

Mapping the Chemical Environment of Urban Areas

 Editors
 Christopher C. Johnson Alecos Demetriades
 Juan Locutura Rolf Tore Ottesen



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Edited by Christopher C. Johnson, Alecos Demetriades, Juan Locutura and Rolf Tore Ottesen



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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 infields, 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,

FOREWORD

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, play-ground 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	С	Celsius or centigrade temperature scale
AAS	atomic absorption spectrometry (or	CA	cluster analysis
	spectrophotometry)	C.A.	French Compagnie Associé; Associate
AAS-GF	atomic absorption spectrometry with		Company
	graphite furnace	ca	Latin circa; about
AAS-HG	atomic absorption spectrometry with hydride	CCA	chromated copper arsenate
	generation	CCMS	Committee on Challenges of Modern Society
ACS	American Chemical Society	CCRM	Canadian Certified Reference materials
AD	Latin <i>anno domini</i> ; in the year of the Lord; (of a date) of the Christian era	CDCP	Centres for Disease Control and Prevention (US)
AHP	analytical hierarchy process	CDF	cumulative distribution function
alr	additive log ratio	CEC	cation-exchange capacity
AMC	Analytical Methods Committee (Royal	CERT	Centre for Energy Research and Training
11110	Society of Chemistry, London)	obiti	(Nigeria)
amsl	above mean sea level	CFC	chlorofluorocarbons
amu	atomic mass unit	CFGC	Central Finland Granitoid Complex
ANOVA	analysis of variance	Ch	percentage input of chalcophiles to total
AOES	atomic optical emission spectrometry (or	on	contamination
	spectrophotometry)	C	contamination index
AOX	adsorbable organically bound halogen	CI	cost index
APCI	atmospheric pressure chemical ionization	CLC	CORINE Land cover
AR	aqua regia	CLEA	Contaminated Land Exposure Assessment
ASTER	Advanced Space-borne Thermal Emission	CDDIT	(United Kingdom)
	and Reflection Radiometer	clr	centred log ratio
ATSDR	Agency for Toxic Substances and Disease	cm	centimetres, a common metric unit of
hibbit	Registry (US)	UIII	distance
AV	accepted value	C.	measured concentration
		CN	cvanide
DAE	hissessible fraction	COHb	carboxyhaemoglobin
D-D	bloaccesible fraction	co-PCB	conlanar polychlorinated binhenyl
BaP	Denzo(<i>a</i>)pyrene	CP	cumulative probability
BARGE	BioAccessibility Rearch Group of Europe	CRM	certified reference material
BAI	best available technologies	CSV	comma senarated variable
BC	before Christ	CV	coefficient of variation
BCR	Community Bureau Reference (European)	CVAAS	cold-vapour atomic absorption
BghiP	benzo(g,h,i)perylene	CVAAS	spectrometry
BGR	Bundesanstalt für Geowissenschaften und		spectrometry
	Rohstoffe (Institute of Geosciences and		
	Natural Resources, Germany)	DAD	diode array detector
BGS	British Geological Survey	DAS+R or	Data Analysis System (graphical user
BI	benefit index	DASplusR	interface for R)
BL	baseline	DC arc spectrometer	direct current arc spectrometer
BL	blood lead	DCC	day-care centre
Bn	Background concentrations	DDT	dichlorodiphenyltrichloroethane
BP	before present (time)	DE	degree of effectiveness
BS	British Standard	DEFRA	Department for Environment, Food and Rural
BSI	British Standards Institution		Affairs (UK)
BSS	Baltic Soil Survey	DEM	digital elevation model
BTEX	benzene, toluene, ethylbenzene and xylene	DL	detection limit

ABBREVIATIONS AND ACRONYMS

DoE	Department of the Environment (UK)	GEMAS	geochemical mapping of agricultural and
F	aast	GFAAS	grazing land solis (EGS project) graphite-furnace atomic absorption
	Environment A concer (LIK)		spectrometry
EA	Environment Agency (UK)	GIS	geographical information system
EA	environmental analysis	GPS	global positioning system
EA	exposure assessment	CDN	Global Defension National
EC	electrical conductivity	GRN	Global Reference Network
EC	European Commission	GSUE	Geochemical Survey of the Urban
ECD	electron-capture device		Environment (UK Urban Geochemical
ECDF	empirical cumulative distribution function		Mapping programme)
EDA	exploratory data analysis	GTK	Geologian Tutkimuskeskuksen (Geological
EDA-links analyser	electronic design automation-links analyser		Survey of Finland)
EDTA	ethylenediaminetetraacetic acid		
ED YRES	energy dispersive X ray fluorescence	h	hour
ED-ARI'S	energy-dispersive X-ray indorescence	HA	hazard assessment
FF (spectrometry	Hb	haemoglobin
EEA	European Environment Agency	HCB	hexachlorobenzene
EF	enrichment factor	HFSE	high field strength element
EFSA	European Food Safety Authority	HGAAS	hydride-generation atomic absorption
e.g.	Latin exempli gratia; for example	110/1110	spectrometry
EGS	EuroGeoSurveys – The Geological Surveys		bumon boolth rick accomment
	of Europe		Human health-fisk assessment
FI	enrichment index	HKI	Hong Kong Island
FI	exposure index	HpCDD	hepta-chlorinated dibenzodioxin
EM		HPLC	high-performance (-pressure) liquid
EM	electromagnetic		chromatography
EOX	extractable organic halogen	HPLC-DAD	HPLC with diode array detector
EPA	Environment Protection Act (Finland)	HPLC-FLD	HPLC with fluorescence detector
EPA	Environmental Protection Agency (Serbia)	HPLC-MS	HPLC with mass spectrometry
ERA	environmental risk assessment	HPLC-MSD	HPLC with mass-spectrometric detector
ESE	east-south-east	HPLC UV	HPLC with ultraviolet absorption detector
ESI	electrospray ionization	III LC-U V	highly velotile helegeneted hydrogenhon
et al.	Latin <i>et alii</i> , <i>et alia</i> ; and others		
etc	Latin <i>et cetera</i> : and the rest: and similar	HXCDF	hexa-chlorinated dibenzofuran
0.00	things: and so on	IARC	International Agency for Research on
ETEE	athylana tatrafluoroathylana	mac	Cancor
ETTL	Enhanced Thematic Manner Dhus	ICD AES	Called
EIM+		ICF-AES	inductively coupled plasma atomic emission
EU	European Union	100 50	spectrometry
EuroGeoSurveys	The Geological Surveys of Europe	ICP-ES	inductively coupled plasma emission
EV	eigenvalue		spectrometry
		ICP-MS	inductively coupled plasma atomic mass
E test	Fisher's <i>F</i> -test is any statistical test in which		spectrometry
1 1051	the test statistic has an E_{-} distribution under	ICP-OES	inductively coupled plasma optical emission
	the mult humothesis		spectrometry (similar to ICP-AES)
T 4	the null hypothesis	ICRAM	Istituto Centrale per la Ricerca Scientifica e
FA	factor analysis	1010 101	Tecnologica Applicata al Mare (Italy)
FAO	Food and Agriculture Organization (UN)	ICDCI	Intendencertmental Committee on the
FEP	fluorinated ethylene propylene	ICKCL	Interdepartmental Committee on the
FI	financial investment		Redevelopment of Contaminated Land (UK)
FID	flame ionization detector	ID ²	inverse distance squared
FLD	fluorescence detector	IDL	instrumental detection limit
FIA	fluoranthene	IDW	inverse distance weighting
FOREGS	Forum of European Geological Surveys (now	i.e.	Latin <i>id est</i> ; that is to say
TORLOS	EuroGooSurveys)	IEC	International Electrotechnical Commission
	EuroGeoSurveys)		standards
σ	gram(s) a common metric unit of weight	IG	Institute of Geology (Lithuania)
G-BASE	Geochemical Baseline Survey of the	ICCD	International Casalogical Correlation
0-DA5L	Environment (JIK Casehemical Manning	IGCF	Disconstructional Geological Correlation
	Environment (UK Geochemical Mapping		Programme
~~	programme)	Igeo	geoaccumulation index
GC	gas chromatograph/chromatography	IGG	Institute of Geology and Geography
GC-ECD	gas chromatography-electron-capture		(Lithuania)
	detector	IGME	Instituto Geológico y Minero de España
GC-MS	gas chromatography-mass spectrometry	IGME	Institute of Geology and Mineral Exploration
	* *		(Hellas)

ABBREVIATIONS AND ACRONYMS

IGRAC	International Groundwater Resources	MetHb	methaemoglobin
	Assessment Centre	MeV	mega-electron volt
ilr	isometric log ratio	Mii	Mineral Information Institute (USA)
IMGA	International Medical Geology Association	μg	microgram(s), a metric unit of mass equal to
IMGRE	Institute of Mineralogy, Geochemistry and		0.001 mg or one-millionth of a gram
	Crystal Chemistry of Rare Elements	μg/dL	microgram per decilitre (one-tenth of a litre)
	(Moscow)	μg/g	micrograms per gram
INAA	instrumental neutron activation analysis	μg/kg	micrograms per kilogram
INETI	Instituto Nacional de Engenharia, Tecnologia	μg/L	micrograms per litre
	e Inovação (Portugal)	μL	microlitre, common metric unit of volume
InP	indeno(1,2,3-c,d)pyrene		equal to one-millionth of a litre $(1 \times 10^{-6} \text{ L})$
IPCC	Intergovernmental Panel on Climate Change	μm	micrometre or micron, a unit of length equal
IPPC	integrated pollution prevention and control		to one-millionth of a metre $(1 \times 10^{-6} \text{ m})$
IQ	intelligence quotient	mg	milligram(s); equivalent to one-millionth of a
IQR	inter-quartile range		gram (10^{-3} g)
IR	infrared	mg/g	milligrams per gram
ISE	International Soil-analytical Exchange	mg/kg	milligrams per kilogram
ISO	International Organization for	mL	millilitre, common metric unit of volume; 1 L
	Standardization		has 1000 mL
ISO- BS EN	International Organization for	mL/g	millilitres per gram
	Standardization – British Standards	min	minute, common metric unit of time; 1 h has
	European Norm		60 min
IT	information technology	mm	millimetre, a unit of length equal to one-
ITE and I-TEQ	international toxicity equivalent		thousandth of a metre $(1 \times 10^{-3} \text{ m})$
IUPAC	International Union of Pure and Applied	MOHC	mineral oil hydrocarbon
	Chemistry	MP	master plan
IECEA	Lint E-mark Committee on Earl Addition	MPC	maximum permitted concentration
JECFA	(EAO/WHO)	MS	mass spectrometer/spectrometry
	(FAU/WHO)	MS	MiscroSoft
ka	kiloannum (10 ³ years)	MSD	mass spectrometric detector
kg	kilogram, a common metric unit of mass.	MSPD	matrix solid-phase dispersion
0	equivalent to 1000 g	MSWI	municipal solid waste incinerator
km	kilometre, a common metric unit of distance.	MTBE	methyl <i>t</i> -butyl ether
	equivalent to 1000 m	MTT	Maa- ja elintarviketalouden tutkimuskeskus
kW	kilowatt, a common metric unit of power.		(Agrifood Research Finland)
	equivalent to 1000 W	MW	megawatt, a common metric unit of power;
			one megawatt is equal to one million watts
LC-MS	liquid chromatograph-mass spectrometer	MWI	medical waste incinerator
LGC	Laboratory of the Government Chemist	MΩ	one million (10^6) ohms, the metric unit of
	(UK's designated National Measurement		electrical impedance
	Institute for chemical and biochemical		
	analysis)	N	a outle
LGS	Lithuanian Geological Survey	IN MAG	Notional Academy of Sciences (USA)
LIFE	European Union's financial instrument	INAS NATO	National Academy of Sciences (USA)
	supporting environmental and nature	NAIO	North Atlantic Treaty Organization
	conservation projects throughout the EU	NEHF	(Australia)
	countries	NEDC	(Australia) Natural Environment Bessereh Council (UK)
LNEG	Laboratório Nacional de Energia e Geologia	NERU	Natural Environment Research Council (UK)
	(Portugal)	NESKEA	National Environmental Standard and
LOI	loss on ignition	20	Regulation Agency (Nigeria)
LLD	lower limit of detection	ng	10^{-9} a or one millionth of a millionem
LRAT	long-range atmospheric transport	NCDC	Notional Cassianas Data Cantra (UK)
LRM	laboratory reference material	NGDU	National Geoscience Data Centre (UK)
100	maan avaraga valua	NOMIAP	Assistance Project
m	metre a common metric unit of distance	NCDI	National Goosciences Passarch Laboratorias
III M	the symbol for 'moler' in chemistry i a it	NGKL	(Nitaoria)
191	describes the concentration of a chemical	NCSA	Nigerian Geological Survey Ageney
	solution in moles per litra (mol/L)	NCU	Norges geologiske undergelieles (Costanies)
ΜΔD	median absolute deviation	UUU	Survey of Norway)
MAC	maximum allowable concentration	NIST	National Institute of Standards and
MC	metal concentration	14101	Technology (USA)
me			Technology (USA)

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ABBREVIATIONS AND ACRONYMS

NORA NPCA	NERC open report archive (UK) Norwegian Pollution Control Authority	PM10	solid particles of dust, smoke, mist, fumes, or smog, found in air or emissions that are
NPD	nitrogen phosphorous detector		smaller than 10 µm
NPL	National Priority List (USA)	POP	persistent organic pollutant
NTNU	Norges teknisk-naturvitenskapelige	PPE	personal protective equipment
	universitet (Norwegian University of Science	ppm	parts per million
	and Technology)	PRISMA	Centre for Development Studies is an
NTUA	National Technical University of Athens		independent consultancy company (Hellas)
NW	north-west	PRM	primary reference material
		PSDVB	polystyrene divinylbenzene
0.000		PT	proficiency testing
OCDD	octa-chlorinated dibenzodioxin	PTFE	polytetrafluoroethene
OCDF	octa-chlorinated dibenzofuran	PTMI	provisional tolerable monthly intake
O ₂ Hb	oxyhaemoglobin	PTWI	provisional tolerable weekly intake
OECD	Organization for Economic Co-operation and	PVA	polyvinyl alcohol
	Development	PVC	polyvinyl chloride
OGRS	Official Gazette of the Republic of Serbia	Pyr	pyrene
OM	organic matter	1 yı	pyrene
		0	quartile or 25th percentile
		ÕA .	quality assurance
Р	analytical precision at the 95% confidence	00	quality control
	level	V 0	quality control
P ₂₅	25th percentile	r	linear correlation coefficient
P ₇₅	75th percentile	R	accuracy (analytical)
P_{95}	95th percentile	R	free software environment for statistical and
<i>P</i> -value or <i>p</i> -value	in statistical hypothesis testing, the <i>p</i> -value is		graphical applications
*	the probability of obtaining a test statistic at	RANOVA	robust analysis of variance
	least as extreme as the one that was actually	RDS	road deposited sediment
	observed, assuming that the null hypothesis is	REACH	Registration Evaluation Authorization and
	true: the null hypothesis is rejected if the <i>p</i> -	RE/ ICH	Restriction of Chemical substances
	value is less than 0.05 or 0.01 corresponding	DEE	rare earth element
	to a 5% or 1% chance respectively of an	REE REFINA	Forschung für die Reduzierung der
	outcome at least that extreme given the null	KEFINA	Flishening für die Keduzierung der
	bunothesis		Flachenmanspluchmanne und em
DALI	nypolitesis		nachnaitiges Flachenmanagement –
	16 DA Ha (on the migrity nellytent list of the		Research programme of the German Federal
PAH_{16}	IO PARS (on the priority pollutant list of the		Ministry of Education and Research
DAN	USEPA)		(reducing the use of land and encouraging
PAN	peroxyacetyl nitrate		sustainable land management)
PBA	Planning and Building Act (Norway)	REZZO	Air Pollution Sources Register (Czech
PBDE	polybrominated diphenyl ether (flame		Republic)
	retardant)	RF	radio-frequency radiation is a subset of
PBET	physiology-based extraction test		electromagnetic radiation with a wavelength
PC	principal component		of 100 km to 1 mm, which is a frequency of
PCA	principal component analysis		3 kHz to 300 GHz respectively
PCA	Pollution Control Act (Norway)	RGB	red, green, blue
PCB	polychlorinated biphenyl	RM	reference material
PCDD	polychlorinated dibenzo-p-dioxin	RP	reversed-phase
PCDF	polychlorinated dibenzofuran	RPD	relative percentage difference
PCDD/F or	polychlorinated dibenzo- <i>p</i> -dioxins and	rpm	revolutions per minute
PCDD/Fs	dibenzofurans: commonly referred to as	RSD	relative standard deviation
	dioxins and furans	100	
P-EDXRF	energy-dispersive XRF	S	second
PFA	perfluoroalkoxy polymer	S	south
PGE	platinum group element	SD	standard deviation
nH	German 'potenz' meaning 'power' plus the	SAL	soil action level
P**	symbol for hydrogen (H): a logarithm of the	SBI	social benefit index
	symbol for hydrogen (11), a logarithm of the	SCI	social cost index
	in moles per litre of a solution giving a	SCM	site conceptual model
	monours of its acidity or alkelinity	SE	sequential extraction
DUE	neasure of its acturity of alkalinity.	SE	south-east
r file DID	potentially nazardous/narmful element	SEGH	Society for Environmental Geochemistry
PID DI CC	proto-ionization detector	52011	and Health
PLSS	Public Lands Survey System (USA)		uno montali

ABBREVIATIONS AND ACRONYMS

SEM	scanning electron microscope	UNEP	United Nations Environmental Programme
SEP	Swedish Environmental Protection Agency	UNFPA	United Nations Population Fund
SFE	supercritical fluid extraction	UPLC	ultra-performance liquid chromatograph/
SFT	Statens forurensningstilsyn (Pollution		chromatography
	Control Authority Norway)	URGE	Urban Geochemistry (EGS project to map 10
SGU	Sveriges geologiska undersökning		European cities)
	(Geological Survey of Sweden)	USA	United States of America
SGV	soil guideline value	USEPA	United States Environmental Protection
SIM	selected ion monitoring		Agency
SIN	National Interest Site (Italy)	USGS	United States Geological Survey
SL	soil lead	UTM	Universal Transverse Mercator
SOC	semi-volatile organic compound	UV	ultraviolet
SPE	solid-phase extraction	* 7	
SPI	soil pollution index	Var	variance
SPSS	Statistical Package for the Social Sciences	VES	vertical electrical sounding
	(computer software)	VHHC	volatile halogenated hydrocarbons
SRM	secondary reference material	VOC	volatile organic compounds
SYKE	Suomen ympäristökeskus (Finnish	VOX	volatile organic halogens
	Environment Institute)	W	west
SW	south-west	WD-XRFS	wavelength-dispersive X-ray fluorescence
+	topped a matric unit of mass equal to 1000 kg		spectrometry
	totrebutyl emmonium	WGS84	World Geodetic System is a standard for use
TC	terrat concentration		in cartography, geodesy and navigation
TC	target concentration		(dating from 1984 and last revised in 2004)
TCDE	totra chloringtad dibanzafuran	WHO	World Health Organization
TEO	toxic equivalent	WNW	west-north-west
TIC	total inorganic carbon	w/w	'by weight'; it is used in chemistry to
TIC	total ion current		describe the concentration of a substance in a
TM	thematic manner		mixture or solution; e.g. 2% w/w means that
TOC	includie mapper		the mass of the substance is 2% of the total
100	total organic carbon		
	total organic carbon		mass of the solution or mixture
UBM	total organic carbon unified BARGE method	WWII	mass of the solution or mixture World War II
UBM UCC	total organic carbon unified BARGE method upper continental crust	WWII	mass of the solution or mixture World War II
UBM UCC UK	total organic carbon unified BARGE method upper continental crust United Kingdom	WWII XRD	world War II X-ray diffraction
UBM UCC UK UKAS	total organic carbon unified BARGE method upper continental crust United Kingdom United Kingdom Accreditation Service	WWII XRD XRF	Mass of the solution or mixture World War II X-ray diffraction X-ray fluorescence

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Introduction

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People are drawn to living together in communities and, although cities began to appear 10000 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

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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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INTRODUCTION



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.

INTRODUCTION



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

¹ http://www.eurogeosurveys.org/.

INTRODUCTION

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