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Platinum and palladium variations through the urban environment: Evidence from 11 sample types from Sheffield, UK

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Abstract

Platinum (Pt) and Palladium (Pd) concentrations have been analysed in 194 samples from within the city of Sheffield in the UK. The samples were taken from road dust, gully pots (also known as drains), soils, a motorway drainage pipe, rivers, lakes, sewage sludge, incinerator ash, incinerator ash in landfill, street cleansers and gully cleansers. The introduction of Pt- and Pd-bearing automobile catalysts, has been cited as the cause of a rise in the concentration of urban Pt and Pd accumulations. Geochemical analyses for the different sample types are used here to show how the Pt and Pd accumulate in different urban environments as they are transported from their catalytic source.

Initially Pt and Pd collect in road dust and gully pots at values of up to 450 ppb although most analyses for both elements are around 100 ppb. The four roadside soils analysed, have a great range in values, the highest with a value of over 600 ppb Pt and 1000 ppb Pd. Then the fate of the Pt and Pd is either to be removed by gully flushers and road sweepers (which contain around half the concentration of that in road dust) or to be washed from the roads, through the gully pots, into either the river or urban drainage systems. Due to the addition of terrestrial sediments, river samples contain much reduced values of Pt and Pd, at approximately an order of magnitude lower than in road dust. Similarly, sewage sludge contains Pt and Pd values which are lower than road dust. However, the Pt and Pd analyses are much higher in incinerated sewage (with many samples over 150 ppb for both metals), probably due to the loss of the mass of other material during the incineration process. Weathered incinerator ash in landfill has lower values of Pt and Pd than fresh ash from the incinerator.

Although the range in values of Pt and Pd is similar for road dust and gully pot sediments their modal values tell a different story. The mode for Pt is very similar for both road dust and gully pot sediments, at around 100 ppb, whereas there is a drop of 50 ppb in the mode for Pd in the gully pots (from 80 ppb to around 40 ppb). Given that gully pot sediment is derived from road dust, it is suggested that in gully pots, Pd is preferentially mobilized over Pt. Furthermore, a comparison of the modal values of Pt and Pd in river sediments suggests that this process continues into the natural drainage system of the city.

Keywords: Platinum; Palladium; Road dust; Gully pot; River; Incinerator

1. Introduction

There has been a rapid increase in the use of Pt and Pd in automobile catalysts in the last 20 years (Johnson Matthey Plc., 2006). This is generally considered to be the cause of a rise in Pt and Pd values in natural and

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artificial sediments in the urban environment during this period (Zereini and Alt, 1999, 2006). There are three major sources of Pt and Pd in the urban environment. Although automobile catalysts recently have become the most common source, using approximately 50% of annual mined Pt and Pd (Johnson Matthey Plc., 2006), it is also possible that Pt and Pd could be accumulated from medical (Fujimori et al., 2005; Lenz et al., 2005) and industrial effluents (Schwesig et al., 2006). Pt and Pd from implanted dental alloys is another possible source (Stüben and Kupper, 2006). Accumulations of Pt and Pd, that are the result of artificial introduction into the environment, may have environmental consequences; for example they could be of value for recycling or a risk to health.

Many researchers have undertaken studies of Pt and Pd concentrations in individual environmental media as reviewed by Zereini and Alt (2006). The following is a summary from the literature of Pt and Pd concentrations in different wastes and sediments from different cities that have been found to contain artificially introduced environmental Pt (Table 1) and Pd (Table 2). However only a few of these studies cover more than one sample type (Schafer et al., 1999; Odiyo et al., 2005) and the Pt and Pd in different sample types have been analysed in scattered locations in different sized cities from all over the world. The values collated for this review of the literature are used here for comparison with the Pt and Pd values presented in this paper from 11 sample types collected from one city, Sheffield.

1.1. Pt and Pd values in urban sediments and waste

The highest published values of Pt and Pd in road dust are 2252 ppb (Gomez et al., 2001) and 556 ppb (Hutchinson et al., 1999) respectively. Pt has been described in road dusts from many countries including: the UK (Farago et al., 1998; Hutchinson et al., 1999; Higney et al., 2002; Ward and Dudding, 2004; Parry and Jarvis, 2006) Germany (Schafer et al., 1999; Boch et al., 2002; Boch and Schuster, 2006), Australia (Whiteley and Murray, 2003), Spain (Gomez et al., 2001), Poland (Lesniewska et al., 2004a,b), Hawaii (Sutherland, 2003) and Ghana (Kylander et al., 2003). As with the airborne particulates, many studies have concluded that the highest Pt and Pd values in road dust are found in areas

Table 1
A summary of the mean and range of published Pt values in environmental samples

Material (references)	*N*	Min	Mean	Max
Car exhaust fumes (a) μg m^{-1}	6	N/A	0.00004	N/A
Hospital effluent (b) μg l^{-1}		0.1		145.0
Airborne particles (c) μg m^{-3}	368	0.0000006	0.0000060	0.0000570
Road dust (d) ppb	223	0.4	128.3	2252.0
Soil (e) ppb	277	0.0	20.3	330.0
Grass (f) ppb	5	1.2	5.1	1.7
Gully pot sediment (g) ppb	23	3.5	8.0	155.0
Sewage sludges (h) ppb	121	nd	63.3	266.0
Incineration ash (i) ppb	8	60.9	N/A	393.0
River water (j) μg l^{-1}	11	0.0102	4.620	34.60
River and lake sediments (k) ppb	33	1.0	24.1	103.8
Marine sediments (l) ppb	14	0.1	4.2	12.5

N: number of samples analysed. nd: below detection. N/A: information not available.
References:
(a) (Konig et al., 1992; Moldovan et al., 1999).
(b) (Kummerer and Helmers, 1997; Kummerer et al., 1999; Lenz et al., 2005).
(c) (Artelt et al., 1999; Bocca et al., 2006; Gomez et al., 2001; Helmers and Mergel, 1998; Kan and Tanner, 2005; Kanitsar et al., 2003; Limbeck, 2006; Rauch et al., 2005a, 2001; Schierl and Fruhmann, 1996; Zereini et al., 2006).
(d) (Boch and Schuster, 2006; Boch et al., 2002; Farago et al., 1998; Gomez et al., 2001; Higney et al., 2002; Hutchinson et al., 1999; Parry and Jarvis, 2006; Schafer et al., 1999; Sutherland, 2003; Ward and Dudding, 2004; Whiteley and Murray, 2003; Riga-Karandinos et al., 2006).
(e) (Ely et al., 2001; Hutchinson et al., 1999; Kylander et al., 2003; Riga-Karandinos et al., 2006; Schafer et al., 1999; Sutherland, 2003; Whiteley, 2005; Whiteley and Murray, 2003).
(f) (Ely et al., 2001; Lesniewska et al., 2004a).
(g) (Wei and Morrison, 1994).
(h) (Stüben and Kupper, 2006; Eriksson, 2001; Laschka and Nachtwey, 1997; Odiyo et al., 2005; Schwesig et al., 2006).
(i) (Fujimori et al., 2005; Schafer et al., 1999).
(j) (Moldovan et al., 2003; Odiyo et al., 2005).
(k) (De Vos et al., 2002; Rauch et al., 2005b; Schwesig et al., 2006; Whiteley and Murray, 2005).
(l) (Tuit et al., 2000).