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Spatial variation of urban soil geochemistry in a roadside sports ground in Galway, Ireland

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ABSTRACT

Characterization of spatial variation of urban soil geochemistry especially heavy metal pollution is essential for a better understanding of pollution sources and potential risks. A total of 294 surface soil samples were collected from a roadside sports ground in Galway, Ireland, and were analysed by ICP-OES for 23 chemical elements (Al, Ca, Ce, Co, Cu, Fe, K, La, Li, Mg, Mn, Na, Ni, P, Pb, S, Sc, Sr, Th, Ti, V, Y and Zn). Strong variations in soil geochemistry were observed and most elements, with the exception of Cu, Pb, P, S and Zn, showed multi-modal features, indicating the existence of mixed populations which proved difficult to separate. To evaluate the pollution level of the study area, the pollution index (PI) values were calculated based on a comparison with the Dutch target and intervention values. None of the concentrations of metal pollutants exceeded their intervention values, indicating the absence of serious contaminated soil, and the ratios to target values were therefore employed to produce the hazard maps. The spatial distribution and hazard maps for Cu, Pb and Zn indicated relatively high levels of pollution along the southern roadside extending almost 30 m into the sports ground, revealing the strong influence of pollution from local traffic. However, heavy metal pollution was alleviated along the eastern roadside of the study area by the presence of a belt of shrubs. Therefore, in order to prevent further contamination from traffic emissions, the planting of hedging or erection of low walls should be considered as shields against traffic pollution for roadside parks. The results in this study are useful for management practices in sports and parks in urban areas.

1. Introduction

Urban soil geochemistry is receiving increasing attention due to the potential long-term toxicity of some heavy metal pollutants (Alloway, 1995; Nyarko et al., 2006; Ajmone-Marsan et al., 2008). Soil pollution by heavy metals, such as Pb, Cu and Cd, is of concern worldwide (Adriano, 2001; Kabata-Pendias and Mukherjee, 2007). Elevated concentrations of some metals in soils pose a threat to public health by leaching into groundwater, entering the food chain through plant uptake, or direct human consumption via wind blown dust or the hand-to-mouth pathway (Ajmone-Marsan et al., 2008; Carr et al., 2008; Morton-Bermea et al., 2009). The toxicological risks of direct ingestion and inhalation of soil particles are especially high for children who are physiologically more vulnerable (Calabrese et al., 1991; Ajmone-Marsan et al., 2008). The U.S. EPA estimated an average of 200 mg day^{-1} of soil is ingested by children between 1 and 6 years of age (U.S. EPA, 2002), while Ljung et al. (2006) reported a value of 100 mg day^{-1} for soil ingestion via the hand-to-mouth activities for children also between 1 and 6 years old.

Furthermore, increasing attention has been paid to the potential risks associated with heavy metal pollution in urban soils by government and regulatory bodies (Morton-Bermea et al., 2009). In September 2006, the European Commission (EC) adopted a Soil Thematic Strategy (EC, 2006a) and a proposal for a Soil Framework Directive (EC, 2006b) with the objective of protecting soils across the European Union (EU). In recent years, national policies or soil remediation guidelines for the management of contaminated lands have been produced by a number of countries, such as China (NSPRC, 1995), the Netherlands (VROM, 2000), and the USA (U.S. EPA, 2001).

It is widely recognized that vehicular traffic is a significant source of heavy metal pollution in urban soils (EEA, 1995; Oliva and Espinosa, 2007). Some heavy metals are present in the anti-wear substances added to lubricants, brake pads and tyres, and are emitted to the environment by traffic (Caselles et al., 2002). These heavy metals are usually dispersed in relatively higher concentrations in the vicinity of a road with a gradual decrease with increasing distance from the source and have a significant impact on the environment (Sezgin et al., 2004). In this case, the location of the sports ground is on the side of two roads in the city of Galway, Ireland.

There are many roadside sports ground in Ireland and elsewhere globally. Few studies have been performed concerning metal pollution in these areas. The aim of this study was to investigate the spatial

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variation of urban geochemistry with a focus on heavy metal contamination in soils of a typical roadside sports ground in Galway, Ireland. The pathway between pollutants and receptors is very short, and there aren't any shelters against the traffic pollution on the southern side. Therefore, the authors speculated the study area might be contaminated. The objectives included investigation of the current status of heavy metal pollution; identification of spatial patterns of pollution and possible pollution sources; and production of hazard maps. Finally, it was hoped that this study could provide scientific evidence for decision-making regarding roadside sports ground management.

2. Methods

2.1. Study area

Galway is an urban centre located along the west coast of Ireland with a population of approximately 80,000. It is a small but rapidly growing tourism city with little heavy industry and few pollution sources. The main pollution sources in the city include traffic and burning of peat and coal for home heating (Zhang, 2006). The bedrock geology of Galway comprises metamorphic, igneous and sedimentary rocks which are covered by a relatively thin layer of recent (<1 million years old) glacial sand and gravel deposits (Coats and Wilson, 1971). In Galway City, the region to the west is comprised of Galway Granite, while the east of the city is carboniferous limestone, and in between the bedrock geology of the inner city is amphibolite and granite gneiss. Naturally, limestone has fairly low concentrations of heavy metals (Zhang, 2006). Based on the simplified geology map of Galway, it was found the sports ground is mainly overlying granite and a little on the metamorphic.

The study site is the Laurel Park Sports Ground, located in the northwest of the city centre, which is surrounded by residential areas and two schools. It is located along a T-junction of a national road and a local road with busy traffic. The sampling site extended 200 m in the E–W direction and 190 m in the N–S direction with an area of about 30,000 m^2. There is a soccer pitch in the west and a rugby football pitch in the east side. The elevation of the east part is about 1 m lower than the west. There is a shrub belt of about 15 m wide along the east edge of the study area, and there are trees along the south edge (see Fig. 1).

2.2. Sampling and chemical analyses

An intensive investigation for soils of this sports ground was conducted during May and June, 2008, and a total of 294 soil samples were collected on a grid system at an interval of 10 m (Fig. 1) using a stainless steel auger of 10 mm in diameter. Each sample is a composite sample, consisting of 70–120 soil cores taken from a 1 × 1 m area. The approximate mass of each primary sample was 500 g, collected from a depth of 0–10 cm. Numerous studies have documented the surface layer in the immediate vicinity of the roadway as the main receptor of emissions from the road, especially metal pollutants (Pagotto et al., 2001). In addition, pollutant concentration decreased rapidly with distance from the road and also with depth. In the present work surface soils were studied because metal contamination of soils in urban areas primarily occurs at the soil surface (De Miguel et al., 1998). Therefore the 0–10 cm depth of surface soil is the most obvious fingerprint of environmental contamination.

Soil samples were placed in clear polythene bags and sent to the laboratory for drying at 40 °C. The samples were rolled manually with a steel roller and then sieved through a mechanically vibrating 2-mm stainless steel mesh to remove stones and plant debris, and mixed thoroughly to obtain a representative sample. Half of each sample was then ground to pass through a 0.1 mm pore size sieve. To avoid cross-

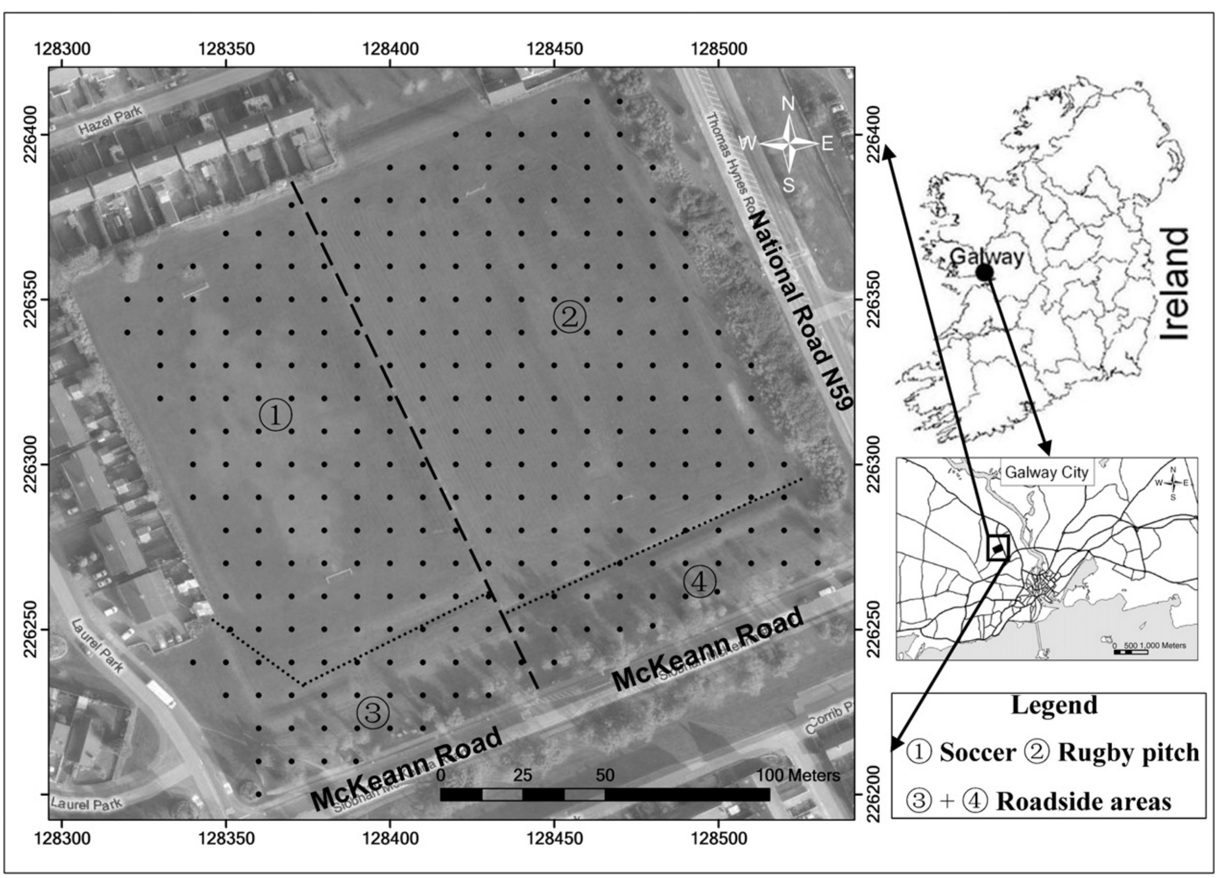

Fig. 1. Soil sampling locations in Newcastle Sports Ground, Galway (on the background image from Microsoft Virtual Earth).