
Alina Kabata-Pendias

Arun B. Mukherjee

Trace Elements from Soil to Human

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With 26 Figures and 209 Tables

 Springer

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Preface

The understanding of fundamental principles and phenomena that control the transfer of trace elements in soil-plant-human chain can contribute to the protection of the environment and human health. Many books, articles, and reports have already described both fundamental and/or detail problems related to these topics.

The intention of the authors is to provide up-to-date and selected interdisciplinary data for the concise presentation of existing knowledge on trace element transfer in the food chain, from soil to human. To accomplish this, the inclusion of appropriate data has been necessary. This book inevitably leaves publications of many investigators' uncited. The authors regret that such approach was necessary.

This volume is composed of two parts. Part I – *Biogeochemistry of the Human Environment* – presents fundamental information on biogeochemical properties of environmental compartments (soil, water, air, plants, humans) concerning trace elements. Part II – *Biogeochemistry of Trace Elements* – provides detailed data of the behavior and the occurrence of trace elements in the environment. There is a close relationship in the biogeochemical behavior between elements and their position in the Periodic System. Therefore, the format of this book follows the elemental sequences of the contemporary Periodic Table. The book provides data on the production usage, and on the occurrence of trace elements in soils, waters, air, plants, and humans (animals). Environmental stress, and biological functions of these elements are widely discussed.

The authors hope that information, presented in this book, will encourage young scientists to undertake further studies for better understanding of all factors that influence cycling of trace elements in a given ecosystem, and to develop the most effective methods for the effective remediation of contaminated sites. Finally, this knowledge will improve the assessment of health and ecological risk. The authors will be satisfied if this book fires the imagination of some readers and encourages them to study the biogeochemistry of trace elements in greater depth.

Alina Kabata-Pendias, Arun B. Mukherjee
January 2007

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Past to Future

Inscription on the Sybilla's Temple
erected 1801 in Puławy, Poland

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Presentation of Data

Basic units of the International System (SI Unit) are used in this book. Mean contents refer to arithmetic mean value, unless otherwise specified.

The concentrations of a trace element in soil, plant, animal, and human samples are based on the total content by weight of the element in air-dried or oven-dried (at 40 °C) material. Otherwise it is indicated as follows:

AW – ash weight
FW – fresh weight or wet weight
BW – body weight

All data are given for topsoils, unless otherwise indicated. If not identified, a content of an element in environmental samples is given as, so called “total”, i.e., measured in totally digested sample or measured directly in a sample.

Units

Mt – million metric tons (10^3 kt)
kt – thousand metric tons (10^3 t)
t – metric ton (10^3 kg)
kg – kilogram (10^3 g)
g – gram (10^{-3} kg)
mg – milligram (10^{-3} g)
µg – microgram (10^{-3} mg)
ng – nanogram (10^{-3} µg)
pg – picogram (10^{-3} ng)
fg – femtogram (10^{-3} pg)
pm – picometer (10^{-12} m); $1 \text{ \AA} = 100 \text{ pm}$
ha – hectare ($10\,000 \text{ m}^2$)
l – liter (1 dm^3)
 m^3 – cubic meter (10^3 dm^3)
Bq – becquerel
mBq – millibecquerel
Ci – curie; $1 \text{ Ci} = 3.7 \times 10^{10} \text{ Bq}$
mCi – millicurie
nCi – nanocurie
pCi – picocurie

Symbols

°C – temperature in Celsius degrees
 $\text{cmol}(+)\text{kg}^{-1}$ – centimoles of positively charged ions (cations) in 1 kg of sample (formerly meq/100 g; $1 \text{ cmol}(+)\text{kg}^{-1} = 1 \text{ meq}/100 \text{ g}$)
Eh – redox potential (volts, millivolts)
pH – negative logarithm, base 10, of hydrogen ion concentration (activity)
M – molar concentration of solution of an element (compound)
 $t_{1/2}$ – half life-time of a radionuclide
 K_d – dissociation constant: product of the activities of cations and anions divided by the activity of the unionized electrolyte

Glossary (Abbreviations, Acronyms)

AAAc	ammonium acetic acid
AAAcEDTA	mixture of ammonium acetic acid with Na ₂ EDTA
AAP	acid available particulate
AD	Alzheimer disease
ADI	acceptable daily intake
AMAP	Arctic Monitoring and Assessment Programme
A/N	ratio of anthropogenic to natural sources
AROMIS	Assessment and Reduction of Heavy Metal Inputs into Agro-Ecosystems
ASB	alkaline-stabilize biosolids
ASM	artisanal and small-scale gold mining
ATSDR	Agency for Toxic Substances and Disease Registry
AHM	Asian herbal medicines
BAC	biological absorption coefficient
BAT	biological tolerance values at workplace
BC	Before Christ
BCF	biological concentration factor
BIM	biologically induced minerals
B-x	blood level of a given element
Cc	continental crust concentration of element
CEC	cation exchangeable capacity
CLPP	community level physiological profile
Clarke	Clarke's data for mean values for chemical elements in a given geological material
COPR	chromite-ore processing residue
Cw	dissolved concentration of element in water
Cw/Cc	ratio of element concentration in water to its content in the continental crust
DBT	dibutyltin
DDI	daily dietary intake
DM-X	dimethylated element
DMT	dimethyltin
DNA	de(s)oxyribonucleic acid, carrier of genetic information

DOC	dissolved organic carbon
DOM	dissolved organic matter
DTPA	diethylenetriaminepentaacetic acid
DU	depleted uranium
EC	European Commission
EDTA	ethylenediaminetetraacetic acid
EF _c	enrichment factor-ratio of element concentration in air to its content in the Earth's crust, normalized to the reference element (Al)
EPA	Environmental Protection Agency
ESADDI	estimated safe and adequate daily dietary intake
FA	fly ash
FAO	Food and Agriculture Organization of the United Nation
FDA	Food and Drug Administration
GIS	geographical information system
GEMS	Global Environment Monitoring System
GERM	Geochemical Environmental Reference Methods
HA	humic acids
HELCOM	Helsinki Commission
HI	hazardous index
HDL	high density lipoproteins
HRE	heavy rare earth
IHC	interactive health communication
IAEA	International Atomic Energy Agency
IARC	International Agency for Research on Cancer
IBA	index of bioaccumulation
ICRP	International Commission on Radiological Protection
IDD	Iodine Deficiency Disorders
IHC	Interactive Health Communication,
IHR	International Health Regulation
IPCS	International Program on Chemical Safety
IUPAC	International Union of Pure and Applied Chemistry
IUR	International Union of Radioecology
JECFA	Joint FAO/WHO Expert Committee on Food Additives
KD	Keshan disease
KBD	Kashin-Beck disease
LDL ₅₀	lethal dose, the simple dose of an element which causes the death of 50% of a population in a specific period of time
LDL ₀	the lowest lethal dose

LDH	low density lipoproteins
LOAEL	lowest-observed-adverse-effect level
LRE	light rare earth
LTI	lowest threshold intake
MAC	maximum allowable concentration
MAK	maximum concentration of a chemical substance on air at the work-place (after German)
MBT	monobutyltin
MCL	maximum concentration level
MCRA	Monte Carlo Risk Assessment
Me-X	methylated metal
MF	modifying factors
ML	maximum level
MPL	maximum permissible limit
MMT	methylcyclopentadienyl manganese tricarbonyl
MM-X	monomethylated metal
MND	motor neuron disease
MPC	maximum permissible concentration
MSW	municipal solid waste
MTD	maximum tolerable dose
NAS	National Academy of Sciences
NIOSH	National Institute for Occupational Safety and Health
NOAEL	no-observed-adverse-effect level
NOEC	no-observed-effect concentration
OEL	occupational exposure limit
OECD	Organization for Economic Cooperation and Development
OTC	organo-tin compound
OSHA	Occupational Safety and Health Administration (in USA)
PbB	lead in blood
PCBs	polychlorinated biphenyls
PGM	platinum group metal
PM	particulate matter (e.g., PM ₁₀ = particle 10 µm in diameter)
PT₅₀	phytotoxicity threshold corresponding to 50% growth retardation
PTDI	provisional tolerable daily intake
PTWI	provisional tolerable weekly intake
PMTD	provisional maximum tolerable daily intake
RDI	recommended daily intake
RDA	recommended dietary allowance
REE	rare earth element
RfD	reference dose
RNA	ribonucleic acid, structural element of the cytoplasm and cell nucleus

SeCys	selenocysteine
SEFcrust	soil enrichment factor in relation to crust mean concentrations (ratio of mean soil content to crustal content)
SeGSH	selenogluthathione
SeMC	selenomethylocysteine
SeMet	selenomethionine
SOD	superoxide dismutase
SETAC	Society of Environmental and Toxicological Chemistry
SOM	soil organic matter
SPTF	soil-plant transfer factor
TAV	trigger action value
TBT	tributyltin
TF	transfer factor (ratio of an element content in plant to its concentration in soil)
TDI	total dietary intake
TDS	Total Diet Study
TI	tolerable intake
TIC	trace inorganic contaminants
TLV	threshold limit value
TUIL	tolerable upper intake level
TWA	time weighted average
UF	uncertainty factors
UL	tolerable upper intake level
UNEP	United Nations Environmental Program
UNESCO	United Nations Educational, Scientific and Cultural Organization
UPAC	International Union of Pure and Applied Chemistry
USEPA	US Environmental Protection Agency
USGS	United States Geological Survey
WHO	World Health Organization
W/S	worms/soil concentration ratio