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Geochemistry of urban surface soils — Monitoring in Trondheim, Norway

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ABSTRACT

The objective of this study was to assess the spatial extent of heavy metal pollution in the urban part of Trondheim City and to assess the temporal variation over a period of ten years (1994–2004) by making comparisons to a previous survey. 321 surface soil samples were analysed, whereof eight of the analysed elements; arsenic (As), cadmium (Cd), chromium (Cr), copper (Cu), mercury (Hg), nickel (Ni), lead (Pb) and zinc (Zn) are presented in this study. Statistical tests show that all elements, except lead, have decreased in concentration statistically significantly over ten years. Three important pollution sources have been closed down at the end of the 1990s, the hospital waste incinerator, one of the crematories and a metal smelter. No correlation between element concentration and organic matter could be found. A principal component analysis (PCA) performed on the results also indicates that Cd, Zn, Pb and Hg correlate with anthropogenic input.

1. Introduction

Urban soil environments are subjected to pollution through several pathways; through local spills and waste deposits and atmospheric deposition from industry, traffic, and domestic heating. In city environments soil pollution is often also spread through excavation and relocation of urban soil. Urban soils can directly influence public health, especially that of children, through suspended dust or direct ingestion of the soil (Mielke et al., 1999; Mielke et al., 2005; Mielke et al., 2007; Miranda et al., 2007).

It is only during the last two decades that is has been recognised that urban soil differs in reactions and processes from natural soil and consequently more urban soil studies have been conducted (Madrid et al., 2002; Manta et al., 2002; Lu et al., 2003; Banat et al., 2005; Norra et al., 2006; Salonen and Korkka-Niemi, 2007). Some of these studies have also been taking health aspects into consideration (Mielke et al., 1999; Aelion et al., 2009). The urban soil studies should in a greater extent contribute to city planners and developers creating appropriate land use (Poggio et al., 2008; Vrščaj et al., 2008). Differences in analytical and sampling methods, however, make it difficult to make any direct comparisons between these studies. A few studies have also been conducted by resampling locations studied in an earlier survey (Pichtel et al., 1997; Meneses et al., 1999; Imperato et al., 2003), but no quality control measures of earlier samples or level adjustments were made in these studies. This study has attempted, through rigorous quality control measures and level adjustments, to assess and understand metal level variations in urban surface soil that has taken place over a decade.

The city of Trondheim lies in central Norway, where the climate is typically cool and humid. Trondheim was founded in 997, and during the first 900 years of its history the urban area was concentrated in the present city centre (Midtbyen, Ilsvika and Fagervika in Fig. 1). During the 20th century, the urban area increased markedly and today the densely populated area covers 70 km^2. The city now has now grown to a city of 160,000 inhabitants.

Metamorphosed volcanic and sedimentary rock sequences of mainly early Ordovician to Early Silurian age constitute a significant part of the allochthon in the Caledonides of central Norway (Wolff, 1979). The Støren Nappe of the Upper Allochthon dominates in the Trondheim region (Gale and Roberts, 1974; Roberts and Gee, 1985). The main rocks in and around the city are tholeiitic basalt with subordinate cherts and hemi-pelagic sediments and also bodies and dykes of trondhjemite, all metamorphosed at greenschist facies. These form part of the Bymarka ophiolite (Slagsstad, 1998).

Most of the city is situated on marine clay, deposited about 10,000 years ago as the sea-level rose during deglaciation. Later, isostatic forces caused a relative sea-level decrease leaving the marine clay onshore. Along the Nidelva river, which runs through the city centre, the city rests on fluvial sediments (Reite, 1983; Reite et al., 1999). In the city centre, the overburden has been used and recycled many times during historical times. The fluvial sediments are mostly covered by a layer of anthropogenic soil, which has an average thickness of 2 m (Ottesen et al., 2000a). Urban soils are unique as they have been highly modified by mankind and contain building materials (bricks, paint, concrete, and metal), waste, ash, slag, transported soils,

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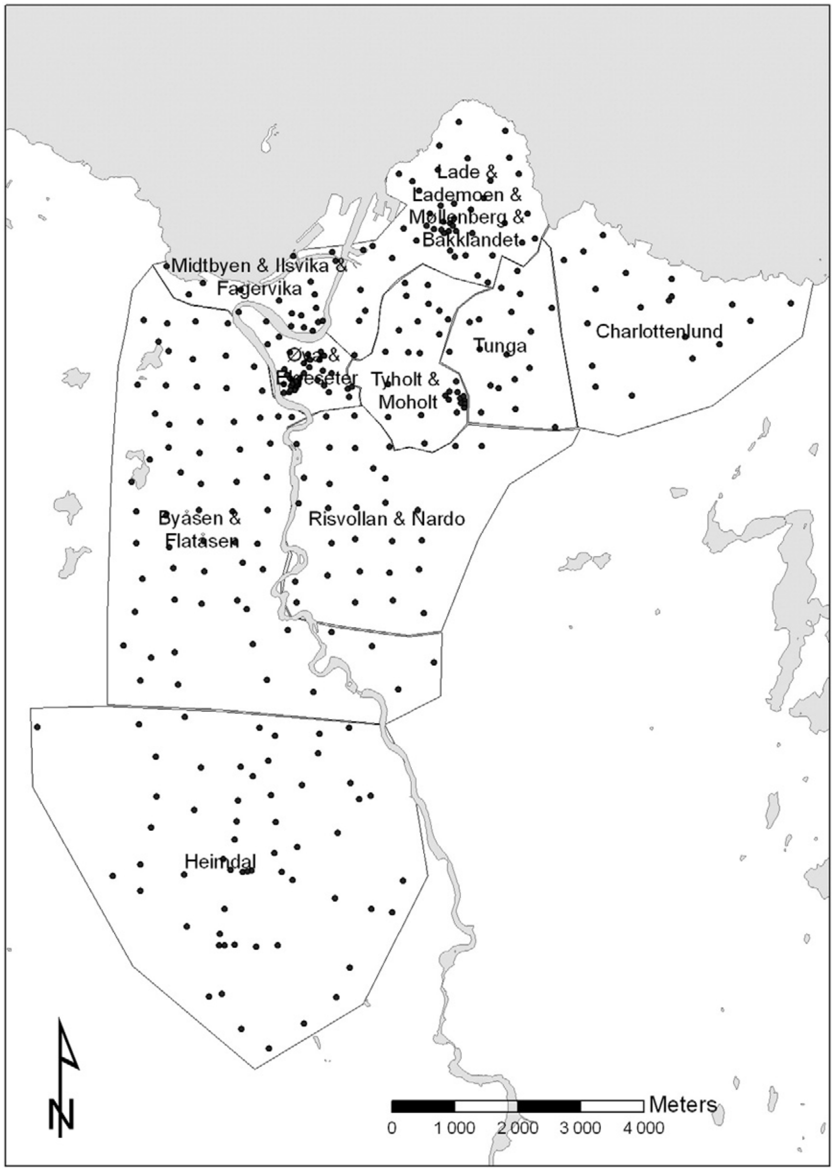

Fig. 1. Sample locations from 2004 and important stationary pollution sources.

organic materials and local original mineral matter (Ottesen and Langedal, 2001; Wong et al., 2006).

The city of Trondheim undertook a soil geochemistry baseline mapping survey in 1994 (Ottesen et al., 1995) that was conducted with several aims in mind: i) to assess the influence of diffuse and point sources, ii) to serve as a baseline survey in subsequent soil monitoring programs and iii) to provide a database for environmental health risk evaluation. The survey triggered several studies and resulted in actions by the city and on a national level, such as investigating and remediating soil pollution in kindergartens and day care centres (Karlsaunet, 1994; Duun-Moen, 1996; Hermansen, 1996; Tijhuis, 1996; Berntzen, 1997; Fossan, 1997; Langedal, 1997; Langedal and Hellesnes, 1997; Ottesen et al., 2000a), geochemical surveys of the probable excavation material and natural background levels (Ottesen et al., 2000b) and local guideline concentrations related to land use categories and health risks (Langedal, 2007). Another outcome of soil surveys in Trondheim is that boundaries for an urban soil area were created. Within this area, the chemical status of the soil must be documented before it is excavated, in the same manner as for locations with former possibly polluting activities.

The city council consequently decided that surface soil monitoring should be repeated every ten years. Our study presents data from the first resampling. Only results for seven metals and arsenic are presented in this paper, results for dioxins and furans are presented in another paper (Andersson and Ottesen, 2008). We attempt to document the temporal variations in pollution levels and provide an explanation for their distribution.

2. Methods and material studied

2.1. Sampling

The data sets from both 2004 and 1994 were collected from surface soil (0–2 cm). Where the sampling was done in grasslands or lawns, the grass was removed and the soil directly under the roots was extracted. All samples were taken as closely as possible to the sample locations in 1994, when the sampling points had been chosen to represent undisturbed soil with easy site accessibility. In the southern part of the study area, some gaps in the sample distribution were filled in 2004. All sample locations from 2004 are shown in Fig. 1. Locations where the topsoil cover was new or locations with agricultural soil