FATE OF MOTORWAY POLLUTANTS THROUGH AN AQUATIC ECOSYSTEM - TRANSFER OF HEAVY METALS TO AQUATIC LIFE

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ABSTRACT

The release of motorway pollutants, especially heavy metals, into the aquatic environment via stormwater run-off is known to cause detrimental effects to the receiving ecosystem. Most heavy metals entering water bodies become associated with particulates and as a result of settling time, accumulate in bottom sediments of the receiving water. In order to ascertain the mobility and bioavailability, of these heavy metals in sediment, it is necessary to use sequential extraction procedures, based on Tessier *et al.,* (1979). In addition, fish can be seen as the main 'critical material' in freshwaters, and as such can be used to assess the bioaccumulation and biomagnification of contaminants within the ecosystem. Results from sediment taken from an unmanaged detention pond showed metals to be associated with the carbonate and residual fractions. In particular, Ni and Cd showed a high percentage association, compared with other geochemical fractions, with these carbonates and residual fractions. Cu and Zn were shown to be associated with carbonates and Fe-Mn oxides, whereas Pb showed the strongest association (71.5%) with the Fe-Mn oxides. When compared to a groundwater fed lake on site, all metals contained within this sediment were strongly associated with the residual fraction (> 50%) and are therefore strongly bound within the sediment. *Juncus effuses* (soft rush) aquatic vegetation showed higher levels of heavy metals in the roots compared with tope. The metal levels decreased with distance form the entry point to the detention pond. Muscle tissue collected from the coarse fish Roach (*Rutilus rutilus*) showed higher concentrations in the detention pond affected lakes than the groundwater fed lake. This highlights the mobility and bioaccumulation of these heavy metals within the freshwater environment.

INTRODUCTION

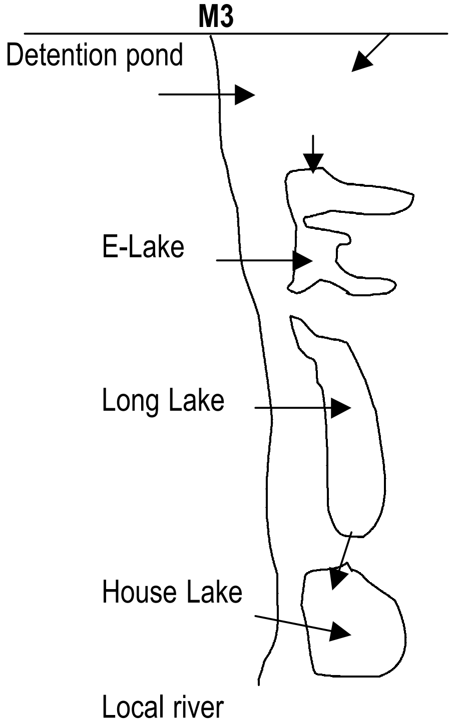
One of the main growing concerns has been the increase in multielement contamination from motor vehicles affecting the terrestrial and aquatic environments, and ultimately their biological affect to man (Bryce-Smith, *et al*., 1978; Schutz, *et al.,* 1984; Ward, 1990). The level of chemical contamination will largely be determined by the type of road near to the receiving waters, and the overall design of the drainage system. Heavy metals entering motorway stormwater may become deposited, with time, to bottom sediments within the receiving freshwater system. However, resuspension may occur allowing the mobility and bioavailability of these contaminants.

When assessing the possible mobility of these metals, the analysis of the total heavy metal content is insufficient when assessing the environmental impact of contaminated sediment. The chemical form which the metal is in will determine its behaviour and hence mobility and bioavailability within the environment.

Different aquatic organisms often respond to external contamination in different ways, where the quantity and form of the element in water, sediment, or food will determine the degree of accumulation (Langston & Spence, 1995). The region of accumulation of heavy metals within fish varies with route of uptake, heavy metal species and species of fish concerned. Their potential use as biomonitors is therefore significant in the assessment of bioaccumulation and biomagnification of contaminants within the ecosystem.

Local river

Figure 1:Study site



The research site used in this study consists of a series of man-made lakes adjacent to the M3 motorway in northwest Surrey, England. Typical daily traffic densities of >85,000 vehicles. The main lake system is a series of interconnecting lakes fed by a detention pond adjacent to the M3, and a local river (Figure 1). The lake system consists of a detention pond; 'E', long and house. A groundwater-fed lake, situated southeast of the study area was selected as a background site.

Although privately owned, the lakes are used for coarse fishing, and are stocked with a variety of coarse fish.

METHODOLOGY

Sediment samples were collected randomly, focusing on regions of maximum/minimum water flow, inlet and outlet areas. Sediments were collected via a polyethylene corer, which removed approximately 10 cm of surface sediment (~100 g wet weight). A sediment subsample was dried at 105°C overnight, homogenised and sieved (2 mm). For the determination of the geochemical fractionation of the sediment, a modified Tessier et al., (1979) procedure was used. A 1.0 g subsample of oven-dried sediment was used for this assessment, since time constraints did not allow the use of fresh sediment. *Juncus effusus* (soft rush) was chosen as the bioaccumulator species representing aquatic vegetation. Samples were collected by hand using polypropylene gloves and immediately placed into polyethylene bags and labelled. Fresh weight samples were oven dried at 110°C for 2 days , dry ashed at 450°C for 12 hours and the homogenised ash digested using 10 ml of conc. HNO_3. The coarse fish Roach were collected by the local fishing club, from the interconnecting lakes fed by the detention pond, and transferred to the laboratory for analysis. When collecting the fish only those samples of identical weight and age were chosen. Muscle tissue samples were removed, oven-dried and wet digested using 10 ml of conc. HNO_3. All geochemical fractionation samples and fish samples were analysed for Cu, Cd, Ni, Zn and Pb using Inductively Coupled Plasma Mass Spectrometry (ICP-MS). Quality control of laboratory methods involved the analysis of the following reference materials: Sediment GBW 07301, Water TMDA 54.2 and IAEA MA-A-2/TM Fish Flesh.

RESULTS & DISCUSSION

Table 1 shows the % geochemical association of the heavy metals Ni, Cu, Zn, Cd and Pb within the detention pond and the groundwater-fed lake sediments. The groundwater-fed lake shows, for Ni, Cu, Cd and Pb, a large percentage (> 50%) are associated with the residual fraction, i.e. are tightly bound within the crystal lattice of the minerals found in the sediment. To remove these metals, both HNO_3 and HF acids were needed.

However, Zn was found to be associated mainly with the carbonate and residual fraction. In comparison, the detention pond sediments showed varied geochemical associations depending on the metal concerned. For both Ni and Cd, bound to carbonates and to residual were the highest percentage associations. For both Cu and Zn, bound to carbonates and Fe-Mn oxides gave the main associations. Lead displayed the strongest association for Fe-Mn oxides (71.5%). out of all the heavy metals analysed. Compared with the groundwater-fed lake sediment, Ni, Cu, Zn, Cd showed an increase mobility due to the association with the carbonate fraction. However, caution must be taken when making conclusions of this work, e.g. changes in sediment chemistry will affect the association of these metals. The fresh sediment, especially within the detention pond and interconnecting lakes, is very anoxic, and hence by removing this sediment, and preparing the sediment for analysis as has been done here, changes in geochemical association could result.

Also, of interest is the continual use by the fisherman of calcium carbonate in the detention pond and interconnecting lakes to maintain freshwater pH. From 1997 - 1998 appreciable amounts of calcium carbonate have been added to the 'E' and Long Lakes. This practice has now stopped, which may present a greater risk to the freshwater environment through the lakes maintaining their 'natural pH' (acidic), and hence causing greater mobility of these metals.

Table 1: Geochemical fractionation of the heavy metals found in sediment

SITE	Geochemical fraction	Sediment total (%)				
		Ni	**Cu**	**Zn**	**Cd**	**Pb**
Detention pond						
	Exchangeable	1.9	0.4	0.9	0.0	0.0
	Bound to carbonates	32.1	42.6	46.9	39.5	11.5
	Bound to Fe-Mn oxides	21.8	42.9	29.0	20.2	71.5
	Bound to organic matter	8.0	5.4	9.8	10.2	7.7
	Residual	36.2	8.8	13.5	30.2	9.2
Groundwater -fed lake						
	Exchangeable	12.5	10.5	7.1	9.4	8.8
	Bound to carbonates	3.7	1.0	23.9	2.7	0.6
	Bound to Fe-Mn oxides	10.2	7.3	21.7	3.7	25.3
	Bound to organic matter	9.1	20.8	18.1	0.0	10.3
	Residual	64.6	60.4	29.2	84.1	55.0

Vegetation is an important phase in the distribution of nutrients and contaminants within the sediment-vegetation-animal/fish ecosystem. Whilst it provides a source of food and habitat for many animals, it also provides a recycling system for nutrients, including heavy metals in the sediment system. The ability to accumulate heavy metals varies from species to species. Some species are known to bioaccumulate, whilst others are good bioindicators. Table 2 reports the lead and cadmium levels (mg/kg, dry weight) for *Juncus effusus* (soft rush) plants collected at the various sampling sites.

Table 2: Lead and cadmium content of *Juncus effusus* (soft rush) vegetation (mg/kg, dry weight)

	Plant	Detention pond	E lake	Long lake	House lake	Ground-fed lake
Lead	**Tops**	2.5	3.1	1.5	1.4	0.25
	Roots	37.5	5.4	5.2	3.4	2.1
Cadmium	**Tops**	0.45	0.23	0.21	0.22	0.02
	Roots	0.65	0.70	0.98	0.35	0.07

Table 2 clearly shows that the roots of *Juncus effusus* plants contains higher levels of both lead and cadmium. in the roots relative to the tops (leaves and stems). This is not surprising considering the high sediment levels. Plants collected from all sampling sites along the drainage system show elevated levels relative to the non-motorway related ground-fed lake. There is a decreasing trend of heavy metal burden in the plants with distance from the detention pond.

Table 3 shows the heavy metal levels found within the muscle tissue of the Roach samples, in the detention pond affected lakes and the groundwater fed lake. For all metals concerned the levels found within the detention pond were higher than those found within the groundwater-fed lake. For some metals, e.g. Pb, levels in the fish taken from the detention pond affected lakes were 85 times higher than fish sampled from the groundwater-fed lake.

Within a freshwater ecosystem fish tend to show characteristics which are indicative of the environmental stress to which they are being subjected. Of concern at this study site is the increase of fish disease, sores and high mortality rates, over a wide range of fish species. This has been attributed mainly to low environmental quality of the freshwater, and the lack of management to help maintain environmental quality of the lakes and surrounding area.

Table 3: Heavy metal concentration found in fish tissue (mg/kg, dry wt)

SITE	**Heavy metal concentration (mg/kg)**				
	Ni	**Cu**	**Zn**	**Cd**	**Pb**
Detention pond affected lakes (n=12)	4.2 ± 0.3	15.7 ± 6.4	69.5 ± 29.3	0.02 ± 0.01	3.4 ± 0.1
Groundwater fed lake (n=8)	0.7 ± 0.3	1.6 ± 0.2	34.9 ± 4.7	0.01 ± 0.001	0.04 ± 0.01

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