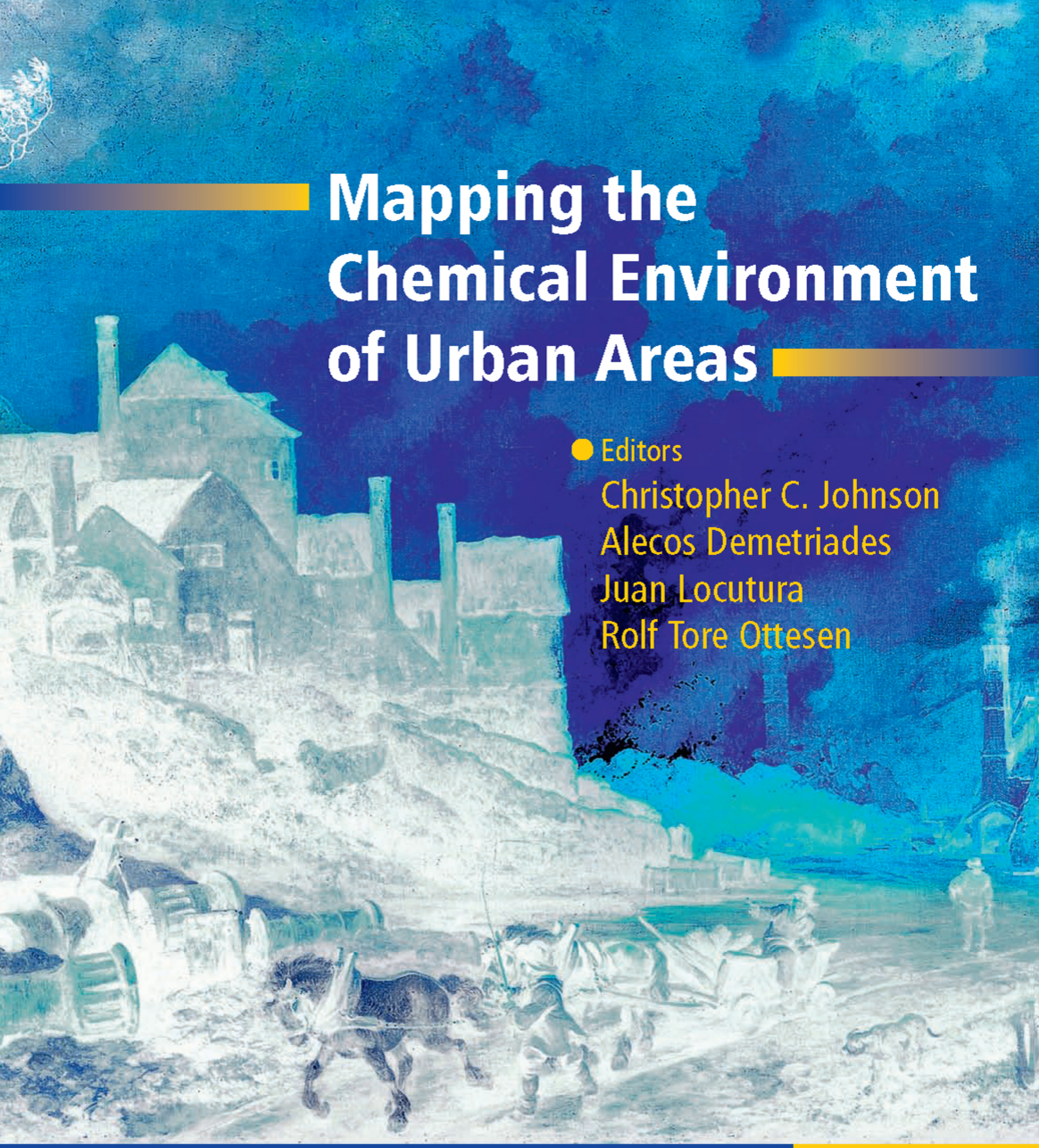

Mapping the Chemical Environment of Urban Areas

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EuroGeoSurveys
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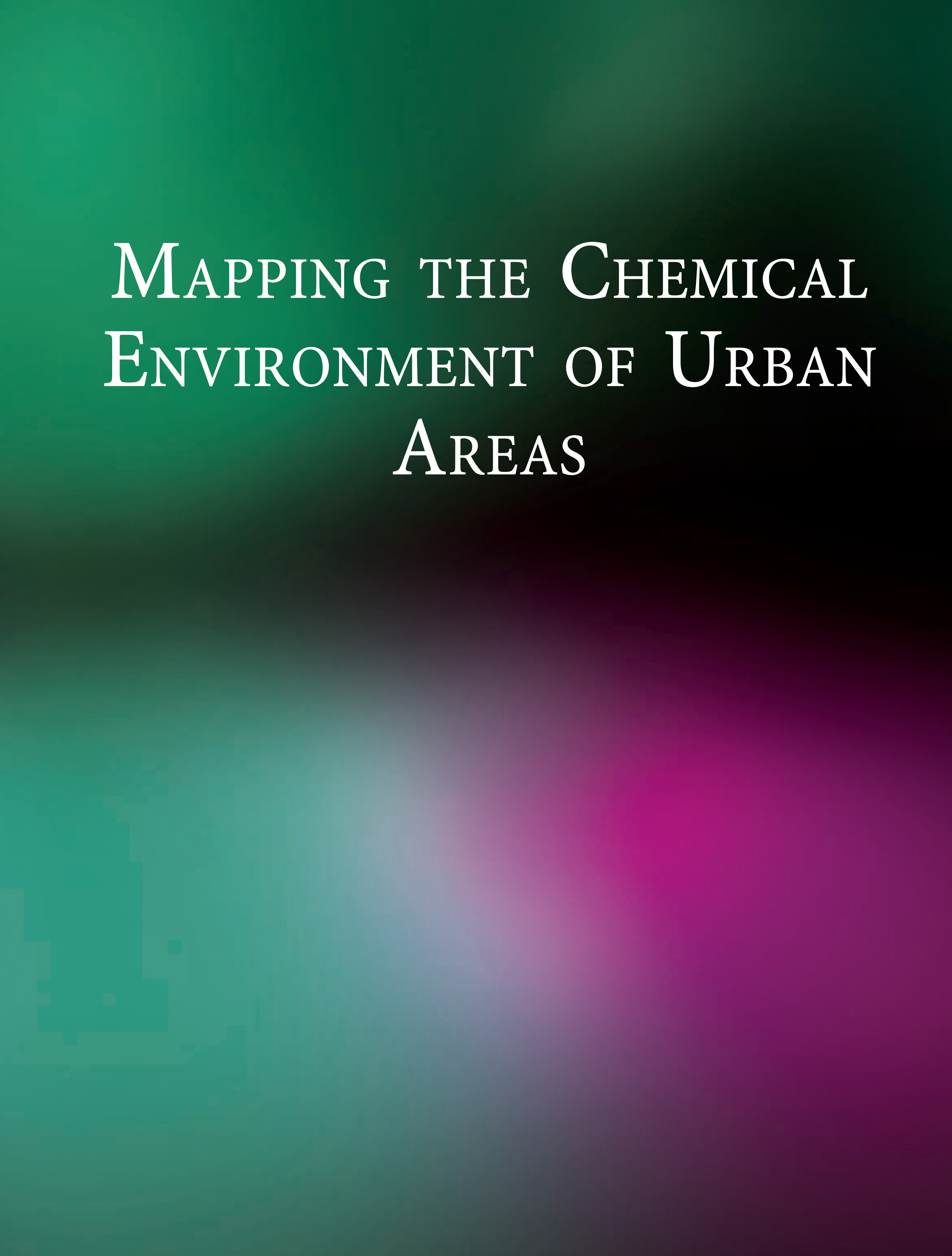

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Foreword

EuroGeoSurveys started 40 years ago as a network of national geological surveys of Europe. Today it is a nonprofit organization that represents 32 national institutions (including all EU states), making it the world's largest consortium of geological surveys, with a workforce of over 20 000. As such, it is in a position to provide the European Commission with answers to the ever-growing specific requests for high-quality geoscientific information in the public interest.

EuroGeoSurveys can lay claim to several success stories; it is especially proud of its reputation as a reference point for the European Union on such topics as natural resources (water, soil, minerals), geoscientific data, land management and environmental protection, and natural risks.

EuroGeoSurveys aims at providing the European institutions with expert, neutral, balanced and practical pan-European advice and information as an aid to problem solving, policy, regulatory and programme formulation in areas such as:

- the use and the management of on- and off-shore natural resources related to the subsurface of the Earth, (energy – including the renewable geothermal energy – minerals, water, soil, underground space and land);
- the identification of natural hazards of geological origin, their monitoring and the mitigation of their impacts (depletion or excess of trace elements in soil and water, earthquakes, natural emissions of hazardous gases, landslides and rockfalls, land heave and subsidence, shrinking and swelling clays);
- environmental management, waste management and disposal, land use planning;
- sustainable urban development and safe construction;
- e-government and access to geoscientific metadata and data;
- the development of interoperable and harmonized geoscientific data at the European scale.

EuroGeoSurveys coordinates the work of specific Expert Groups which, usually responding to specific EU policies, integrate all information, knowledge and expertise derived from all participating countries in-fields, such as geochemistry, spatial data, geological hazards, marine geology, mineral resources, soil and water. The present book, *Mapping the Chemical Environment of Urban Areas*, is another success story of the Geochemistry Expert Group of EuroGeoSurveys.

From 1996 to 2006, 26 European Geological Surveys cooperated to produce the *Geochemical Atlas of Europe*, presenting for the first time directly comparable data on the chemical composition of top- and sub soil, stream water, stream sediment and floodplain sediment at the European scale. With the publication of the two-volume atlas, the datasets were made publicly available (http://www.gtk.fi/publ/foregsatlas/). Since then they have been used in a wide variety of applications by diverse organizations throughout Europe, including EU Commission institutions. Another important group contribution is an atlas of European groundwater geochemistry, using bottled water as a sampling medium, which was published in September 2010 with the title *Geochemistry of European Bottled Water* (http://www.schweizerbart.de/publications/detail/artno/001201002).

This book is another significant publication of the Geochemistry Expert Group in which the quality of the urban environment is being discussed. We know that the majority of Europeans live and work in cities, and urbanization goes hand in hand with development; more often than not in emerging nations of the world the cities grow rapidly and unplanned. The large cities of Africa, Asia, South and Central America should be able to benefit from the knowledge and lessons learnt from the legacy of industrialization in cities of the Western world.

- Imagine crowded cities at risk of failure of foundations, and ground collapse, at risk of landslides or erosion, or regular inundation, or even cities sinking away rapidly!
- Imagine cities short of drinking water, and where plants and trees cannot grow because of polluted soils!
- Imagine cities where children cannot play outside, because of polluted soil in their house garden, playground and schoolyard!
- Whole generations are subjected to a lifetime of poor health and learning disabilities, because of the chemical environment in which they live.

One may think that this is a science fiction story. Unfortunately, it is not! Urban areas, owing to the population density and the high degree of infrastructural development, industries, traffic, wastes, etc., are not only extra-vulnerable to pollution of soil and air, but also to other geological hazards.

The chapters in this book describe mainly soil pollution and how it affects the quality of life of urban population. Geology is seen to exert a fundamental control on the chemical environment of urban areas, and nature itself does produce soil that can be classified as ‘contaminated’ by existing health-related criteria. The contribution of national Geological Surveys to the mapping of the chemical environment of urban areas is significant, since they provide data and information to decision-makers and town planners to remediate polluted soil and, thus, improve the quality of life of the inhabitants. Although each case study has been carefully planned and executed, and the results are of good quality, the methodologies used are different, which makes data comparison difficult. The Geochemistry Expert Group recognizing this drawback has initiated, with the approval of the EuroGeoSurveys Directors, an Urban Geochemistry project with the acronym URGE. The objective of this project is to carry out and harmonize urban geochemical mapping initially in 10 European cities, producing the first ever comparable results across Europe. Progress of this, as well as other activities of the Geochemistry Expert Group, is provided by the EuroGeoSurveys portal (http://www.eurogeosurveys.org/).

The portal also provides access to different types of geoscientific metadata, information and knowledge at European and national scales, by following the links on the thematic pages. In addition, it presents information on EuroGeoSurveys, its activities and its member organizations.

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Abbreviations and Acronyms

AADT	annual average daily traffic
AAS	atomic absorption spectrometry (or spectrophotometry)
AAS-GF	atomic absorption spectrometry with graphite furnace
AAS-HG	atomic absorption spectrometry with hydride generation
ACS	American Chemical Society
AD	Latin *anno domini*; in the year of the Lord; (of a date) of the Christian era
AHP	analytical hierarchy process
alr	additive log ratio
AMC	Analytical Methods Committee (Royal Society of Chemistry, London)
amsl	above mean sea level
amu	atomic mass unit
ANOVA	analysis of variance
AOES	atomic optical emission spectrometry (or spectrophotometry)
AOX	adsorbable organically bound halogen
APCI	atmospheric pressure chemical ionization
AR	aqua regia
ASTER	Advanced Space-borne Thermal Emission and Reflection Radiometer
ATSDR	Agency for Toxic Substances and Disease Registry (US)
AV	accepted value

BAF	bioaccesible fraction
BaP	benzo(*a*)pyrene
BARGE	BioAccessibility Rearch Group of Europe
BAT	best available technologies
BC	before Christ
BCR	Community Bureau Reference (European)
BghiP	benzo(*g*,*h*,*i*)perylene
BGR	Bundesanstalt für Geowissenschaften und Rohstoffe (Institute of Geosciences and Natural Resources, Germany)
BGS	British Geological Survey
BI	benefit index
BL	baseline
BL	blood lead
Bn	Background concentrations
BP	before present (time)
BS	British Standard
BSI	British Standards Institution
BSS	Baltic Soil Survey
BTEX	benzene, toluene, ethylbenzene and xylene

C	Celsius or centigrade temperature scale
CA	cluster analysis
C.A.	French *Compagnie Associé*; Associate Company
ca	Latin circa; about
CCA	chromated copper arsenate
CCMS	Committee on Challenges of Modern Society
CCRM	Canadian Certified Reference materials
CDCP	Centres for Disease Control and Prevention (US)
CDF	cumulative distribution function
CEC	cation-exchange capacity
CERT	Centre for Energy Research and Training (Nigeria)
CFC	chlorofluorocarbons
CFGC	Central Finland Granitoid Complex
Ch	percentage input of chalcophiles to total contamination
C_i	contamination index
CI	cost index
CLC	CORINE Land cover
CLEA	Contaminated Land Exposure Assessment (United Kingdom)
clr	centred log ratio
cm	centimetres, a common metric unit of distance
C_n	measured concentration
CN	cyanide
COHb	carboxyhaemoglobin
co-PCB	coplanar polychlorinated biphenyl
CP	cumulative probability
CRM	certified reference material
CSV	comma separated variable
CV	coefficient of variation
CVAAS	cold-vapour atomic absorption spectrometry

DAD	diode array detector
DAS+R or DASplusR	Data Analysis System (graphical user interface for R)
DC arc spectrometer	direct current arc spectrometer
DCC	day-care centre
DDT	dichlorodiphenyltrichloroethane
DE	degree of effectiveness
DEFRA	Department for Environment, Food and Rural Affairs (UK)
DEM	digital elevation model
DL	detection limit

DoE	Department of the Environment (UK)
E	east
EA	Environment Agency (UK)
EA	environmental analysis
EA	exposure assessment
EC	electrical conductivity
EC	European Commission
ECD	electron-capture device
ECDF	empirical cumulative distribution function
EDA	exploratory data analysis
EDA-links analyser	electronic design automation-links analyser
EDTA	ethylenediaminetetraacetic acid
ED-XRFS	energy-dispersive X-ray fluorescence spectrometry
EEA	European Environment Agency
EF	enrichment factor
EFSA	European Food Safety Authority
e.g.	Latin *exempli gratia*; for example
EGS	EuroGeoSurveys – The Geological Surveys of Europe
EI	enrichment index
EI	exposure index
EM	electromagnetic
EOX	extractable organic halogen
EPA	Environment Protection Act (Finland)
EPA	Environmental Protection Agency (Serbia)
ERA	environmental risk assessment
ESE	east-south-east
ESI	electrospray ionization
et al.	Latin *et alii*, *et alia*; and others
etc.	Latin *et cetera*; and the rest; and similar things; and so on
ETFE	ethylene tetrafluoroethylene
ETM+	Enhanced Thematic Mapper Plus
EU	European Union
EuroGeoSurveys	The Geological Surveys of Europe
EV	eigenvalue
F test	Fisher's *F*-test is any statistical test in which the test statistic has an *F*-distribution under the null hypothesis
FA	factor analysis
FAO	Food and Agriculture Organization (UN)
FEP	fluorinated ethylene propylene
FI	financial investment
FID	flame ionization detector
FLD	fluorescence detector
FlA	fluoranthene
FOREGS	Forum of European Geological Surveys (now EuroGeoSurveys)
g	gram(s), a common metric unit of weight
G-BASE	Geochemical Baseline Survey of the Environment (UK Geochemical Mapping programme)
GC	gas chromatograph/chromatography
GC-ECD	gas chromatography-electron-capture detector
GC–MS	gas chromatography-mass spectrometry
GEMAS	geochemical mapping of agricultural and grazing land soils (EGS project)
GFAAS	graphite-furnace atomic absorption spectrometry
GIS	geographical information system
GPS	global positioning system
GRN	Global Reference Network
GSUE	Geochemical Survey of the Urban Environment (UK Urban Geochemical Mapping programme)
GTK	Geologian Tutkimuskeskuksen (Geological Survey of Finland)
h	hour
HA	hazard assessment
Hb	haemoglobin
HCB	hexachlorobenzene
HFSE	high field strength element
HGAAS	hydride-generation atomic absorption spectrometry
HHRA	human health-risk assessment
HKI	Hong Kong Island
HpCDD	hepta-chlorinated dibenzodioxin
HPLC	high-performance (-pressure) liquid chromatography
HPLC-DAD	HPLC with diode array detector
HPLC-FLD	HPLC with fluorescence detector
HPLC-MS	HPLC with mass spectrometry
HPLC-MSD	HPLC with mass-spectrometric detector
HPLC-UV	HPLC with ultraviolet absorption detector
HVHC	highly volatile halogenated hydrocarbon
HxCDF	hexa-chlorinated dibenzofuran
IARC	International Agency for Research on Cancer
ICP-AES	inductively coupled plasma atomic emission spectrometry
ICP-ES	inductively coupled plasma emission spectrometry
ICP-MS	inductively coupled plasma atomic mass spectrometry
ICP-OES	inductively coupled plasma optical emission spectrometry (similar to ICP-AES)
ICRAM	Istituto Centrale per la Ricerca Scientifica e Tecnologica Applicata al Mare (Italy)
ICRCL	Interdepartmental Committee on the Redevelopment of Contaminated Land (UK)
ID^2	inverse distance squared
IDL	instrumental detection limit
IDW	inverse distance weighting
i.e.	Latin *id est*; that is to say
IEC	International Electrotechnical Commission standards
IG	Institute of Geology (Lithuania)
IGCP	International Geological Correlation Programme
I_{geo}	geoaccumulation index
IGG	Institute of Geology and Geography (Lithuania)
IGME	Instituto Geológico y Minero de España
IGME	Institute of Geology and Mineral Exploration (Hellas)

IGRAC	International Groundwater Resources Assessment Centre
ilr	isometric log ratio
IMGA	International Medical Geology Association
IMGRE	Institute of Mineralogy, Geochemistry and Crystal Chemistry of Rare Elements (Moscow)
INAA	instrumental neutron activation analysis
INETI	Instituto Nacional de Engenharia, Tecnologia e Inovação (Portugal)
InP	indeno(1,2,3-*c*,*d*)pyrene
IPCC	Intergovernmental Panel on Climate Change
IPPC	integrated pollution prevention and control
IQ	intelligence quotient
IQR	inter-quartile range
IR	infrared
ISE	International Soil-analytical Exchange
ISO	International Organization for Standardization
ISO- BS EN	International Organization for Standardization – British Standards European Norm
IT	information technology
ITE and I-TEQ	international toxicity equivalent
IUPAC	International Union of Pure and Applied Chemistry
JECFA	Joint Expert Committee on Food Additives (FAO/WHO)
ka	kiloannum (10^3 years)
kg	kilogram, a common metric unit of mass, equivalent to 1000 g
km	kilometre, a common metric unit of distance, equivalent to 1000 m
kW	kilowatt, a common metric unit of power, equivalent to 1000 W
LC–MS	liquid chromatograph–mass spectrometer
LGC	Laboratory of the Government Chemist (UK's designated National Measurement Institute for chemical and biochemical analysis)
LGS	Lithuanian Geological Survey
LIFE	European Union's financial instrument supporting environmental and nature conservation projects throughout the EU countries
LNEG	Laboratório Nacional de Energia e Geologia (Portugal)
LOI	loss on ignition
LLD	lower limit of detection
LRAT	long-range atmospheric transport
LRM	laboratory reference material
m	mean – average value
m	metre, a common metric unit of distance
M	the symbol for 'molar' in chemistry, i.e. it describes the concentration of a chemical solution in moles per litre (mol/L)
MAD	median absolute deviation
MAC	maximum allowable concentration
MC	metal concentration
MetHb	methaemoglobin
MeV	mega-electron volt
Mii	Mineral Information Institute (USA)
µg	microgram(s), a metric unit of mass equal to 0.001 mg or one-millionth of a gram
µg/dL	microgram per decilitre (one-tenth of a litre)
µg/g	micrograms per gram
µg/kg	micrograms per kilogram
µg/L	micrograms per litre
µL	microlitre, common metric unit of volume equal to one-millionth of a litre (1×10^{-6} L)
µm	micrometre or micron, a unit of length equal to one-millionth of a metre (1×10^{-6} m)
mg	milligram(s); equivalent to one-millionth of a gram (10^{-3} g)
mg/g	milligrams per gram
mg/kg	milligrams per kilogram
mL	millilitre, common metric unit of volume; 1 L has 1000 mL
mL/g	millilitres per gram
min	minute, common metric unit of time; 1 h has 60 min
mm	millimetre, a unit of length equal to one-thousandth of a metre (1×10^{-3} m)
MOHC	mineral oil hydrocarbon
MP	master plan
MPC	maximum permitted concentration
MS	mass spectrometer/spectrometry
MS	MiscroSoft
MSD	mass spectrometric detector
MSPD	matrix solid-phase dispersion
MSWI	municipal solid waste incinerator
MTBE	methyl *t*-butyl ether
MTT	Maa- ja elintarviketalouden tutkimuskeskus (Agrifood Research Finland)
MW	megawatt, a common metric unit of power; one megawatt is equal to one million watts
MWI	medical waste incinerator
MΩ	one million (10^6) ohms, the metric unit of electrical impedance
N	north
NAS	National Academy of Sciences (USA)
NATO	North Atlantic Treaty Organization
NEHF	National Environmental Health Forum (Australia)
NERC	Natural Environment Research Council (UK)
NESREA	National Environmental Standard and Regulation Agency (Nigeria)
ng	nanogram(s), a metric unit of mass equal to 10^{-9} g, or one-millionth of a milligram
NGDC	National Geoscience Data Centre (UK)
NGMTAP	Nigerian Geochemical Mapping Technical Assistance Project
NGRL	National Geosciences Research Laboratories (Nigeria)
NGSA	Nigerian Geological Survey Agency
NGU	Norges geologiske undersøkelse (Geological Survey of Norway)
NIST	National Institute of Standards and Technology (USA)

NORA	NERC open report archive (UK)
NPCA	Norwegian Pollution Control Authority
NPD	nitrogen phosphorous detector
NPL	National Priority List (USA)
NTNU	Norges teknisk-naturvitenskapelige universitet (Norwegian University of Science and Technology)
NTUA	National Technical University of Athens
NW	north-west
OCDD	octa-chlorinated dibenzodioxin
OCDF	octa-chlorinated dibenzofuran
O_2Hb	oxyhaemoglobin
OECD	Organization for Economic Co-operation and Development
OGRS	Official Gazette of the Republic of Serbia
OM	organic matter
P	analytical precision at the 95% confidence level
P_{25}	25th percentile
P_{75}	75th percentile
P_{95}	95th percentile
P-value or *p*-value	in statistical hypothesis testing, the *p*-value is the probability of obtaining a test statistic at least as extreme as the one that was actually observed, assuming that the null hypothesis is true; the null hypothesis is rejected if the *p*-value is less than 0.05 or 0.01, corresponding to a 5% or 1% chance respectively of an outcome at least that extreme, given the null hypothesis
PAH	polycyclic aromatic hydrocarbon
PAH_{16}	16 PAHs (on the priority pollutant list of the USEPA)
PAN	peroxyacetyl nitrate
PBA	Planning and Building Act (Norway)
PBDE	polybrominated diphenyl ether (flame retardant)
PBET	physiology-based extraction test
PC	principal component
PCA	principal component analysis
PCA	Pollution Control Act (Norway)
PCB	polychlorinated biphenyl
PCDD	polychlorinated dibenzo-*p*-dioxin
PCDF	polychlorinated dibenzofuran
PCDD/F or PCDD/Fs	polychlorinated dibenzo-*p*-dioxins and dibenzofurans; commonly referred to as dioxins and furans
P-EDXRF	energy-dispersive XRF
PFA	perfluoroalkoxy polymer
PGE	platinum group element
pH	German 'potenz' meaning 'power' plus the symbol for hydrogen (H); a logarithm of the reciprocal of the hydrogen ion concentration in moles per litre of a solution, giving a measure of its acidity or alkalinity.
PHE	potentially hazardous/harmful element
PID	photo-ionization detector
PLSS	Public Lands Survey System (USA)
PM10	solid particles of dust, smoke, mist, fumes, or smog, found in air or emissions that are smaller than 10 μm
POP	persistent organic pollutant
PPE	personal protective equipment
ppm	parts per million
PRISMA	Centre for Development Studies is an independent consultancy company (Hellas)
PRM	primary reference material
PSDVB	polystyrene divinylbenzene
PT	proficiency testing
PTFE	polytetrafluoroethene
PTMI	provisional tolerable monthly intake
PTWI	provisional tolerable weekly intake
PVA	polyvinyl alcohol
PVC	polyvinyl chloride
Pyr	pyrene
Q	quartile or 25th percentile
QA	quality assurance
QC	quality control
r	linear correlation coefficient
R	accuracy (analytical)
R	free software environment for statistical and graphical applications
RANOVA	robust analysis of variance
RDS	road deposited sediment
REACH	Registration, Evaluation, Authorization and Restriction of Chemical substances
REE	rare earth element
REFINA	Forschung für die Reduzierung der Flächeninanspruchnahme und ein nachhaltiges Flächenmanagement – Research programme of the German Federal Ministry of Education and Research (reducing the use of land and encouraging sustainable land management)
REZZO	Air Pollution Sources Register (Czech Republic)
RF	radio-frequency radiation is a subset of electromagnetic radiation with a wavelength of 100 km to 1 mm, which is a frequency of 3 kHz to 300 GHz respectively
RGB	red, green, blue
RM	reference material
RP	reversed-phase
RPD	relative percentage difference
rpm	revolutions per minute
RSD	relative standard deviation
s	second
S	south
SD	standard deviation
SAL	soil action level
SBI	social benefit index
SCI	social cost index
SCM	site conceptual model
SE	sequential extraction
SE	south-east
SEGH	Society for Environmental Geochemistry and Health

SEM	scanning electron microscope
SEP	Swedish Environmental Protection Agency
SFE	supercritical fluid extraction
SFT	Statens forurensningstilsyn (Pollution Control Authority Norway)
SGU	Sveriges geologiska undersökning (Geological Survey of Sweden)
SGV	soil guideline value
SIM	selected ion monitoring
SIN	National Interest Site (Italy)
SL	soil lead
SOC	semi-volatile organic compound
SPE	solid-phase extraction
SPI	soil pollution index
SPSS	Statistical Package for the Social Sciences (computer software)
SRM	secondary reference material
SYKE	Suomen ympäristökeskus (Finnish Environment Institute)
SW	south-west
t	tonnes, a metric unit of mass equal to 1000 kg
TBA	tetrabutyl ammonium
TC	target concentration
TC	total carbon
TCDF	tetra-chlorinated dibenzofuran
TEQ	toxic equivalent
TIC	total inorganic carbon
TIC	total ion current
TM	thematic mapper
TOC	total organic carbon
UBM	unified BARGE method
UCC	upper continental crust
UK	United Kingdom
UKAS	United Kingdom Accreditation Service
UN	United Nations
UNEP	United Nations Environmental Programme
UNFPA	United Nations Population Fund
UPLC	ultra-performance liquid chromatograph/ chromatography
URGE	Urban Geochemistry (EGS project to map 10 European cities)
USA	United States of America
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey
UTM	Universal Transverse Mercator
UV	ultraviolet
Var	variance
VES	vertical electrical sounding
VHHC	volatile halogenated hydrocarbons
VOC	volatile organic compounds
VOX	volatile organic halogens
W	west
WD-XRFS	wavelength-dispersive X-ray fluorescence spectrometry
WGS84	World Geodetic System is a standard for use in cartography, geodesy and navigation (dating from 1984 and last revised in 2004)
WHO	World Health Organization
WNW	west-north-west
w/w	'by weight'; it is used in chemistry to describe the concentration of a substance in a mixture or solution; e.g. 2% w/w means that the mass of the substance is 2% of the total mass of the solution or mixture
WWII	World War II
XRD	X-ray diffraction
XRF	X-ray fluorescence
XRFS	X-ray fluorescence spectrometry

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 3000 years that they have become relatively numerous and inhabited by large numbers of people (Macionis and Parillo, 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% by 2030 (Figure 1.1; 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.

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 (PHEs), 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. lead (Pb), mercury (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.

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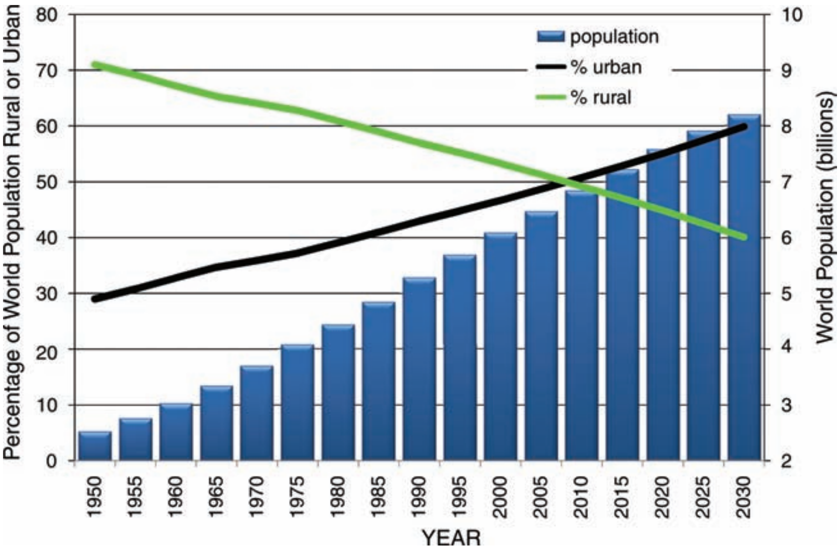

Figure 1.1 The urban and rural population of the world, 1950–2030 (after data from UN, 2006)

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 kilograms 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 thousands of kilometres from their source of origin. Our food supermarkets thus play 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 urbanized 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. sixth–fifth centuries BC), which are situated in the Lavreotiki peninsula to the south-east of Athens, Hellas, soil became contaminated by Pb as far back as 3500 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 eighteenth and nineteenth centuries, and the continued industrialization into the twentieth century, that not only transformed socio-economic 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 industrialization 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.

Photograph 1.1 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 eighteenth century revolutionized 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. Coalbrookdale by Night 1801. Oil on canvas, 680 × 1067 mm. © Science Museum, London

Paintings from the period also graphically illustrate the impact of the industrial revolution on the environment (Photograph 1.1). 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.

Developments in agriculture, manufacturing and transportation started in Europe and spread throughout the rest of the world. It is no coincidence, therefore, 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 cited 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 urbanization has spread around the globe, and so 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 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

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

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 their attention during the last 30 years 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 from 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 of 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 of 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 overemphasized. 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 everyday 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 1.2). 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

Photograph 1.2 It is our children that are most vulnerable to the health-risks of a contaminated urban environment, particularly through hand-to-mouth ingestion of soil. *Source*: Photograph provided by the Geological Survey of Norway