Heavy Metal Contamination of Roadside Soils of Northern England

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Abstract: Environmental pollution of heavy metals from automobiles has attained much attention in the recent past. The present research was conducted to study heavy metal contamination in roadside soils of northern England. Roadside soil samples were collected from 35 sites in some counties of northern England and analysed for four heavy metals (cadmium, copper, lead, zinc). Their concentrations and distributions in different road verge zones (border, verge, slope, ditch) were determined. Lead concentration was the highest in the soil and ranged from 25.0 to 1198.0 μg/g (mean, 232.7 μg/g). Zinc concentration ranged from 56.7 to 480.0 μg/g (mean, 174.6 μg/g) and copper concentration ranged from 15.5 to 240.0 μg/g (mean, 87.3 μg/g). Cadmium concentration was the lowest in the soil and varied from 0.3 to 3.8 μg/g (mean, 1.4 μg/g). Though the levels of heavy metals in roadside soils were higher as compared to their natural background levels in British soils, their concentrations in general, however, were below the 'critical trigger concentrations' for the contaminated soils. All the four heavy metals exhibited a significant decrease in the roadside soils with the increasing distance from the road. The border zone had the highest mean concentration of the four metals whereas the ditch zone exhibited the lowest mean concentration.

Keywords: roadside soils; heavy metals; contamination; northern England

The pollution of soils by heavy metals from automobile sources is a serious environmental issue. These metals are released during different operations of the road transport such as combustion, component wear, fluid leakage and corrosion of metals. Lead, cadmium, copper, and zinc are the major metal pollutants of the roadside environments and are released from fuel burning, wear out of tyres, leakage of oils, and corrosion of batteries and metallic parts such as radiators etc. (Dolan *et al.* 2006).

The majority of the heavy metals are toxic to the living organisms and even those considered as essential can be toxic if present in excess. The heavy metals can impair important biochemical processes posing a threat to human health, plant growth and animal life (Jarup 2003; Michalke 2003; Silva *et al.* 2005). Studies have shown that such pollutants can be harmful to the roadside vegetation, wildlife, and the neighbouring human settlements (Muskett & Jones 1980; Khan & Frankland 1983; Ndiokwere 1984; Iqbal *et al.* 1994; Ferretti *et al.* 1995; Caselles 1998; Turer & Maynard 2003). The distribution of these metals in the roadside soils is strongly but inversely correlated with the increase in the distance from road (Warren & Birch 1987; Bhatia & Choudhri 1991; Aksoy 1996). This study constitutes a part of a broader research project on the ecology and conservation of the roadside vegetation in northern England (Akbar *et al.* 2003, 2006). The present research was undertaken to study heavy metal (cadmium, copper, lead, zinc) contamination in the roadside soils in relation to their natural background levels. In addition, the spatial distribution of the four heavy metals in the roadside verges was also investigated.

MATERIALS AND METHODS

The study area

The study area consisted of 35 roadside sites in north and west Yorkshire, England, along different A- and B-class roads. A few road verges in the Peak district were also sampled to survey the upland verges. The study area had carboniferous rocks and Permian Trias as two main geological formations (Rayner & Hemingway 1974). The roadside vegetation in the study area was dominated by four grasses (*Arrhenatherum elatius*, *Festuca rubra*, *Dactylis glomerata* and *Lolium perenne*). A typical road verge can be divided into four arbitrary zones, border, verge, slope and ditch/hedge (Dowdeswell 1987). The border is the narrow zone adjacent to the paved road and is heavily disturbed. The verge is next to it and is usually 1–3 m wide. The slope, where present, is 1–3 m in height with 30–35 degrees of inclination. The ditch is the last zone and usually has a hedge along it. The soil sampling along the roadside verges was therefore carried out according to the different zones in the roadside verges. During the survey, however, it happened sometimes that not all the four zones (particularly slope) were present at each site.

Collection of soil samples

At each site, a 50-meter tape was laid parallel to the road (on both sides) in each arbitrary zone of the verge. Three quadrats (0.5 × 4 m) were placed at equal distances along the 50-meter tape in each zone. The soil samples were taken from each quadrat at two points with a stainless trowel from the top 10–15 cm of the soil. Samples from three quadrats of a zone were mixed together to make a composite sample representative of that zone of a particular site. A total of 233 composite samples were collected and analysed for heavy metals concentrations. All soil samples were air-dried and ground to < 2mm before chemical analysis.

Determination of heavy metals

One gram of each air-dried and sieved soil sample was ashed in a muffle furnace at 460°C for 24 hours. The ash was digested in 10 mL Aqua regia (1 part conc. HNO_3 to 3 parts HCl) in a digestion tube on the heating blocks at different temperatures and times (2 h at 25°C ; 2 h at 60°C, 2 h at 105°C, and 3 h at 125°C), spreading over a total of nine hours. After the digestion, the digests were first centrifuged and then made up to the volume with 10% HNO_3. Standard solutions for each element were prepared in 10% HNO_3. The concentrations of cadmium, copper, lead, and zinc in the diluted digests were measured by Perkin Elmer 1100 atomic absorption spectrophotometer (Al-Shayeb *et al.* 1995). All the samples were run in triplicates. Data were subjected to analysis of variance (ANOVA) by SPSS to determine the differences in the concentration of each metal between different verge zones.

RESULTS AND DISCUSSION

Lead

In the present study, the lead content of the roadside soils ranged from 25 to 1198 µg/g with the mean value of 232.7 µg/g (Table 1). Out of 233 samples, 130 samples contained lead up to 200 µg/g while 70 samples had the lead concentration ranging from 200 to 400 µg/g, and 33 samples contained lead in the a range of 400 to 1200 µg/g. Alloway (1995) mentioned that the total lead content of normal British soils ranged from 2 to 300 µg/g while McGrath (1986) reported 75 mg per kg as the mean value for lead in urban top soils of England and Wales. The roadside soils usually contain higher lead contents. Culbard *et al.* (1988) reported the range of 45 to 9660 mg/kg of total lead in the roadside dust of urban areas in UK with the (geometric) mean value of 786 mg/kg. By considering the general range of the total lead content, it appears that the total lead content in 85% roadside soils was below the critical concentration of 400 mg/kg (ICRCL 1987). Only few soils from the roadside verges were heavily contaminated.

In the last decades, much attention has been directed towards lead in the roadside environments as a result of its widespread use as an anti-knocking agent in gasoline (Davies & Holmes 1972; Wheeler & Rolfe 1979; Hafen & Brinkmann

Table 1. Concentration of four heavy metals in roadside soils from northern England

Metal	Minimum (µg/g)	Maximum (µg/g)	Median (µg/g)	Mean ± S.E (µg/g)
Lead	25.0	1198.0	175.0	232.7 ± 12.7
Cadmium	0.3	3.8	1.2	1.4 ± 0.1
Copper	15.5	240.0	80.4	87.3 ± 3.0
Zinc	56.7	480.0	150.0	174.6 ± 4.9

1996; Turer & Maynard 2003). In the recent years, however, the lead content in gasoline was markedly decreased in the UK after the introduction of the regulations requiring the reduction in the lead content from 0.64 g/l in 1966 to 0.14 g/l in 1986. This decrease has reduced the addition of lead to the environments by motor vehicles. However, the previously deposited lead remains a major contaminant of the roadside environments. Although the lead content in gasoline is minimised these days, the increased traffic has caused an increase in the lead emission in the roadside environments (Jones *et al.* 1991).

The amount of lead in the roadside soils is strongly but inversely correlated with the increase in the distance from the road (Motto *et al.* 1970). In the present study, a distinct gradient with a pronounced decrease in the lead content from the first zone to the last zone was also observed (Figure 1). There was a sharp decrease ($P \leq 0.001$) from the first zone to the second zone which indicates that there is a great decrease in the lead content within a distance of few meters from the road. With the increase in distance, this decrease is not so sharp. Warren and Birch (1987) found the lead content of 956.6, 442.6, 347.2, and 299.6 µg/g in the highway soils 6, 10, 20, and 30 meters away, respectively.

Cadmium

In the present study, cadmium concentrations ranged from 0.3 µg/g to 3.8 µg/g with the mean value of 1.4 µg/g (Table 1). Kabata-Pendias and Pendias (1984) reported that the background concentrations of cadmium in the surface soils in Britain are 1.05 µg/g. Aksoy (1996) found mean cadmium concentrations for urban roadside soils and rural roadside soils near Bradford as 2.44 µg/g and 1.04 µg/g, respectively.

The frequency distribution of cadmium in the roadside soils showed that 78 samples had the cadmium content below 1 µg/g while 107 samples contained cadmium in the amount between 1 and 2 µg/g. The remaining 36 samples contained more than 2 µg/g cadmium.

Alloway (1995) mentioned that 0–1 µg/g of cadmium in soils indicates non-contamination, 1–3 µg/g indicates slight contamination and 3–10 µg/g indicates a contaminated soil. Only 13 samples from the roadside soils contained more cadmium than 3 µg/g and could be considered as contaminated. The cadmium concentration decreased with the increasing distance from the road. This decrease was significant ($P \leq 0.001$) between the border and verge zones (Figure 2). The ditch zone showed the lowest mean concentration of cadmium, similar

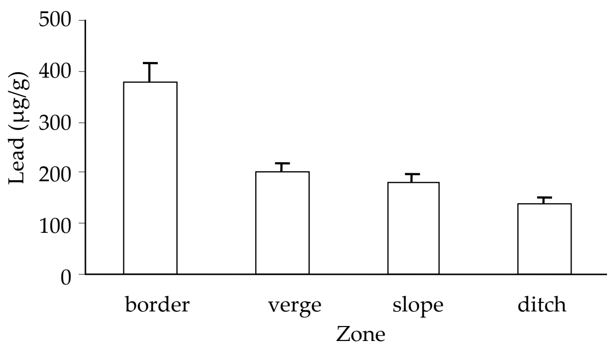

Figure 1. Mean concentration (µg/g) with standard error bars of lead in different road verge zones; mean values are significantly different at $P \leq 0.001$

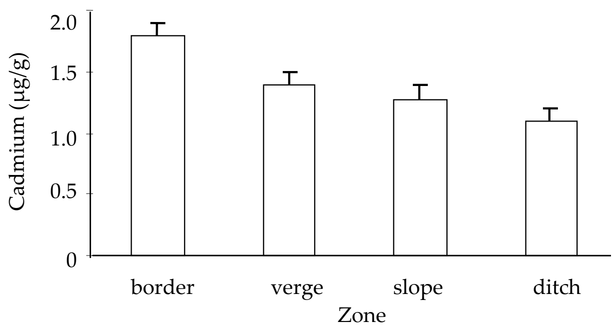

Figure 2. Mean concentration (µg/g) with standard error bars of cadmium in different road verge zones; mean values are significantly different at $P \leq 0.001$

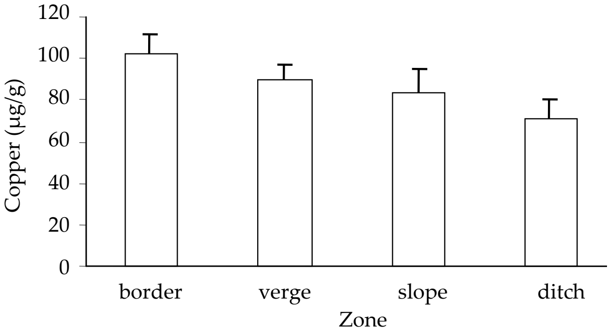

Figure 3. Mean concentrations (μg/g) with standard error bars of copper in different road verge zones; mean values are significantly different at $P \leq 0.001$

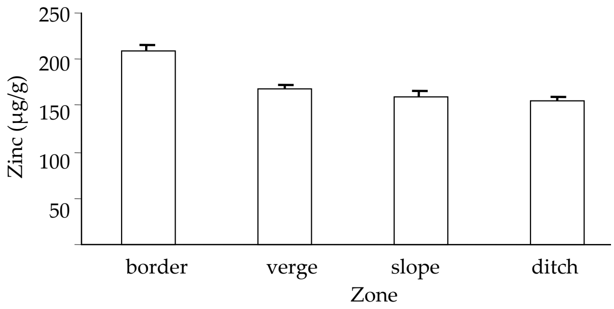

Figure 4. Mean concentrations (μg/g) with standard error bars of zinc in different road verge zones; mean values are significantly different at $P \leq 0.001$

to the other contaminants of the roadside environment.

Copper

The copper content in the roadside soils ranged from 15 to 240 μg/g with the mean value of 87.3 μg/g (Table 1). Copper is usually present in soils within the range of 0 to 250 μg/g (Alloway 1995). McGrath and Loveland (1992) reported the range of 1.2 to1507.7 mg/kg for copper in the soils of England and Wales with a median value of 18.1 mg/kg. Its amount in urban and roadside soils, however, is reported to be 5–10 times higher than the normal concentrations (Baker & Senft 1995; Nriagu 1979). Copper was found within the range of 60 to 120 μg/g in 109 soil samples, with 76 samples containing the total copper amount below than 60 μg/g. Total copper content in most of the roadside soils was below or within the limits of the critical soil concentration of 60–125 μg/g (ICRCL 1987). Only 49 samples contained copper above this limit and could be designated as contaminated. These samples came mainly from the road verges near urban areas. Copper, like other metal contaminants, also showed the highest concentrations in the border zones with a significant ($P \leq 0.001$) decrease towards the ditch zones (Figure 3).

Zinc

The amount of zinc in the roadside soils ranged from 56.7 to 480 μg/g with the mean value of 174.6 μg/g (Table 1). Normal concentrations of zinc in soil range from 1 to 900 μg/g (Alloway 1995). The majority of the roadside soil samples (159) contained less than 200 μg/g of zinc while 58 samples contained more than 200 μg/g and 17 samples contained more than 300 μg/g of zinc. McGrath and Loveland (1992) reported that the zinc concentration in the soils of England and Wales ranged from 5 to 3648 mg/kg with the median value of 82 mg/kg. In the present study, the concentration of zinc falls within this range but the median value (151 μg/g) was twice the background level. This may be due to the higher input of zinc in the roadside environments by motor vehicles. Kiekens (1995) stated that the total zinc levels in polluted soils in industrialised countries may account for hundred to thousand times higher than those in unpolluted soils. Aksoy (1996) reported the mean zinc concentration of 410 μg/g in soils collected from urban roadside soils in Bradford. There was a significant ($P \leq 0.001$) decrease in the zinc content from the border zone to the ditch zone (Figure 4). The border zone showed the highest mean value of 208 μg/g and the ditch zone had the lowest concentration of 154 μg/g.

CONCLUSION

Heavy metal contamination in the soils from the roadside verges in the study area was higher as compared to the background levels for lead, cadmium, copper, and zinc. These concentrations, however, were below the critical maximum levels above which toxicity is possible. The highest concentrations were detected in the samples collected from the border zone of the verges and there was a trend of gradual decrease in the metal contents with the increasing distance from the paved roads.

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