Metal contamination on, and adjacent to, road pavement at two tunnel sites in Korea

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Abstract: In this study, environmental monitoring of non-point source pollution at two road tunnel sites was conducted. Artificial runoff water was collected at a number of locations and analysed for a range of metals, showing that metal concentrations in runoff were higher at the tunnel entrance than within the tunnel. This was attributed to ventilation system effects.

Metal concentrations in roadside soils were also measured and found to be high in comparison to runoff. This was attributed to adsorption onto soil particles.

Résumé: Dans cette étude, le contrôle de l'environnement de la pollution de source de non-point à deux emplacements de tunnel de route a été conduit. L'eau artificielle d'écoulement a été recueillie à un certain nombre d'endroits et analysée une gamme des métaux, prouvant que les concentrations en métal dans l'écoulement étaient plus hautes à l'entrée de tunnel que dans le tunnel. Ceci a été attribué aux effets de système de ventilation.

Des concentrations en métal dans des sols de bord de la route ont été également mesurées et ont trouvé pour être hautes par rapport à l'écoulement. Ceci a été attribué à l'adsorption sur des particules de sol.

Keywords: non-point source of contaminants, heavy metals, roadside soils, tunnel environs, construction work.

INTRODUCTION

There are many different pollutants that affect waterways associated with NPS (non-point source) pollution. The types of pollutants vary depending on the surrounding land use that is generating the NPS. In roadway corridors and urban areas, the major NPS pollutants consist of fertilizers, pesticides, sediment, bacteria and viruses, road salt, heavy metals, thermal pollution, motor oil and other petroleum products associated with cars. When working in areas dominated by agricultural land use the major pollutants consist of fertilizers, pesticides, soil and sediment, and animal wastes. Finally, forested areas can also produce some NPS pollution, mostly from mining, road construction, and tree harvesting operations. The major contaminants in forested land areas are soil, fertilizers, and pesticides.

When dealing with NPS issues, the percentage of impervious surface in a watershed can have a drastic effect on the impact of polluted runoff. If there is an increase in impervious surface cover there will necessarily be a decrease in infiltration rates. With the decreased amount of infiltration will come an increase in the rates of runoff. These increased flow rates can carry higher levels of contaminated particles and also cause more severe erosion at inputs to our waterways. A recent document shows an estimated increase of runoff amounts from 10% for an area of natural ground cover to 55% for a highly urbanized area with 75-100% impervious surface. This increase results in a dramatically larger amount of water flowing into local waterways without first being filtered through soil and vegetated areas. This filtration can significantly decrease the amount of runoff before it reaches a water body.

The non-point source of contaminants, such as heavy metals, resulting from vehicles has been a worldwide problem. Contaminants have been discharged with into rivers and streams without treatment and dispersed over a widespread area by numerous pathways (e.g., ditches and groundwater). It is difficult to measure those spreading non-point sources correctly as they enter the underground. Heavy metals, which accumulate in roadside soils and sediments, exert a continuous impact on the natural biological systems (Smith and Lord, 1990).

In general, cars discharge pollutants into the air via emission gases that eventually settle on the roads and their environs. Runoff water from roads carries many different pollutants including sediments, nutrients, bacteria, oil, heavy metals, chemicals, salt, and pet droppings. The lead contamination of roadside soils has been extensively investigated and reported due to its toxic nature (Hafen and Brinkmann, 1996). The contamination level of roadside soils often exceeds the local environmental regulations (Preciado and Li, 2003). Other studies also indicate a high accumulation of heavy metals including zinc, copper, manganese, and lead in plants and soils near highways (Albasel and Cottenie, 1985; Majdi and Persson, 1989).

Natural environments and watersheds can be changed due to the tunnel construction. Tunnels are likely to be filled with dirt and concrete during the construction work, and natural streams around the tunnel are required to be redirected by man-made channels. Pollutants generated from tunnel construction work are often directly spilled in and around the ground of tunnel. Up to date, the non-point source of metal contaminants caused by tunnel constructions and the environs of operating tunnels has not been extensively investigated in the literature.

This paper describes the non-point source of contaminants generated from one operational tunnel and another under construction. Comprehensive sampling and analysis for contaminants was conducted in the environs of the tunnels in order to determine the most significant metal pollutants. From the field investigations and laboratory chemical analysis, the contamination of road and roadside soils were analyzed and summarized.

MATERIALS AND METHODS

Monitoring locations and sampling methods

Two different tunnels (i.e. a tunnel under operation and a tunnel under construction) located in KyungKi province were chosen for the monitoring of non-point contaminant sources. A lorry equipped with a water reservoir and sprinkler system ran for about 200 m spreading clean water on the road, and the runoff on the road was collected by dustpans at each of four sampling points. Schematic diagrams of the sampling locations are presented in Figure 1. The clean water was spread over the road for about 15 minutes through the 20 valves connected to the water reservoir on the lorry, and the amount of spreading water was approximately 1.5 L/sec (i.e. 1350 L per 15 minutes). After the field monitoring, chemical analysis was carried out with the collected runoff samples.

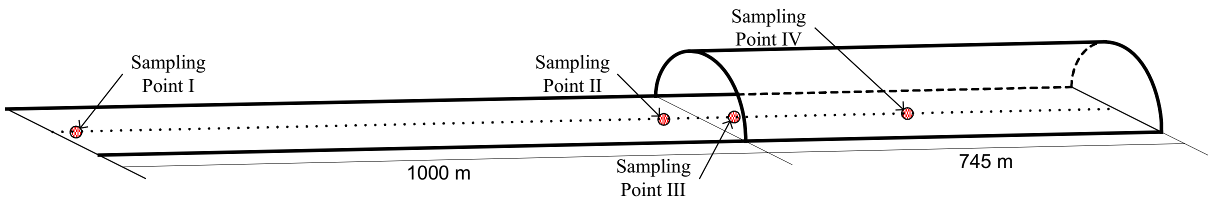

Figure 1. Sampling locations: sampling point I, II, III, and IV.

Metal concentrations in roadside soils were also measured for comparison.

RESULTS AND DISCUSSION

Non-point source of contaminants at the operating tunnel

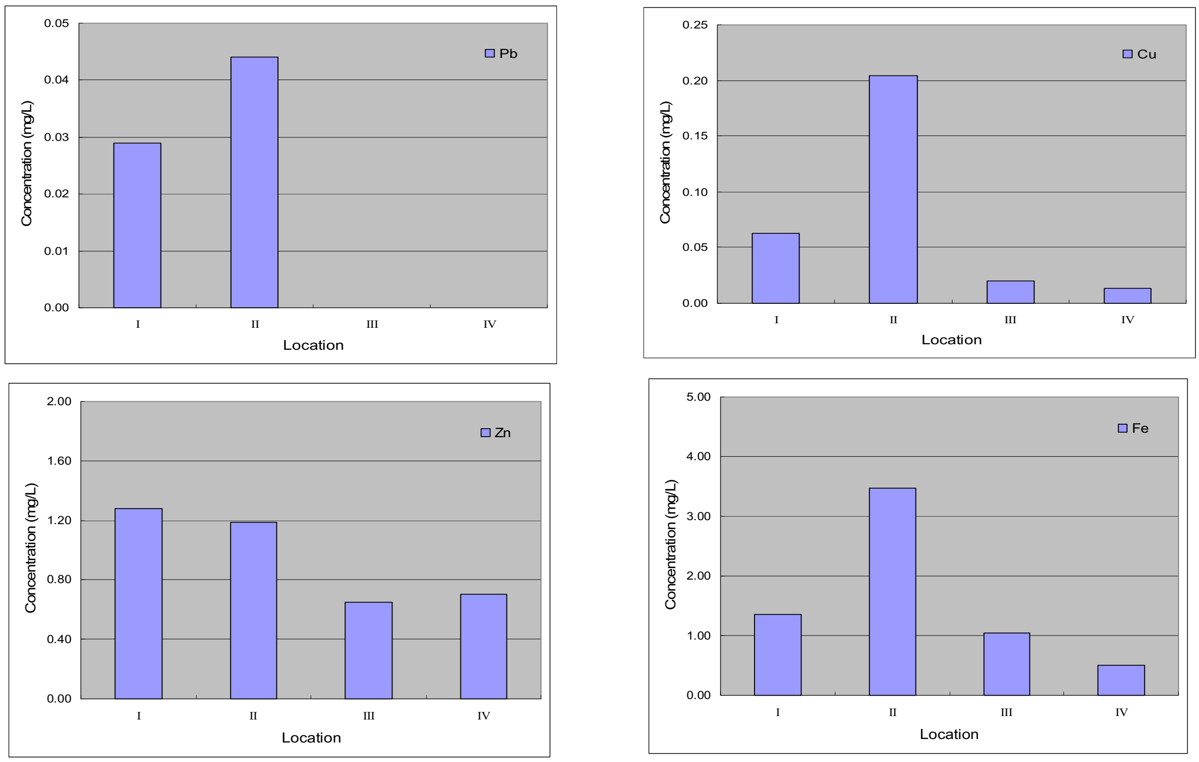

Figure 2. Deposition pattern of heavy metals as the non-point source of contaminants: (a) lead; (b) copper; (c) zinc; and (d) iron.

Figure 2 shows distributions of heavy metal concentration by sampling location. It was expected that the level of heavy metal contamination inside the tunnel would be higher than outside. However, the heavy metal concentrations at the entry of tunnel (i.e. sampling point II) were higher than those near the tunnel environs and the inside of the tunnel (e.g. sampling points I, III, and IV). It appears that the heavy metals released from the emission gases are immediately exhausted by the ventilation system, so that the contamination level inside the tunnel is relatively lower than those outside of the tunnel.

The main contributor was found to be the iron (0.50 ~ 3.47 mg/L), followed by zinc (0.70 ~ 1.28 mg/L), copper (0.01 ~ 0.20 mg/L), and lead (0.03 ~ 0.04 mg/L). Lead was not detected inside the tunnel.

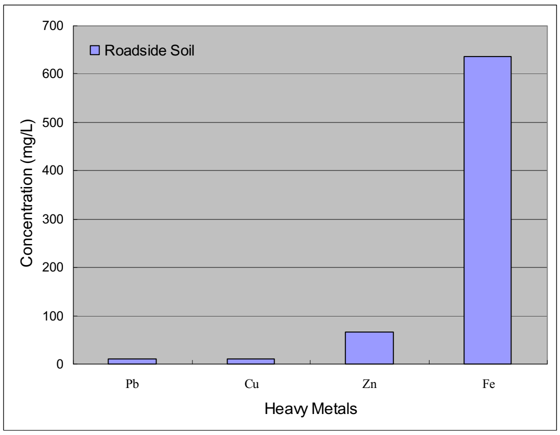

Figure 3. Heavy metal concentrations of roadside soil.

Metal concentrations of roadside soils are presented in Figure 3. The heavy metal concentrations were much higher than those obtained from the surface of the road (see Figure 2). The heavy metal contaminants on the road surface may have been regularly washed out by rainfall, so that the concentration is lower than those of roadside soil in which the heavy metals may have been adsorbed onto the soil particles.

Non-point source of contaminants at the tunnel under construction

In the case of the tunnel under construction, the main contaminants were found to be in the order: iron (7.98 mg/L) > zinc (0.98 mg/L) > copper (0.11 mg/L). Lead was not detected by the chemical analysis.

CONCLUSIONS

The monitoring results for non-point source of contaminants carried out in 2 tunnels located in KyungKi province are as follows:

1. It was found that heavy metal concentrations at an operational tunnel entrance were higher than those measured inside the tunnel. It seems that the heavy metals generated from the emission gases are exhausted by the ventilation system, so that the contamination level inside the tunnel appears to be relatively lower than that outside of the tunnel.
2. Iron (0.50 ~ 3.47 mg/L) was the main contributor as a non-point source of contaminant for the operating tunnel, followed by zinc (0.70 ~ 1.28 mg/L), copper (0.01 ~ 0.20 mg/L), and lead (0.03 ~ 0.04 mg/L).
3. In the case of the tunnel under construction, the main source of non-point contaminants was also the iron (7.98 mg/L), followed by zinc (0.98 mg/L) and copper (0.11 mg/L). Lead was not detected.
4. It may be that the heavy metal concentrations are related to the length of tunnel, traffic density, ventilation, and the environs of tunnel.

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