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Analysis of non-point source characteristics of heavy metals and oil and grease at railway bridge area with various land uses

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ABSTRACT

Many studies have been conducted on the topic of non-point source management in various land-use areas to suggest non-point source management methods. However, the non-point source research pertaining to railway facilities is incomplete. In this study, six instances of rainfall monitoring were accomplished in a target railway bridge area on heavy metals (cadmium (Cd), copper (Cu), and lead (Pb)) and oil and greases (O&G). Based on the monitored data, heavy metals and O&G run-off characteristics, the event mean concentration (EMC) data, and pollutant load per unit area were analyzed. The concrete road-bed area run-off showed the characteristic first flush effect. The gravel road-bed area run-off characteristic showed the first flush effect or showed two-peaks. The EMC data showed higher values for the concrete road-bed area than for the gravel road-bed area. Heavy metals and O&G pollutant load per unit area in a railway bridge area showed higher values than those of pavement and urban areas. These results indicate that a considerable amount of heavy metals and O&G mass occur during rainfall events, indicating the need to manage non-point sources pollution in railway bridge areas.

Keywords: Non-point source pollution; Railway; Concrete road-bed; Gravel road-bed; Heavy metal; O&G

1. Introduction

Non-point source pollutants refer to wash out the accumulated pollutants by surface run-off effluent during rainfall events. Non-point source pollutants are difficult to determine, being even more difficult than point source pollutants [1]. Especially in areas near rivers and lakes, non-point source pollutants were influent water systems without any management to decrease pollutants, which is one of the reasons why water quality of the water system has decreased [2–4]. Previous researches were reported that non-point source pollutant loads are higher than sewage treatment plant effluent [5,6]. For the management of non-point sources pollution, many researchers are conducting studies on non-point source pollution management methods [7–9].

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The railway industry is continuously developing due to its low energy requirements and environmental and economic advantages. In the railway environment, concentrated efforts to control noise and oscillation to improve the convenience of surrounding areas have been undertaken [10,11]. However, the design of railway facilities does not sufficiently consider the generation of non-point source pollution. Railway bridge areas consist of concrete, gravel, and reinforcement materials, for which the discharge coefficients are difference. According to EPA research results, heavy metals and oil and greases (O&G) reportedly occur around railway facilities [12,13]. The railway bridge areas mostly near rivers and near lakes are associated. So, non-point source pollutants are directly inflow the water system. Especially, heavy metals and O&G have harmful effects on the human body and on algae conditions.

In this research, the characteristics of non-point sources of heavy metals and O&G are analyzed using a rainfall monitoring. The run-off characteristics, EMC, and pollutant load per unit area were analyzed on railway bridge areas (a concrete road-bed and gravel road-bed).

2. Experimental methods

2.1. Monitoring location and method

The monitoring locations in this study are shown in Fig. 1 and the characteristics of the locations are shown in Table 1. The discharge areas are a concrete road-bed area in Dang-san dong, Yeongdeungpo gu, Seoul, South Korea (the Dang-san railway bridge) and a gravel road-bed area in Shin-chun dong, Songpa gu, Seoul, South Korea (the Jam-sil railway bridge). The sizes of the areas are 306 and 168 m^2, respectively. The sample collection method and preparation steps for the monitoring were completed before a major rainfall period to wait for the rainfall run-off. To measure the flow rate, a "direct measuring" method was used. Sampling and sampling intervals were determined by turbidity [14–16]. The collected samples were transported immediately to a laboratory after a rainfall event. All of the pollutants were analyzed according to Standard Methods [17].

2.2. Monitored rainfall

A total of six rainfall events were monitored during 2012. These monitoring results are shown in Table 2. The antecedent dry days ranged from 2 to 40 d, the total rainfall was 6.5–174.5 mm, the run-off duration time was 6–38 h, and the average rainfall intensity was 1.1–5.9 mm/h.

2.3. EMC and pollutant unit load

The pollutant concentration is used to calculate the pollutant load per unit area from various rainfall events. The event mean concentration (EMC) is one of

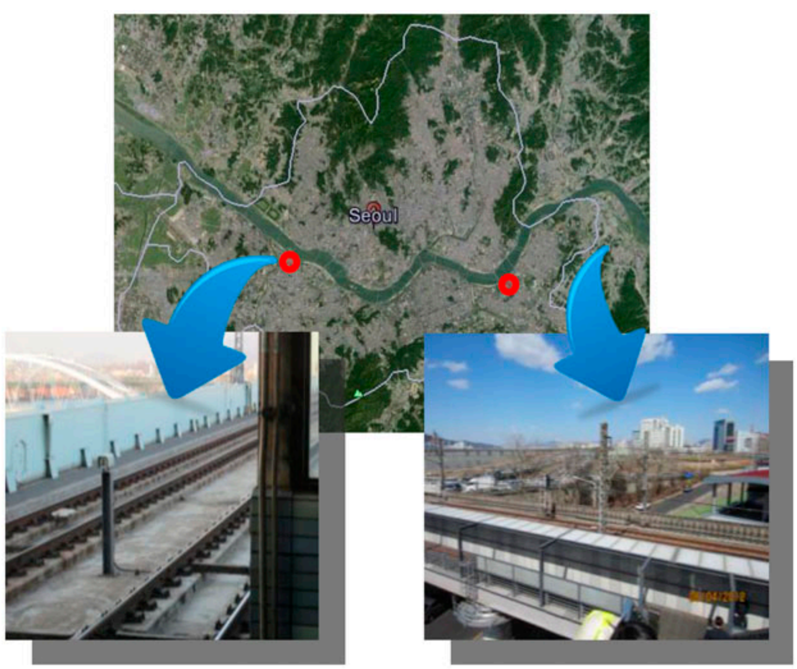

Fig. 1. Map showing the monitoring locations.

Table 1
Characteristics of the monitoring locations

Monitoring site	Location	Area (m^2)	Pavement type
Dang-san railway bridge	Dang-san dong, Yeongdeungpo gu, Seoul, South Korea	306	Concrete reinforced
Jam-sil railway bridge	Sin-chun dong, Songpa gu, Seoul, South Korea	168	Gravel concrete reinforced

Table 2
Event table for monitored events

Event date (yy/mm/dd)	ADD (d)	Total rainfall (mm)	Duration time (h)	Average rainfall intensity (mm/h)
2012/04/21	9	56.5	36	1.6
2012/05/15	10	6.5	6	1.1
2012/06/29	20	89.5	15	5.9
2012/07/05	2	174.5	38	4.6
2012/09/13	4	15.5	10	1.6
2012/10/27	4	44.0	14	3.1

the most important factors for analyses of rainfall events. The EMC can be calculated by dividing the total mass amount during the total run-off time by the total run-off volume during the total rainfall run-off time. The EMC can be expressed by Eq. (1).

$$\text{EMC (mg/L)} = \frac{\text{Total amount of pollutant mass during an event}}{\text{Total run-off volume}} = \frac{\int_0^t C(t) \times Q(t)dt}{\int_0^t Q(t)dt} \quad (1)$$

Here $C(t)$ and $Q(t)$ indicate the concentration and the run-off volume during the total run-off time.

The pollutant load per unit area is considered to be important data for calculating the pollutant load from various land uses. The pollutant load per unit area can be calculated by dividing the total mass amount during the total run-off time by the area of the catch basin. The pollutant load per unit area can be expressed by Eq. (2).

$$\text{Pollutant load per unit } (\text{kg/km}^2) = \frac{\text{Total amount of pollutant mass}}{\text{Area of catch basin}} \quad (2)$$

3. Results and discussion

3.1. Result of monitoring

Figs. 2 and 3 show hydro–polluto graphs (Fig. 2: concrete road-bed area; Fig. 3: gravel road-bed area). The hydro–polluto graphs show event 3 in the case of the concrete road-bed area and event 5 in the case of the gravel road-bed area. Figs. 2 and 3 show that heavy metal (Cd, Cu, and Pb) and O&G concentrations change according to the rainfall run-off time. The concrete road-bed area (Fig. 2) analysis parameters (i.e. Cd, Cu, Pb, and O&G) concentrations showed the highest values at the initial rainfall time during a rainfall event. The heavy metals and O&G concentrations in run-off effluent decreased following the rainfall duration time. In concrete road-bed area, the rainfall run-off showed the characteristic first flush effect because the land has been concreted and reinforced. Thus, the non-point source run-off in the concrete road-bed area shows the characteristic first flush effect. For the gravel road-bed area (Fig. 3) the analysis parameter (Cu and O&G) concentrations show higher values at the initial rainfall time and increasing flow times. However, the Pb concentration showed the highest value at the initial rainfall time during the rainfall events. Cd did not show any relationship between the concentration and rainfall time, indicating that the Cd run-off characteristic is random run-off. In the gravel road-bed area, the rainfall run-off characteristic showed a two-peak as a effect of different land uses (i.e. gravel, concrete, and reinforced).

3.2. Event mean concentration

The EMC of each pollutant (Cd, Cu, Pb, and O&G) was calculated using the monitored data from six

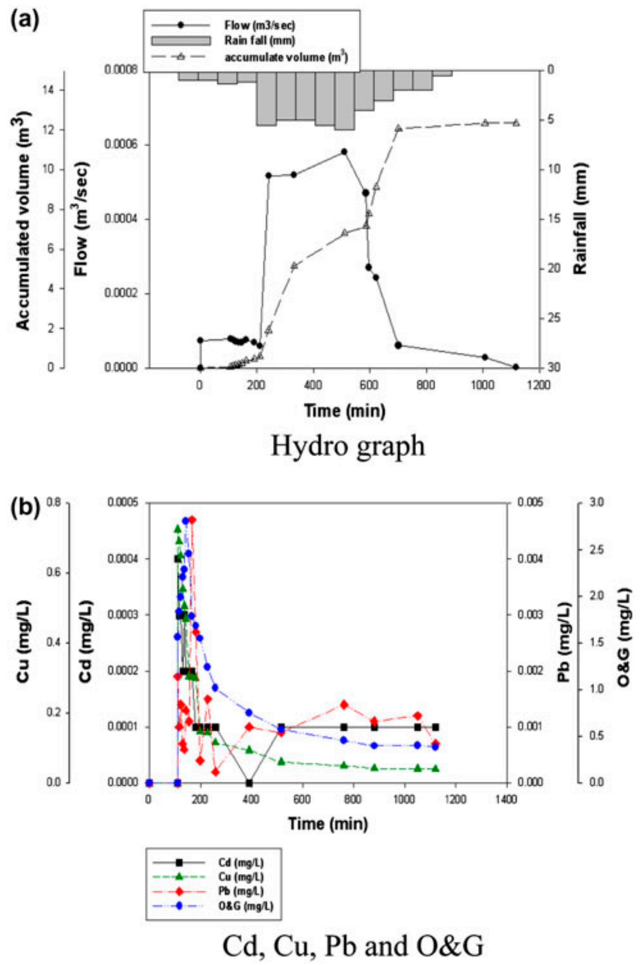

Fig. 2. Hydro–polluto graph of concrete road-bed area: (a) Hydro graph and (b) Cd, Cu, Pb, and O&G.

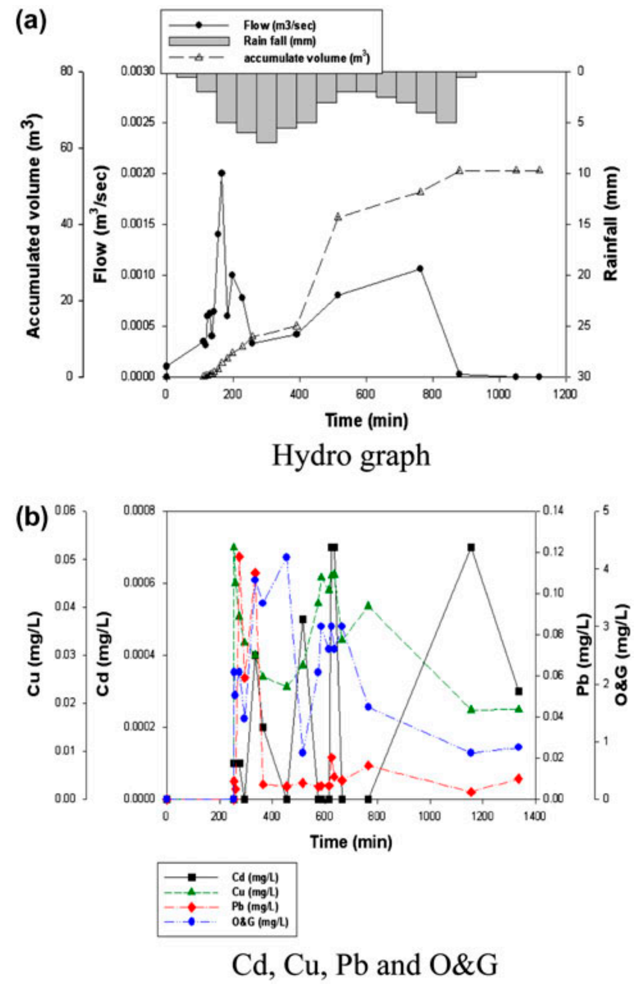

Fig. 3. Hydro–polluto graph of gravel road-bed area: (a) Hydro graph and (b) Cd, Cu, Pb, and O&G.

rainfall events. These results are shown in Fig. 4. The EMC pertaining to these events shows the following range in the concrete road-bed area (Fig. 5(a)): Cd 0.000016–0.0031 mg/L, Cu 0.032– 0.27 mg/L, Pb 0.0092–0.015 mg/L, and O&G 0.20–2.9 mg/L. The EMC data of these events shows the following range in the gravel road-bed area (Fig. 5(b)): Cd 0.000015–0.00099 mg/L, Cu 0.025–0.16 mg/L, Pb 0.002–0.063 mg/L, and O&G 0.61–6.7 mg/L. Generally, the concrete road-bed EMC values were higher than the gravel road-bed EMC values. Previous researches were reported that heavy metals and O&G are important pollutants in pavement area and urban area. And management of heavy metals and O&G are necessary to manage non-point source pollutants in these areas [14,15]. This result shows the seriousness of non-point source pollution in railway bridges.

3.3. Pollutant load per unit area

Fig. 5 shows a comparison of pollution load per unit area values (Cu, Pb, and O&G) in various land-use areas. The results for Dang-san (the concrete road-bed area) and Jam-sil (the gravel road-bed area) are the results from this study, and the results for pavement area and urban area are results from previous researches. The values for the railway bridge areas pollution load per unit area are higher than the pavement area and urban area values for all compared pollutant parameters (heavy metals and O&G). In the railway bridge areas, the Pb pollution load per unit area showed similar values for each area. However, the values for the Cu and O&G pollution load per unit area differed. The Cu pollution load per unit area value is higher in the

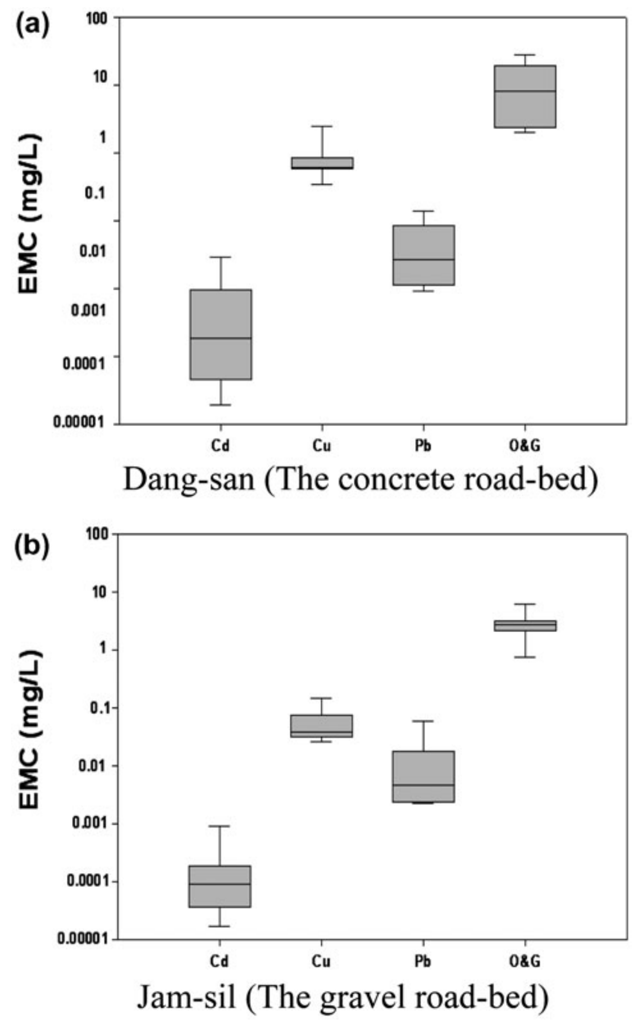

Fig. 4. Analysis of heavy metal and O&G EMC: (a) Dang-san (the concrete road-bed) and (b) Jam-sil (the gravel road-bed).

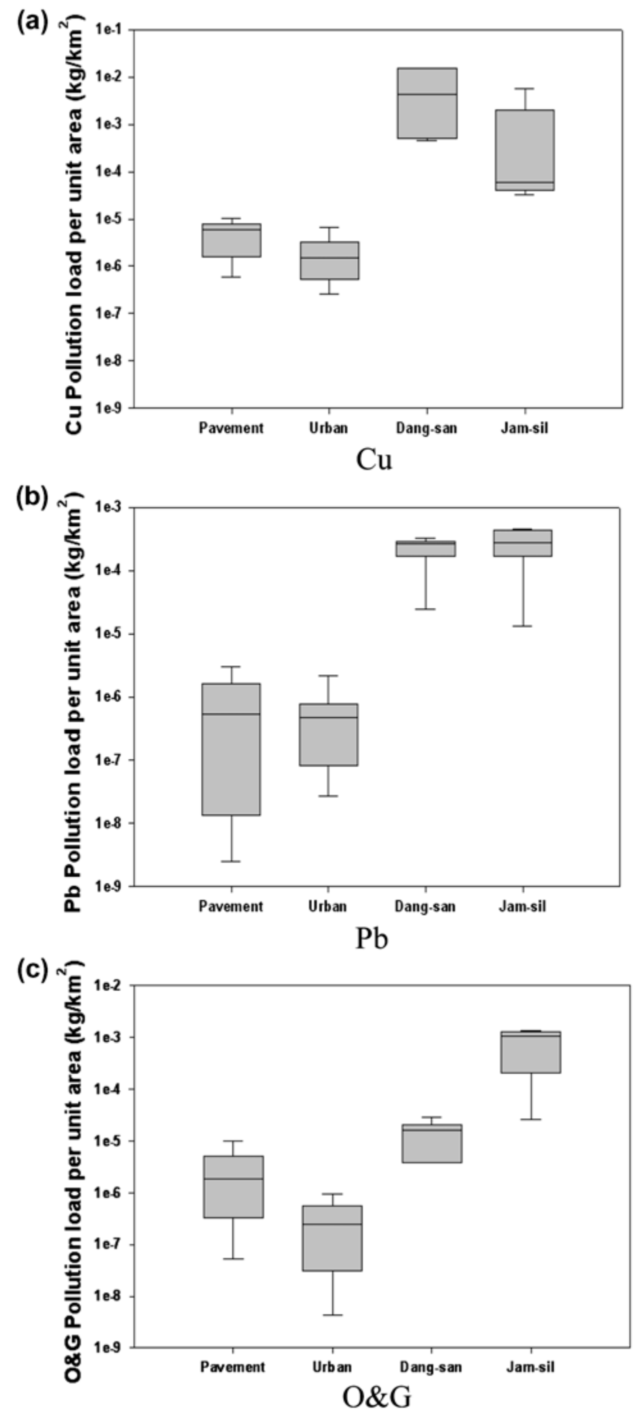

Fig. 5. Analysis of the pollutant load per unit area: (a) Cu, (b) Pb, and (c) O&G.

concrete road-bed area, and the O&G pollution load per unit area value is higher in the gravel road-bed area. For Cu, the concrete road-bed samples showed higher concentrations than those of the gravel road-bed area. This result was affected by land-use characteristic. The gravel has a higher adsorption than concrete. So, much of heavy metals were adsorbed onto the gravels. The pollutant load per unit area values are higher than those of the pavement and urban areas, indicating that much of the heavy metals pollutant load and O&G pollutant load occurred during the rainfall events. Railway bridges are located near water system (such as rivers and lakes). So, non-point source pollutants are washed out without any management. Through, management of non-point source pollutants in railway bridges is urgently required.

4. Conclusions

These conclusions are derived from the rainfall monitoring results at the railway bridge area.

(1) For the concrete road-bed area, the non-point source run-off showed the characteristic occur is first flush effect. However, for the gravel road-bed area, the non-point source run-off characteristics showed two-peak, a first flush effect, and a random result. The reason of the difference in the run-off characteristics was the different land uses of each area.

(2) As a result of calculating the EMC for six rainfall events at the railway bridge area, the following values were noted: concrete road-bed area (dang-san area) Cd 0.00009 mg/L, Cu 0.039 mg/L, Pb 0.0047 mg/L, and O&G 2.68 mg/L; gravel road-bed area (Jam-sil area) Cd 0.00018 mg/L, Cu 0.062 mg/L, Pb 0.0027 mg/L, and O&G 0.83 mg/L.

(3) In a comparison of the railway bridge areas, the pavement area and the urban area pollutant load per unit area values, the railway bridge heavy metal and O&G pollutant load per unit area values are higher than those for the pavement area and urban area. This result means that much of the heavy metals pollutant load and O&G pollutant load occurred during rainfall events, indicating the need to manage non-point source pollution in railway bridge areas.

The values for the heavy metals and O&G pollutant load per unit area in the railway bridge area are higher than those of the pavement and urban areas. In pavement and urban areas, heavy metals and O&G were serious pollutant of non-point source pollution. Thus, the management of non-point sources (such as heavy metals and O&G) is urgent in railway areas. Although there results were derived from the rainfall monitoring of six events, this represents important data with which to manage railway non-point source pollutants in the near of railway facilities. Because of there is no researches of non-point source pollution in railway facilities. In other words, non-point source pollution researches must be conducted in relation to railway facilities. There is a need for continues researches on the topic of non-point source pollution in railway facilities.

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