOC decreased to 0.58 and 0.54, respectively. Only conductivity-hardness correlation increased slightly to 0.97.

The result of particle strength (Fig. 4) shows that the mercury of 8–20 μm fraction has the highest mean particle strength for both influent and effluent, whereas F4 and F5 fractions have the lowest mean particle strength for influent and effluent, respectively. This agrees with the results of particle strength for conventional heavy metals (cadmium, chromium, copper, lead, nickel, and zinc) and other heavy metals (aluminum, arsenic, cobalt, iron, manganese, selenium, strontium, and vanadium) (Ferreira et al. 2013). This implies that the BMPs designed to reduce mercury discharge should be able to remove particles in the 8–20 μm fraction. The presence of large particles was not important for mercury loading because

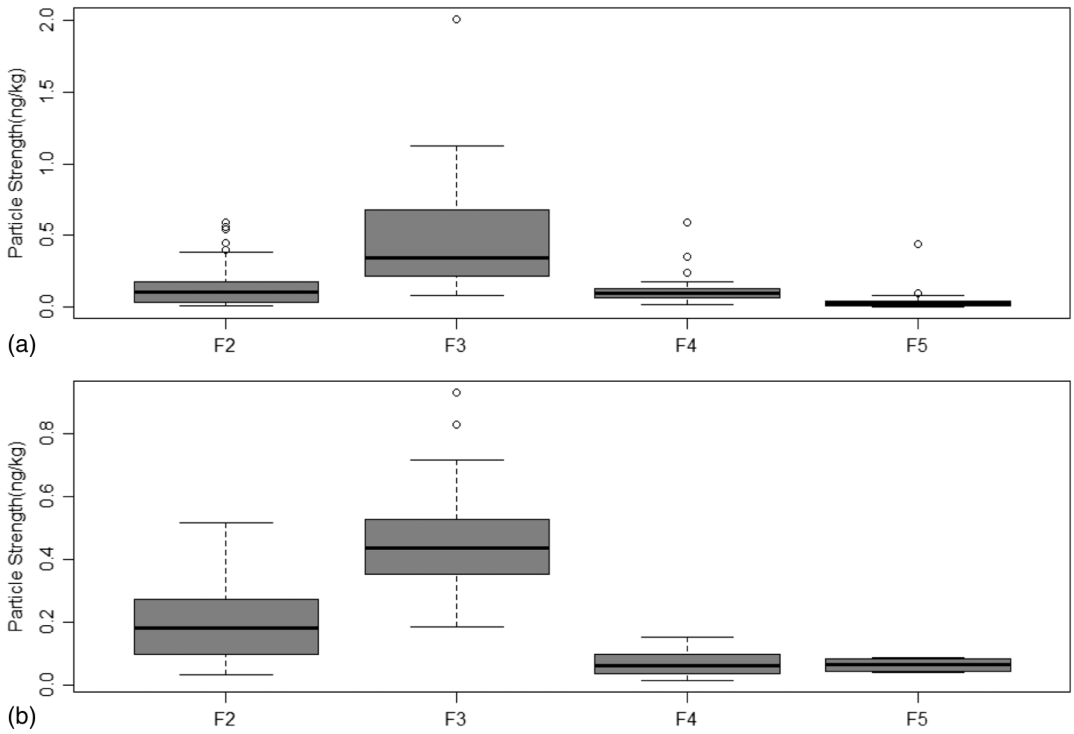

Fig. 4. Boxplots for the particle strength for mercury in each size fraction in (a) influent; and (b) effluent.

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the mercury is less concentrated on the largest particles or does not aggregate over the storm duration.

The results show the majority of mercury in stormwater runoff from the study area near highways was mostly in particulate form, with the majority of the particulate-bound Hg found in the 8–20 micron size fraction. Unlike other particles reported in a previous study (Li et al. 2005), the mercury-containing particles do not seem to aggregate over time. Their peak concentrations showed first flush effects in the first hour. The detention basin had reasonably good sedimentation removal efficiency of particulate pollutants. The overall mercury removal was 77%, and the TSS removal efficiency was 85%. This demonstrates the effectiveness of SCMs in removing pollutants in particulate forms. The statistical correlations demonstrate the use of TSS and/or VSS as a surrogate for mercury is a qualitative measure for mercury removal, but in high concentrations of TSS or when mercury removal quantification is especially important, actual mercury analysis may be needed. The results also show that SCMs designed to remove the particulate-phase metals and other pollutants will also remove mercury.

Conclusions

Treatment units are usually developed for removing a small suite of contaminants based upon total maximum daily load (TMDL) or other permitting requirements. However, stormwater runoff contains dozens of contaminants and many, if not most, treatment units are capable of removing a large suite of contaminants present in specific size fractions. Mercury is just one example. Therefore, the benefits of treatment units developed to comply with a specific TMDL will likely assist in complying with other TMDLs.

The highway runoff averaged 555 μg/L Hg, which were all assumed to be particulate-bound. Particulates were divided into five size fractions (<0.45 μm, 0.45–8 μm, 8–20 μm, 20–100 μm, and >100 μm), and the 8–20 μm fraction had the highest solid phase concentration in both the influent and effluent to the dry detention basin, whereas the fraction of <0.45 μm and >100 μm had the lowest concentration. The particulate mercury was not highly correlated with the TSS or other conventional water quality constituents. The correlation between particle fraction and TSS was dominated by large fractions (F4 and F5).

The International BMP Database has many reports that show no significant removal of certain pollutants. However, this does not necessarily show lack of removal when using just nonsize fractioned samples because removal for sedimentation-based treatment units is dependent on size fraction. When one size fraction is removed but not others, the comparison of the entire sample might indicate poor or no removal, masking the results. Since percent removal is an easy to understand metric, it is often used; however, this study advocates its use only in specific size fractions, with Hg reported here as a meaningful example.

Data Availability Statement

All data, models, and code generated or used during the study appear in the submitted article.

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