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Chapter 1 INTRODUCTION

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People are drawn to living together in communities and, although cities began to appear 10,000 years ago, it is only in the last 3,000 years that they have become relatively numerous and inhabited by a large numbers of people (Macionis and Parrillo, 2009). Towards the end of the first decade of the twenty-first century more than half of the world's population is living in urban areas – this is predicted to rise to 60 percent by 2030 (Figure 1, UN, 2006). In some parts of the world, where cities have been established for a long time, *e.g.*, in Western Europe, the percentage of the population living in urban areas is even higher at >70% (Population Reference Bureau, 2007). **Why then, for a species that shows a preference for natural sceneries (Ulrich, 1981), are we so keen to live in artificially built environments?** The answer is that cities offer us security and the chance of a better standard and quality of life, though the latter fact may be hard to believe in many of the deprived, crime-ridden inner-city slums of the world.

<<<INSERT FIGURE 1 NEAR HERE >>>

Our very existence causes us to modify the surrounding environment, whether by the tiny amounts of waste discarded by primitive societies or the huge landfill sites for rubbish disposal associated with modern cities. Demand for food, energy, water and land alters the natural environment, inevitably making significant changes to its physical and chemical equilibrium. Changes that, when compared with natural transformations (with the exception of catastrophic events, such as earthquakes), have happened over a very short span of time. **Today, it is the sheer scale and rapidity of the modifications to the natural environment that give cause for concern.** The manifestations of physical hazards in the urban environment (such as subsidence, flooding or earthquakes) are readily observable and understood by the general public. However, the consequences of living with potentially hazardous elements (PHE), or harmful chemical compounds, in our surroundings are not so easy to see or comprehend because they take a longer time span to manifest themselves. Yet, the results of having harmful elements and compounds in our living environment is just as detrimental - probably more so. Excessive exposure to chemical elements and organic compounds (*e.g.*, Pb, Hg and dioxins) at an early age is likely to leave an individual with a lifetime of disability. Physical damage to buildings can be repaired and property replaced, but remedying the effects of toxic chemical elements on living organisms is not easily achieved. We should, therefore, not be surprised that political action tends to be more forthcoming, as a result of physical damage to property, but is less evident in response to the "silent" hazards of living with the less obvious hazards of contamination.

One does not need to be a chemist to understand that what we do to meet the essentials of modern day living will change the chemical balance of our environment. We make, for example, fundamental changes to the landscape, redistributing huge volumes of natural superficial material that would otherwise have been in a state of natural equilibrium for hundreds and thousands of years. According to Mii (2009) each American uses during the course of a lifetime 1.5 million kg of raw materials. This amount of material has to "end" somewhere. Consider also the global market for food. Food crops will extract water and their nutrients (and other chemical elements) from soil in which they are grown. The water and these chemical elements will ultimately end up being discharged in the country of consumption, often 1000s of kilometres from their source of origin. Our food supermarkets play thus an unexpected but important part in the global redistribution of chemical elements in the environment. In view of the amount of food and resources (acquired from all over the globe) that are used by an urbanised individual over the course of a lifetime, which, when discarded as waste, will most likely end near the point of use or consumption, it should be no surprise that we are significantly changing the chemical balance of our planet, most obviously in the urban areas.

Much of the legacy for some of our contaminated urban areas goes back thousands of years. For example, in the ancient settlements of Lavrion, Thorikon, Pefka, and Agrileza (*ca*. 6^{th}-5^{th} BC), which are situated in the Lavreotiki peninsula to the south-east of Athens, Hellas, soil became contaminated by lead (Pb) as far back as 3,500 BC from the mining and smelting activities of argentiferous or silver bearing lead ore (Conophagos, 1980; Demetriades *et al.*, 1996; see also Chapter 25 in this volume). Many old mining areas bear a legacy of heavily contaminated soils in their immediate surroundings.

However, **it was the industrial revolution of the 18^{th} and 19^{th} centuries, and the continued industrialisation into the 20^{th} century that not only transformed**

socioeconomic and cultural conditions, but had also the most severe detrimental effects on our environment. Life during the industrial revolution is described in literature from the period, for example, Charles Dickens' assessment of the ills of industrialisation in England. He describes the effect it had on the people in the fictional Coketown in his 1854 novel "Hard Times". He wrote "*It was a town of unnatural red brick, or of brick that would have been red if the smoke and ashes had allowed it; but as matters stood, it was a town of unnatural red and black like the painted face of a savage. It was a town of machinery and tall chimneys, out of which interminable serpents of smoke trailed themselves for ever and ever, and never got uncoiled*". Paintings from the period also graphically illustrate the impact of the industrial revolution on the environment (Photograph 1). Philippe Jacques de Loutherbourg's painting, the image used for the cover of this book, presents the scene of the Bedlam foundry in Coalbrookdale, the heart of the industrial revolution in England, as a vision of hell. Bedlam was initially the name associated with an infamous hospital in London to which mental patients were consigned to live out their lives in the most miserable conditions.

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Developments in agriculture, manufacturing and transportation started in Europe and spread throughout the rest of the world. It is, therefore, no coincidence that an awareness of the **legacy of industrial contamination of our cities has first grown throughout Europe, and it is probably for this reason the majority of the earliest environmental studies of cities were carried out in Europe** (e.g., see Thornton, 1991 and references therein). This is also reflected in the balance of case studies in this book with the majority coming from Europe. However, in recent years, awareness about the contamination issues related to urbanisation has spread around the globe and some international examples are included as well.

Another reason for the dominance of European case-studies in this volume is the fact **that this book is a project initiated by the EuroGeoSurveys[1] Geochemistry Expert Group**. This group consists of many scientists with the knowledge and experience of mapping chemical elements at the earth's surface. As evidenced by this volume, the urban environment found their particular interest. It is the discipline of applied geochemistry that is important in the regional study of element distributions across urban areas. As many of the

[1] http://www.eurogeosurveys.org/

chapters of this book show, underlying geology has a fundamental control in the distribution of elements in the urban environment and must be considered for identifying contamination.

In urban areas, contamination of the atmosphere via industrial and residential chimneys, vehicular exhaust and wind blown dust derived from soil and sediment, was probably the first clearly visible sign of the detrimental effects of modern life. In Europe legislation has had a significant effect on improving the quality of the air in our cities, though automobile exhausts and dust emissions related to traffic continue to be a problem in many congested cities of the world. An early focus on the atmosphere and air quality has led many researchers to focus during the last 30 years their attention on atmospheric transport of contaminants. We are all aware of desert storms, *e.g.*, in the Sahara, transporting vast amounts of dust over long distances in the atmosphere. It is thus not surprising, that small amounts of contaminants can be found even in remote sites around the globe. However, serious contamination of the environment is closely related to scale (Reimann *et al*., 2009, 2010). It is the cities, the immediate surroundings where our children grow up and play, that really matter in a global human health perspective. The studies in this book show that even in most cities local variation is very large and that contamination is usually concentrated in rather small areas within a city (a noteworthy exception may be cases like Lavrion, where thousands of years or mining and smelting have contaminated a more sizable area - see Chapter 25). It is thus a problem where something can and must be done locally.

The main receptor, the depository of contamination over a long period of time, however, is the soil, especially in urban areas. It is generally the main receptor for much of the urban contamination, from both diffuse and point sources. Throughout the development of humanity we have tended to dispose our waste in holes in the ground (*i.e*. soil) or in rivers, which puts it out of immediate sight and further thought. However, our lives depend on the soil, it is needed for much of our food production. The importance of healthy and clean soil for the further development of humanity cannot be overemphasised. In urban environments soils are not primarily used for food production though many houses will have gardens and the new populous cities of emerging continents like Africa rely on produce grown from urban plots of land (see Chapter 31). However, we are all in contact with the soils in our every day life. Much of the dust in the urban atmosphere is wind-blown soil. Our children play on and in the soil and many even eat it (Photograph 2). At each building site vast amounts of soil are excavated and moved around in the cities. **It is thus the soil and surface overburden of urban areas that is the principal environmental compartment studied in this volume.**

The ubiquitous nature of soil makes it an ideal sample material for studies of the chemical environment of urban areas. In addition, soil profiles can be used to study the development of the soil (and of contamination) over time, they allow us to look back at the past.

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Whilst most chapters in this volume have been written by contributors, who would call themselves applied geochemists, **the work in surveying and interpreting the chemical urban environment is very much a multi-disciplinary effort**. Mapping the chemical environment touches the boundaries of many scientific disciplines. The interpretation and communication of the results of urban geochemical mapping requires cooperation with many others, including city/municipal authorities (especially Environmental Health Departments), medical workers, and social scientists and economists, who can communicate the findings of the investigations to urban residents and calculate the economic benefit and impact of these studies. The reduction of Pb in the urban environment through the banning of Pb-additives to automobile fuel is one example of the success of the multi-disciplinary approach to tackling problems of the urban chemical environment. Such collaborative work between different branches of science has been greatly assisted by scientific groups that actively encourage this multi-disciplinary approach, *e.g.*, the Society for Environmental Geochemistry and Health (SEGH)[2], and the International Medical Geology Association (IMGA)[3]

Much of the remedial effort in urban areas is focused on those most vulnerable to the toxic effects of the urban environment – our children (Photograph 2). The results obtained from mapping the distribution of chemical elements in urban areas are not always what people really want to hear. Politicians and administrators often fear possible detrimental effects on property prices (although experience has shown that this is usually not the case). **Urban geochemical mapping is thus work that requires good communication and an interaction with politicians** at an early stage. The local politicians will, more often than not, have to resort to legislation to protect the health of the urban population. Discussing local

[2] http://www.segh.net/

[3] http://www.medicalgeology.org/

contamination is never as easy as blaming “long range atmospheric transport”, the results will always have an immediate effect on the local population.

The Chapters in this book demonstrate that there exist very different approaches to urban geochemical mapping (see the next Chapter). The scale of the surveys is surprisingly different, some authors focus on the inner cores of the cities (or the kindergardens and playgrounds), others include the surroundings of a city to get a better impression of the natural background and the scale of the human impact. The sample materials vary a lot, some authors used not only soil but attic dust or vegetation as “their” sample material. When collecting soils, the sample depth used for urban mapping varies substantially. The sample density is often quite different. The grain size fraction of the soil samples analysed may be different for a variety of reasons (soil scientists use traditionally the <2 mm fraction, geochemists often finer grain size fractions). The analytical parameters determined are different though the “classical” contaminants in the urban environment As, Cd, Co, Cr, Cu, Mo, Ni, Pb, Sb, V and Zn are probably part of the analytical spectrum of most surveys. A number of researchers have focussed on organic pollutants like PAHs and PCBs. The differences continue in the way how the results are statically analysed, mapped and presented. To provide a good selection of these differences in approach, and to allow the reader to judge their advantages and disadvantages to solving their own problems, was one of the aims when setting out to collect the Chapters of this book.

This book describes the methods presently used for identifying, describing and evaluating urban contamination and its sources. It provides the knowledge needed for informed political decisions regarding some of the major environmental challenges found in the town and cities of the world, right where the majority of the population of our Planet lives.

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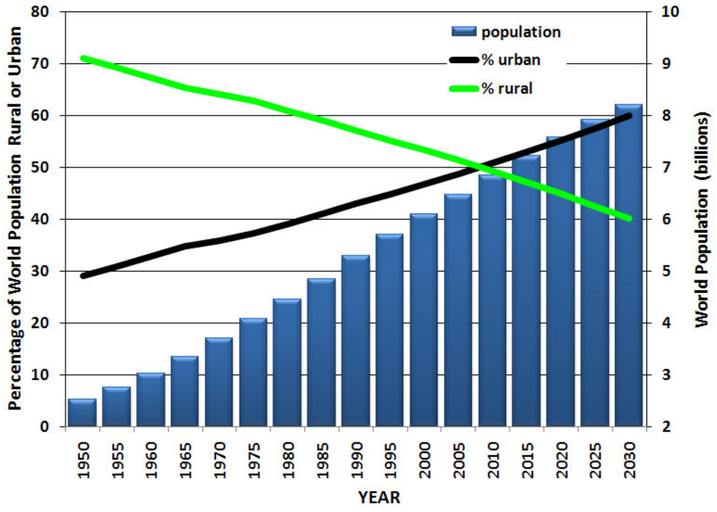

Figure 1: The urban and rural population of the world, 1950-2030 (after data from UN, 2006)

Coalbrookdale by Night 1801. Oil on canvas, 680 x 1067 mm. © Science Museum, London {Wiley have permission to use this – see Cover}

Photograph 1: Oil painting by Philippe Jacques de Loutherbourg (1740-1812) showing one of the Coalbrookdale ironworks [England], the Bedlam Furnaces along the river Severn, at night silhouetted against the fiery glow of a furnace being tapped. The development of coke smelting in this area of Shropshire by Abraham Darby and his family in the 18th century revolutionised the production of iron and helped fuel the Industrial Revolution. Its unique combination of natural resources also led it to produce Britain's first iron rails, iron bridge, iron boat and steam locomotive.

Source: Photograph provided by the Geological Survey of Norway

Photograph 2: It is our children that our most vulnerable to the health risks of a contaminated urban environment, particularly through hand-to-mouth ingestion of soil.