The Fate of Contaminants in Urban Soils and Sediments: Novel Assessments and Implications for Risks

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To my beloved parents and brother, 
for your love, endless support and dedication, 
and without whom none of this would be possible.

“Temos, todos que vivemos, 
Uma vida que é vivida
E outra vida que é pensada,
E a única vida que temos
É essa que é dividida
Entre a verdadeira e a errada.
Qual porém é verdadeira
E qual errada, ninguém
Nos saberá explicar;
E vivemos de maneira
Que a vida que a gente tem
É a que tem que pensar.”

Fernando Pessoa, Portuguese author (1888 - 1935).

“In rivers, the water that you touch is the last of what has passed and the first of that which comes; so with present time.”

Abstract

Soils and road-deposited sediments (RDS) are ubiquitously present in the urban environment and may act as sinks or sources for potentially harmful elements (PHE), namely trace metals, with possible deleterious human health effects. Their proximity to human populations in urban centres evokes the need to fully characterise the occurrence of PHE and their dynamics within and between these media.

This research has provided a detailed characterization of Manchester’s soils and RDS in terms of geochemistry, mineralogy and spatial variability by using the quantification and statistical comparison of the presence of PHE in soils and RDS; and by exploring their spatial, geochemical and mineralogical linkages.

Soil and RDS geochemical analysis shows that maximum PHE concentrations are often well above the dataset median values and established guidelines, indicating that contamination is present at many locations especially for Cr (max. soil 1238, RDS 544 mg/kg), Ni (max. soil 148, RDS 82.4 mg/kg), Cu (max. soil 2073, RDS 493 mg/kg), Zn (max. soil 1763, RDS 1325 mg/kg) and Pb (max. soil 2758, RDS 2027 mg/kg). RDS contamination is closely related to the proximity of present-day sources; whereas soil contamination derives mainly from historical sources and the accumulation of trace metals over long periods of time. SEM-EDS analysis of soil and RDS grains reveal the presence of natural and anthropogenic-related grains in different proportions, and the detailed characterization of PHE-bearing grains shows that these, by their morphology of size, are likely to impact human and ecosystem health. In RDS, grain size and speciation analyses provided a further insight on the availability and summer/winter variations of PHE in this media - whereas total extractable concentrations are higher in winter RDS, also due to their generally small grain size, exchangeable and reducible concentrations are higher in summer, when coarse fractions are predominant. Multivariate and spatial statistical analyses reveal that element associations in soils and RDS are diverse and attributed to a plethora of sources (e.g. industry; vehicle-related sources such as automotive electronics, the wear and tear of tyres and car parts, and car servicing and repair businesses; wastewater treatment plants; historical industry and coal-related sources) through the mapping of component scores and the modelling of PHE concentrations by OLS and GWR. These techniques evidence the differences and similarities between element groupings for soils and RDS and are a powerful tool to aid source apportionment.

This research has contributed to a better understanding of the complex controls on PHE dynamics in urban systems, adding vital information to the assessment of risks posed by PHE exposure on human health.