British Geological Survey

NATURAL ENVIRONMENT RESEARCH COUNCIL

Spatial distribution of trace metals in urban soils and road dusts — an example from Manchester, UK

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Introduction

Urban soil quality is of concern under current UK contaminated land legislation in terms of potential impacts on human health, due to the legacy of industrial, mining and waste disposal activities and the fact that soils can act as a sink for potentially harmful substances (PHS) in the urban environment. As part of the the Geochemical Baseline Survey of the Environment (G-BASE) project of the British Geological Survey (BGS), 27 UK cities have been surveyed to establish baselines and assess the quality of urban soils. The G-BASE soil geochemical dataset for Manchester forms the basis of this project. Another medium that is a likely sink for PHS in urban environments is road dust sediment (RDS). RDS forms as an accumulation of particles on pavements and road surfaces, and has been shown to be both spatially and temporally highly variable in composition, as it is more susceptible to remobilisation and transport. RDS has been documented as carrying a high loading of contaminant species, including significant amounts of trace metals. Geochemical data from both soils and RDS, despite having different properties, are essential for environmental assessment in urban areas. Although studies of PHS in RDS and soils have been published, little is known about the spatial, geochemical and mineralogical linkages between these two media. The aim of this research is to define and establish these linkages, and produce novel mineralogical data on the PHS–particulate relationships within soils and RDS.

Study area

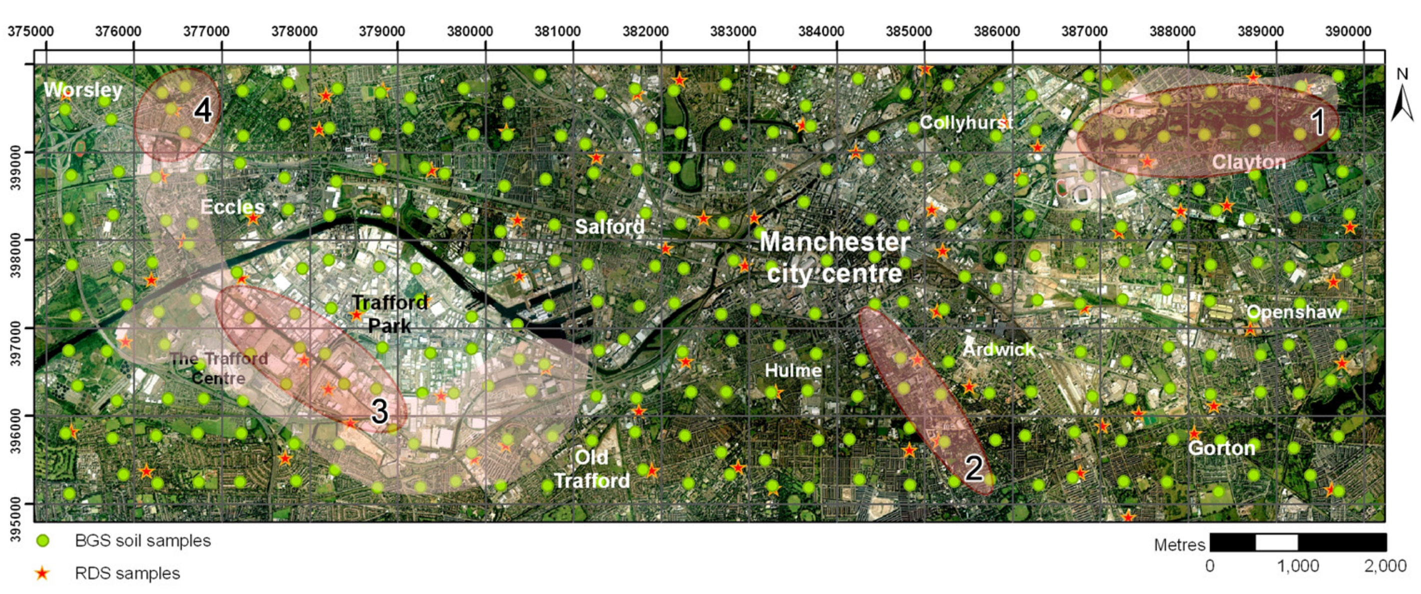


Figure 1 Map of the study area — Manchester, UK.

Methods

- Three hundred topsoil samples (5–20 cm) were collected previously by the G-BASE project covering 75 km^2 of Manchester city (4 per km^2), and analysed for major and trace elements by X-ray fluorescence spectrometry (XRF).
- RDS were collected in January and June 2010, to account for seasonal differences in geochemical composition. One hundred and forty-four samples were collected in total and analysed by XRF at BGS.
- After data levelling and conditioning, soil and RDS geochemical datasets were integrated using geographic information systems (GIS). Geochemical distributions were mapped using ESRI® ArcMap™ 9.3.1. both for soils and RDS, allowing for the recognition of spatial patterns.
- One hundred and fifty topsoils were subsampled from the BGS archives and, so far, 30 have been analysed under scanning electron microscopy (SEM-EDS) in polished grain mounts.

SEM

Analysis of topsoils by XRF gives the total concentration of an element in a given sample. However, it does not distinguish between elements which are evenly distributed throughout the soil matrix and those which are concentrated in individual grains. SEM-EDS allows for the identification and analysis of specific grains. This method reveals the composition of metal-bearing particles that can be used to establish and recognise metal assemblages. Figure 7 shows some examples of the SEM work that has been done on the Manchester soil samples — metal-bearing grain identification and source determination is currently a work in progress.

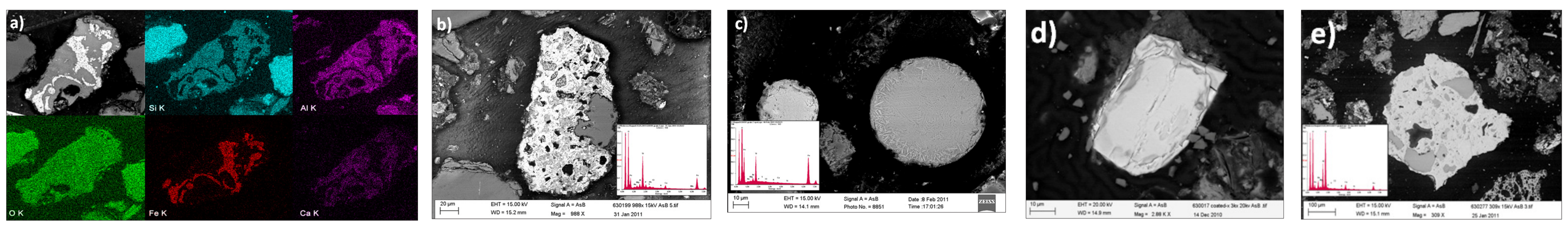


Figure 7 Examples of Manchester topsoil SEM images: a) Geochemical map of a topsoil grain showing Fe-rich zoning in a Si+Al+Ca matrix, b) Grain enriched in Fe+Pb+S, c) Fe-rich spherical glass grain, d) Zircon, e) Fe-Si grain.

Conclusion *(continued opposite)*

GIS-based interrogations of the soil and RDS geochemical datasets for the Manchester area show that maximum and average concentrations of PHS are generally higher in soils than in RDS — most significantly for Cr, Ba, Cu, As and Cd. The spatial distribution of trace elements in topsoil highlights four broad areas that show systematically high concentrations of As, Sb, Cd, Cr, Cu, Pb, Mo, Ni, and Zn at levels in excess of the regional 90th percentile. Both RDS and soils clearly show the influence of discrete sources. However, the more dense soil sampling scheme also allowed for the definition of zones that show generally higher trace element contents, providing grounds for more detailed and site-specific assessments in the future.

An important part of this project is to account for seasonal differences between RDS collected in winter and summer conditions. Once these data are available, seasonal patterns might be established and more on the RDS/soil relationship can be determined. Mineralogical and geochemical analysis by SEM-EDS will also play an essential role. This will produce novel data which are essential for a better understanding of the contaminant pathways between RDS and soils, their fate in the urban environment and how they may affect the ecosystem and human health.

The author (RC) would like to acknowledge the joint funding by BGS University Funding Initiative (BUFI) / Manchester Metropolitan University.

Results

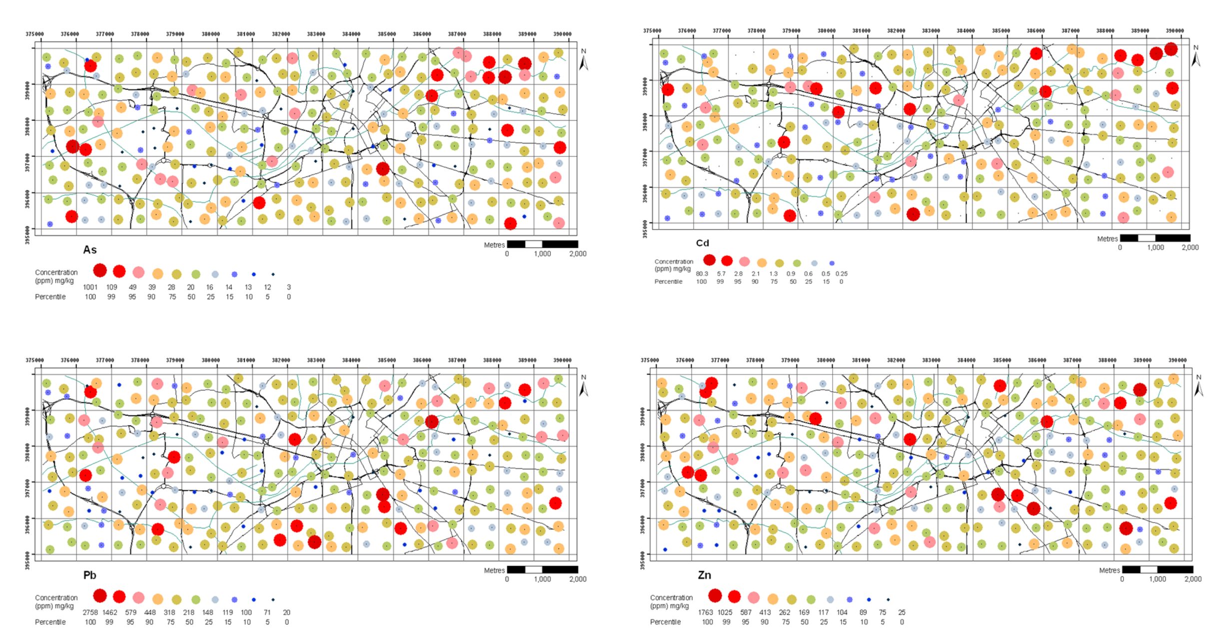
Mean and maximum trace element concentrations are generally higher in soils than RDS — more significantly for Cr, Ba, Cu and As, as well as for W, Cd and Sn. Averages for CaO, Na_2O, MgO and Br are significantly higher in RDS samples.

Elements such as MgO, Al_2O_3, SiO_2, K_2O and Fe_2O_3 are the most abundant both in soils and RDS. The spatial distributions show that samples with high Al_2O_3 contents tend to coincide with those with high metal contents — an indication that these might be associated with the fine fraction of the sediment/soil, mainly composed of aluminosilicates.

4.1 Trace elements — soils

Soil geochemical maps of Figures 2 to 5 show the spatial distribution of four selected trace elements. These indicate four areas (Fig. 1) where soils measure systematically higher concentrations of As, Sb, Ba, Cd, Cr, Co, Cu, Fe, Pb, Mo, Ni, Sn, V and Zn:

- the Clayton/Miles Platting area, especially around Medlock River/Phillips Park, in the north-eastern part of the study area
- the Oxford Road/Wilmslow Road alignment
- the Trafford Park industrial area, namely in the alignment of the Bridgewater Canal
- the residential area south of Worsley golf course, in the north-western part of the study area.



Figures 2–5 Graduated G-BASE symbol/colour maps of As, Pb, Cd and Zn concentrations in topsoils of central Manchester.

4.2 Trace elements — RDS

RDS elemental concentrations were mapped similarly to G-BASE soil data, using graduated symbol-colour maps. Figure 6 shows 33 locations where elemental concentrations are systematically above the 90th percentile for As, Sb, Ba, Cd, Cr, Co, Cu, Fe, Pb, Mo, Ni, Sn, V and Zn.

It is noticeable that RDS samples collected near heavy-traffic roads have the highest trace element contents, such as those collected in Trafford Park. However, samples that show highest concentrations in trace metals are not always from obvious locations, for example Parkfield St, Sunny Brow Rd and Ashton New Road that have rather low traffic. This indicates that discrete point sources might account for an important load of contaminants to RDS at these locations — these sources, along with the spatial linkages between RDS and soils, have yet to be determined.

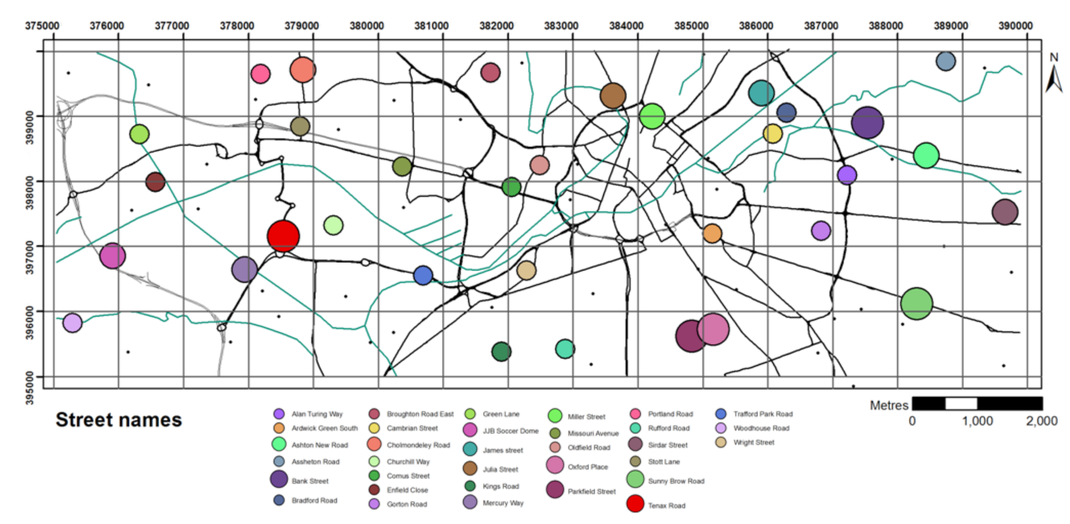


Figure 6 Map showing RDS locations with trace metal concentrations above the 90th percentile.

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