Desalination and Water Treatment
www.deswater.com

19 (2010) 86–91
July

doi: 10.5004/dwt.2010.1882

Physico-chemical characteristics of sediment accumulated in settling basin of a filtration best management practice

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Received 25 September 2009; Accepted 25 January 2010

ABSTRACT

Transport of constituents by stormwater runoff from paved surfaces in urban areas can directly affect the water quality of receiving waters and soils. Metal elements are the most evident constituents associated with particles found in stormwater runoff and the mitigation of its impact considers best management practices (BMPs). Physical treatment facilities such as filtration and sedimentation systems are typically applied to remove the particles and associated pollutants carried by the runoff. Hydrological characteristics of runoff as well as the physical and chemical characteristic of the particles influence the performance of BMPs. In this study, the size distribution of accumulated sediment and associated heavy metals in different particle size fractions generated specifically from the settling basin of a filtration BMP located at the Vehicle Registration Office parking lot in Samgadong, Yongin City, Kyunggi Province, Korea were determined. The highest fraction of particles collected from the basin was in the 425–2,000 μm size range. The greatest metal concentrations are higher with decreasing particle size fraction. X-ray diffraction analysis revealed that most of the particulates were originated from the pavement materials due to surface abrasion and transported by the stormwater runoff.

Keywords: Best management practices; Metals; Particle size; Sediment; X-ray diffraction (XRD)

1. Introduction

Urban paved surfaces such as highways, streets and parking lots were recognized as the major metal contributing areas, where heavy metal emissions from urban transportation are deposited onto these surfaces and transported to receiving waters through runoff [1–3]. Particles washed-off from the paved areas contain various sorbed pollutants, and many best management practices (BMPs) can be selected in removing particles, which makes particle size distribution a crucial BMP design parameter. Much of the pollutant load associated with stormwater runoff is carried by sediment and the removal of sediment or prevention of its transport to surface waters is the major aim of most stormwater pollution controls [4]. Also fine sediment is important when considering pollutant mitigation because the pollutant metal concentrations have been found to increase with respect to sediment particle size decrease [5–7]. Vehicular activity has the potential to release fine material from brake pad, tire wear and pavement. The presence of pollutants such as heavy metals in road deposited sediments play an important role in dictating urban stormwater quality [8–11].

Knowing the characteristics of sediment is important because accumulated particles on the paved areas during dry periods are the main sources of particulate matter during a storm and are affecting as serious pollutants on the receiving waters [12]. Information about particle size distributions of sediment is also important to design the treatment facilities on the purpose of managing nonpoint source (NPS). NPS pollution management initiated

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by the Ministry of Environment (MOE) in Korea resulted to the construction of several stormwater treatment pilot BMP facilities. Long term monitoring is being conducted to assess the pollutant removal efficiency of the BMPs [13]. Most of the BMP facilities constructed by the plan of MOE are adapting the physical treatment mechanism for the pretreatment, which is the sedimentation. The sedimentation basin functions as a pretreatment process by reducing the mass of particulate materials before entering the next process. The settling basins are typically located at the drainage system of roads and parking lots, which will serve as pretreatment for BMPs. Therefore, the analysis of physico-chemical characteristics of the sediment accumulated in the settling basin is important to predict the removal efficiency of the next BMP process.

The objective of this study was to recognize the characteristics of metal pollutants (Cd, Cr, Cu, Fe, Ni, Pb and Zn) in each particle size fractions (<0.75 μm, 75–150 μm, 150–180 μm, 180–250 μm, 250–425 μm, 425–850 μm and 850–2,000 μm) of the accumulated sediment from the settling basin of the BMP in paved area. In addition, pollutant levels compared to surrounding soils is to be assessed with reference to Korea Soil Environmental Law (SEL).

2. Methods

The monitoring site is the settling basin of a filtration BMP located at the Vehicle Registration Office parking lot in Samgadong, Yongin City, Kyunggi Province, Korea (Fig. 1) and only treating stormwater runoff from the parking lot during a storm. The operation of the facility started in December, 2005 and sediment sample collection was done once in each year during 2006–2007. Table 1 describes the site description along with the design factors used in the filtration system BMP while the settling basin dimensions are: 1 m length, 1 m width and 2 m depth, with 0.5 m pipe outlet height from the bottom.

Analyses were performed to determine the particle size distributions and metal compounds following the scheme shown in Fig. 2. Particle size distributions of sediment samples were analyzed using standard sieves and LS 230 particle size analyzer [14]. Sediment samples after being collected from the settling basin were air-dried then wet sieved using stainless-steel test sieves of sizes of 2,000, 1,000, 850, 425, 250, 180, 150 and 75 μm. This procedure resulted to seven sub-sets of particle ranges 0–75, 75–150, 150–180, 180–250, 250–425, 425–850, and 850–2,000 μm. Heavy metals of each sub-set were measured. Each sample was acidified to a pH of 1–2 with high-purity HNO_3 for metal analysis. After filtering with 0.45 μm pore-size membrane, metal concentrations were examined by ICP (Inductively Coupled Plasma) to determine the chemical characteristics of the accumulated sediment. X-ray diffraction (XRD) analyses were also

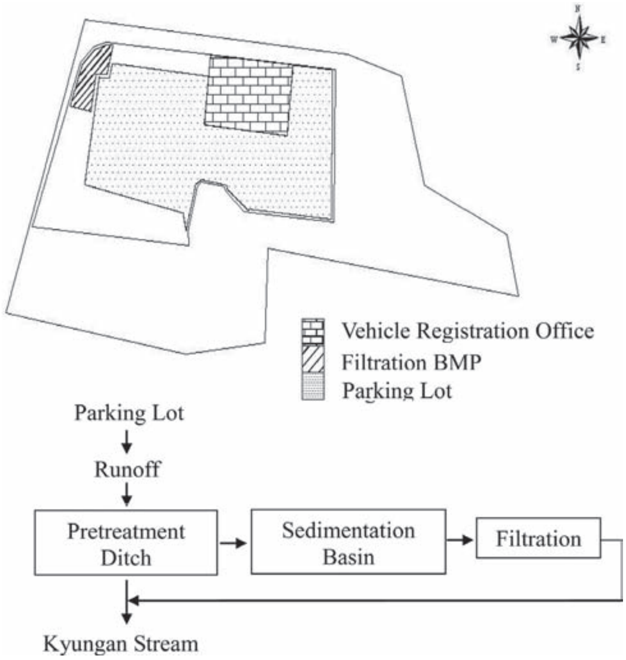

Fig. 1. Monitoring site located in Yongin City, Korea.

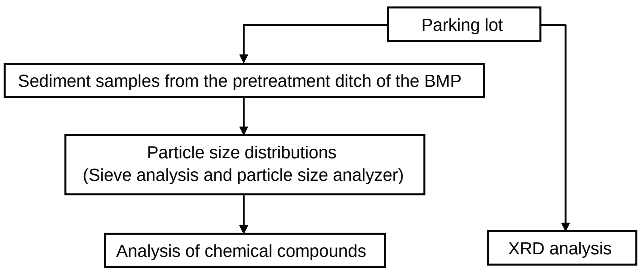

Fig. 2. Sediment analysis scheme for chemical compounds and XRD.

Table 1
Monitoring site descriptions.

Location	Land use	Pavement type	Drainage area (m^2)	Imperviousness rate (%)
Samgadong, Yongin city, Kyunggi Province, Korea	Parking lot	Asphalt	10,700	100

performed to evaluate mineral components using RIGAKU D/MAX 2500 (Japan). Diffraction data were collected using Cu Ka radiation and scans were conducted from 5° to 45° at a step size of 0.02 q [15].

3. Results and discussions

3.1. Particle size distribution of accumulated sediment

Fig. 3 shows the particle size distribution of the accumulated sediment. Based on the fig. 3, the highest amount of particles collected was in the 425–2,000 μm size range while lower amount of particles was observed below 250 μm. Apparently during the second year, less amount of particles under bigger size range and greater amount of particles for small size range were generated compared to the previous year. This was probably due to varying particle concentration affected by transportation/vehicular activities. Moreover, during the monitoring period, the total suspended solids (TSS) removal efficiency for influent and the reduction of TSS load influenced with generated TSS load are considerable. It is likely that the characteristics of the accumulated materials on paved areas are known to have enriched coarser particles through the re-suspension and loss of finer sediment taking into account [16].

3.2. Metal concentrations adsorbed on each particle size fraction

In Table 2, the mean metal concentrations associated with each particle size fraction are summarized. The greatest metal concentrations are higher with decreasing particle size fraction. This data is very important in selecting treatment methods for the sediments. Fe concentration prevails to be the highest compare to other metals while the least detected was Cr followed by Cd.

Meanwhile, with the particle size fraction of 850 μm and below but greater than 75 μm, the concentrations of Cu, Zn and Pb were large. Heavy metal concentration for each sub-set range for total sediment using the distribution data for each particle based on weight and the concentration of heavy metal was calculated and presented in Fig. 4. These data provide information on the amount of the whole sample.

Fig. 5 shows the proportion of respective heavy metal concentration with whole sample. The amount of concentration is higher at above 425 μm size comparable to results presented in Fig. 3. These findings regarding the contributed percentage of each heavy metal as shown in Fig. 5 justify the fact that the content of particle size is a very important factor for generated sediment. At this point, it is provided that the highest concentration observed among various heavy metals should be managed likewise heavy metal of the highest content must be targeted for maintenance of stormwater treatment facility. Consistent monitoring is advised for a more comprehensive future evaluation of the treatment facility.

In order to recognize the heavy metal pollution from accumulated sediment, the concentration of heavy metal from surrounding soils was measured and comparison was done with the sediment collected from the basin as presented in Fig. 6. Evidently, Zn appears to have relatively large concentration difference compare to other metals. It is likely that the particles related with heavy metal on the surveyed area were carried by runoff and directed into the BMP facility though accumulated pollutants were controlled in the settling basin of the BMP. Since standards and laws related to management of accumulated sediment from BMP facility lacks availability in Korea, the heavy metal pollution level of sediment collected from the settling basin of the BMP was evaluated in

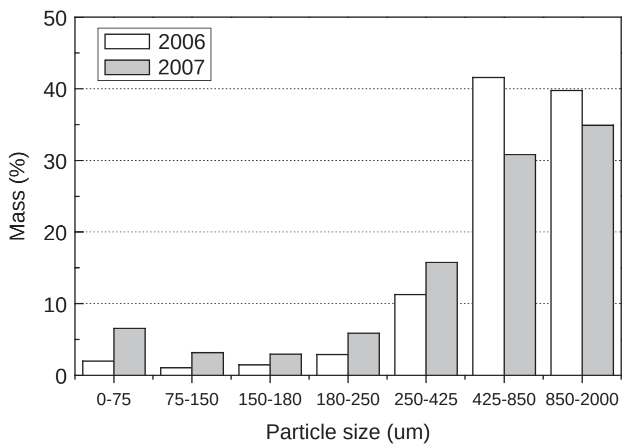

Fig. 3. Particle size distribution of accumulated sediment.

Table 2
Mean metal concentrations adsorbed on each particle size fraction.

Particle size fraction (μm)	Metal concentration – Total (mg/kg)						
	Cu	Zn	Pb	Cr	Fe	Ni	Cd
< 75	8.16	66.4	11.7	0.46	314	2.18	0.28
75–150	3.36	31.7	4.67	0.29	276	1.02	0.11
150–180	2.59	26.0	3.19	0.24	281	0.83	0.08
180–250	2.64	24.8	2.92	0.27	316	0.85	0.09
250–425	2.83	27.9	2.90	0.39	430	0.97	0.12
425–850	3.49	33.6	3.63	0.62	586	1.37	0.16
850–2,000	3.29	29.3	3.45	0.64	639	1.32	0.16
Whole sample	26.4	240	32.4	2.90	2842	8.53	1.00

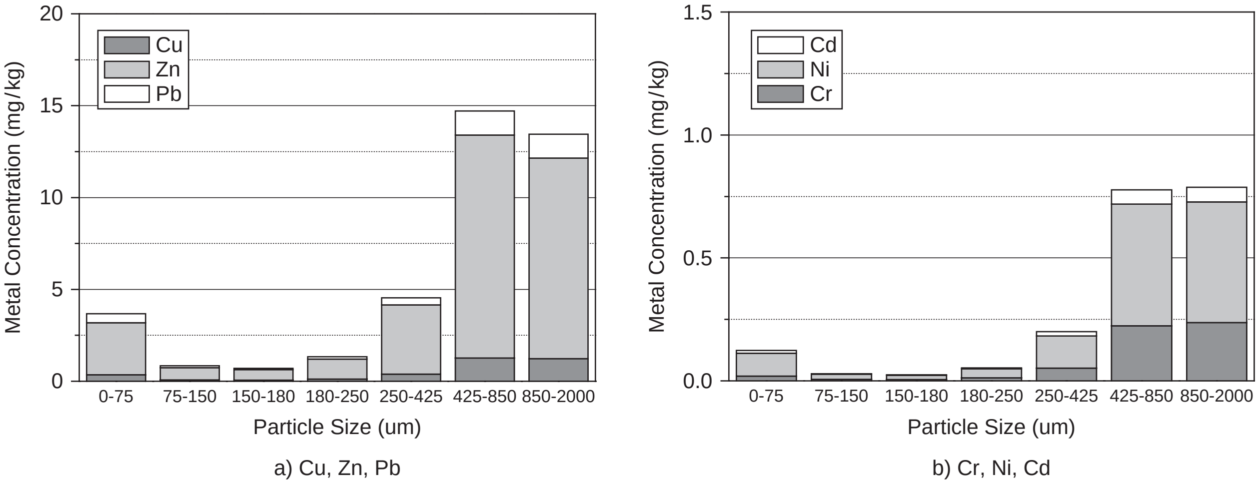

Fig. 4. Metal concentration in each particle size fraction.

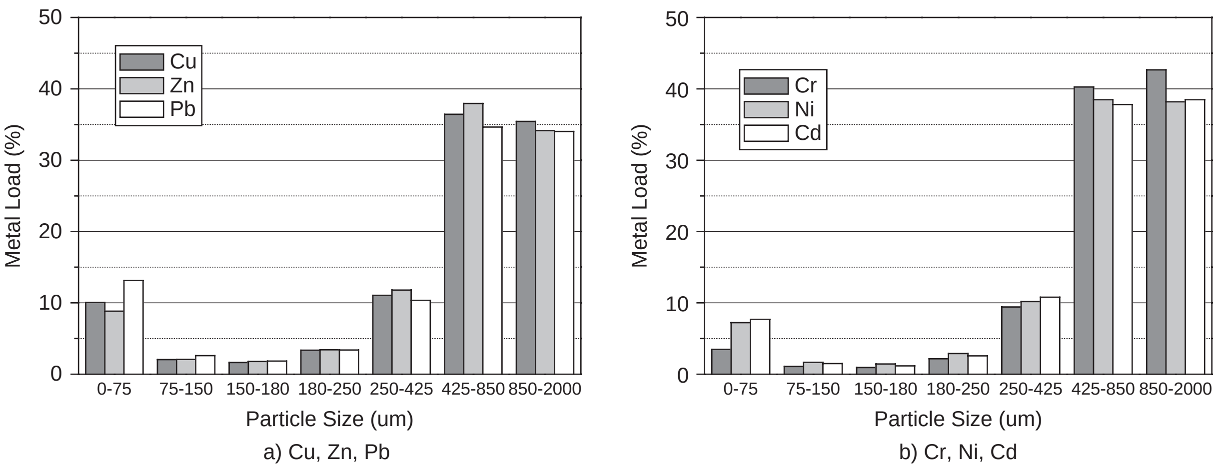

Fig. 5. Metal load fraction in different particle size ranges.

accordance with the standards stated in the SEL. On the other hand, results ascertain that it is still within the safe level and considered the area to be not polluted. However, continuous monitoring shall be done to assess accurately the pollution level.

3.3. X-ray diffraction analysis

Fig. 7 illustrates XRD patterns of the accumulated sediments from the settling basin. Major components including quartz, albite, microcline, muscovite and dolomite resulted from the XRD analysis. Through the XRD analysis, the atomic components of the particulate materials can be detected. Based on the results, most of the particulate materials were originated from the pavement materials due to surface abrasion and transported by the stormwater runoff. During the transport process, the particles are attaching metals on their surface areas.

4. Conclusions

In stormwater treatment BMP facility operations, it is important that pollutant removal efficiency is maintained under considerable level. Discharging of undesirable treated effluent initiates impact on water

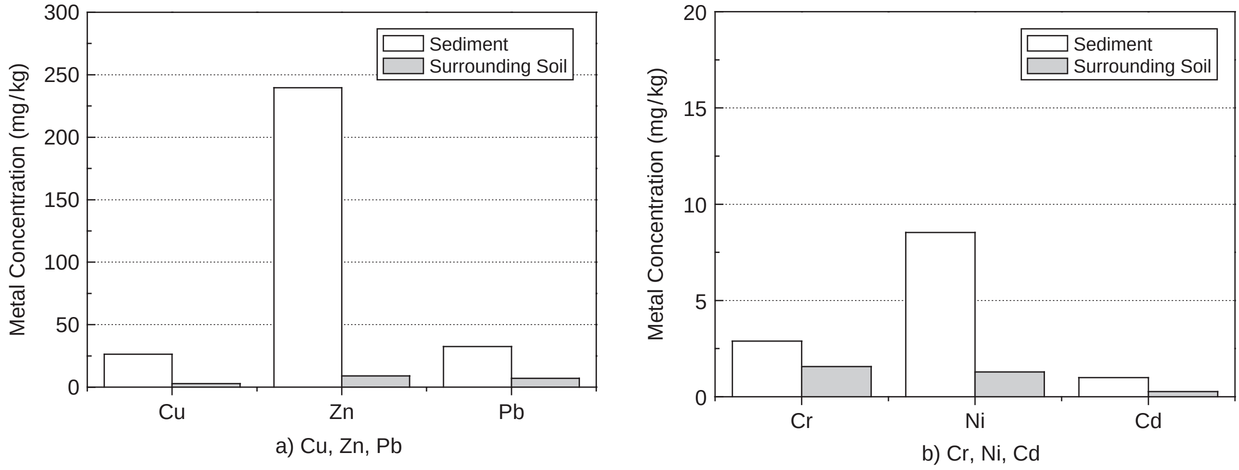

Fig. 6. Comparison of metal concentrations in sediment and surrounding soil.

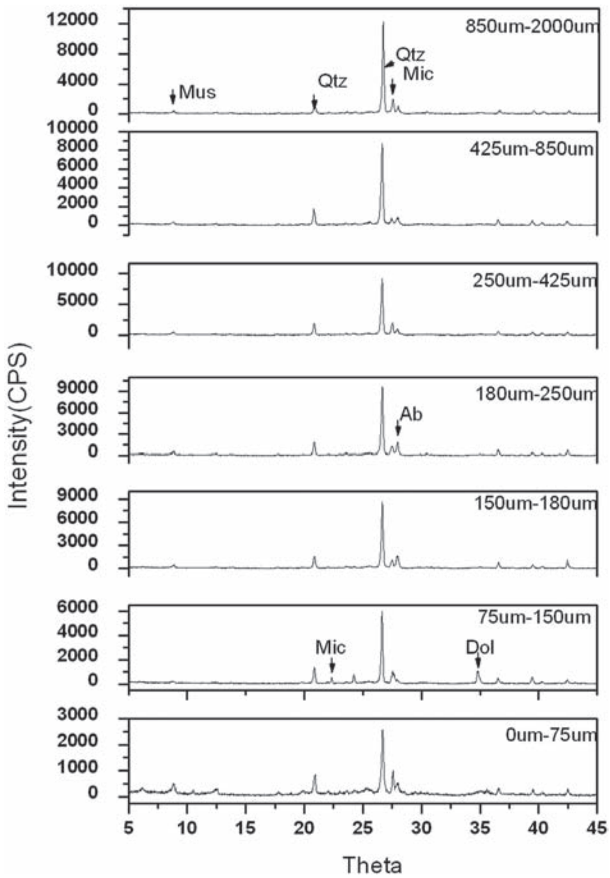

Fig. 7. XRD Patterns of the accumulated sediment. (Qtz; quartz, Mic; microcline, Ab; albite, Mus; muscovite, and Dol; dolomite).

bodies. Accumulated particles on the paved areas indicate particular matters in stormwater. Major findings for the accumulated sediment collected from the settling basin of a filtration BMP facility are as follows:

- The highest amount of particles collected was in the 425–2,000 μm size range because the sediment was accumulated in the settling basin which functions as pretreatment BMP, while the small particles would have entered the BMP facility.
- Fe concentration prevails to be the highest compare to other metals while the least detected was Cr followed by Cd
- The particle size fraction of 850 mm and below but greater than 75 mm, the concentrations of Cu, Zn and Pb were large.
- From the XRD analysis, most of the particulate materials were originated from the pavement materials due to surface abrasion and transported by the stormwater runoff.

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