

NATO Science Series
IV: Earth and Environmental Sciences

 springer.com

ISBN 978-1-4020-4726-8

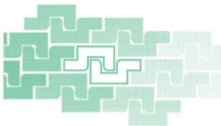


9 781402 047268



I. Twardowska
H.E. Allen
M.H. Häggblom

Soil and Water Pollution Monitoring,
Protection and Remediation



Soil and Water Pollution Monitoring, Protection and Remediation

Edited by

Irena Twardowska, Herbert E. Allen
and Max H. Häggblom

NATO Science Series

ISBN 978-1-4020-4726-8

IV/69

IV: Earth and Environmental Sciences – Vol. 69

Soil and Water Pollution Monitoring, Protection and Remediation

NATO Science Series

A Series presenting the results of scientific meetings supported under the NATO Science Programme.

The Series is published by IOS Press, Amsterdam, and Springer in conjunction with the NATO Public Diplomacy Division

Sub-Series

| | |
|---|-----------|
| I. Life and Behavioural Sciences | IOS Press |
| II. Mathematics, Physics and Chemistry | Springer |
| III. Computer and Systems Science | IOS Press |
| IV. Earth and Environmental Sciences | Springer |

The NATO Science Series continues the series of books published formerly as the NATO ASI Series.

The NATO Science Programme offers support for collaboration in civil science between scientists of countries of the Euro-Atlantic Partnership Council. The types of scientific meeting generally supported are "Advanced Study Institutes" and "Advanced Research Workshops", and the NATO Science Series collects together the results of these meetings. The meetings are co-organized by scientists from NATO countries and scientists from NATO's Partner countries – countries of the CIS and Central and Eastern Europe.

Advanced Study Institutes are high-level tutorial courses offering in-depth study of latest advances in a field.

Advanced Research Workshops are expert meetings aimed at critical assessment of a field, and identification of directions for future action.

As a consequence of the restructuring of the NATO Science Programme in 1999, the NATO Science Series was re-organised to the four sub-series noted above. Please consult the following web sites for information on previous volumes published in the Series.

<http://www.nato.int/science>

<http://www.springer.com>

<http://www.iospress.nl>



Soil and Water Pollution Monitoring, Protection and Remediation

edited by

Irena Twardowska

Polish Academy of Sciences,
Institute of Environmental Engineering,
Zabrze, Poland

Herbert E. Allen

Center for Study of Metals in the Environment,
Department of Civil and Environmental Engineering,
University of Delaware,
Newark, DE, U.S.A.

Max M. Häggblom

Department of Biochemistry and Microbiology,
Biotechnology Center for Agriculture and the Environment,
Rutgers, The State University of New Jersey,
New Brunswick, NJ, U.S.A.

Managing editor

Sebastian Stefaniak

Polish Academy of Sciences,
Institute of Environmental Engineering,
Zabrze, Poland



Published in cooperation with NATO Public Diplomacy Division

Proceedings of the NATO Advanced Research Workshop on
Viable Methods of Soil and Water Pollution Monitoring, Protection and Remediation
Krakow, Poland
27 June – 1 July 2005

A C.I.P. Catalogue record for this book is available from the Library of Congress.

ISBN-10 1-4020-4727-4 (PB)
ISBN-13 978-1-4020-4727-5 (PB)
ISBN-10 1-4020-4726-6 (HB)
ISBN-13 978-1-4020-4726-8 (HB)
ISBN-10 1-4020-4728-2 (e-book)
ISBN-13 978-1-4020-4728-2 (e-book)

Published by Springer,
P.O. Box 17, 3300 AA Dordrecht, The Netherlands.

www.springer.com

Printed on acid-free paper

All Rights Reserved

© 2006 Springer

No part of this work may be reproduced, stored in a retrieval system, or transmitted in any form or by any means, electronic, mechanical, photocopying, microfilming, recording or otherwise, without written permission from the Publisher, with the exception of any material supplied specifically for the purpose of being entered and executed on a computer system, for exclusive use by the purchaser of the work.

CONTENTS

| | |
|-----------------------|------|
| Preface..... | xi |
| Acknowledgements..... | xvii |
| Contributors | xix |

1. Introduction: Spread and Distribution of Hazardous Chemicals in Soils and Water – A Global Problem

- 1.1. Diagnosis and prognosis of the distribution of contaminants in the geosphere.....3**
Uri Mingelgrin and Ahmed Nasser
- 1.2. Persistent organic pollutants in Egypt - an overview.....25**
Mohamed Tawfic Ahmed

2. Fate and Behavior of Anthropogenic Pollutants in Soils and Water

- 2.1. Fundamental Issues in Sorption Related to Physical and Biological Remediation of Soils.....41**
Joseph J. Pignatello
- 2.2. The role of humic substances in the fate of anthropogenic organic pollutants in soil with emphasis on endocrine disruptor compounds69**
Elisabetta Loffredo and Nicola Senesi
- 2.3. Incorporating bioavailability into criteria for metals.....93**
Herbert E. Allen and Colin R. Janssen
- 2.4. The metal uptake and accumulation in fish living in polluted waters.....107**
Barbara Jezierska and Małgorzata Witeska

| | |
|---|------------|
| 3. Advances in Chemical and Biological Techniques for Environmental Monitoring and Predicting | |
| 3.1. Sensoristic approach to biological damage and risk assessment..... | 117 |
| Luigi Campanella and Cecilia Costanza | |
| 3.2. Advanced environmental biochemical sensor for water monitoring: Automated Water Analyser Computer Supported System (AWACSS) | 131 |
| Guenther Proll, Jens Tschmelak, Joachim Kaiser, Peter Kraemmer, Frank Sacher, Jan Stien and Guenther Gauglitz | |
| 3.3. Genetically engineered microorganisms for pollution monitoring | 147 |
| Shimshon Belkin | |
| 3.4. Some advances in environmental analytics and monitoring..... | 161 |
| Agata Kot-Wasik and Jacek Namieśnik | |
| 3.5. Fiber optic system for water spectroscopy..... | 175 |
| Anna G. Mignani, Andrea A. Mencaglia and Leonardo Ciaccheri | |
| 3.6. Predicting metal uptake by plants using DGT technique | 187 |
| Hao Zhang and William Davison | |
| 3.7. On conceptual and numerical modeling of flow and transport in groundwater with the aid of tracers: a case study | 199 |
| Jaroslaw Kania, Kazimierz Rozanski, Stanislaw Witczak and Andrzej Zuber | |
| 4. Novel Physico-Chemical Techniques of Soil and Water Protection and Remediation | |
| 4.1. Current and future in situ treatment techniques for the remediation of hazardous substances in soil, sediments, and groundwater | 211 |
| Robert A. Olexsey and Randy A. Parker | |

- 4.2. Long-term performance of permeable reactive barriers: lessons learned on design, contaminant treatment, longevity, performance monitoring and cost – an overview221**
Robert W. Puls
- 4.3. Using abundant waste and natural materials for soil and groundwater protection against contamination with heavy metals: Prospects and areas of application 231**
Irena Twardowska, Joanna Kyziol, Yoram Avnimelech, Sebastian Stefaniak and Krystyna Janta-Koszuta
- 4.4. Mediating effects of humic substances in the contaminated environments: Concepts, results, and prospects.....249**
Irina V. Perminova, Natalia A. Kulikova, Denis M. Zhilin, Natalia Yu. Grechischeva, Dmitrii V. Kovalevskii, Galina F. Lebedeva, Dmitrii N. Matorin, Pavel S. Venediktov, Andrey I. Konstantinov, Vladimir A. Kholodov, Valery S. Petrosyan
- 4.5. Metal binding by humic substances and dissolved organic matter derived from compost275**
Yona Chen, Pearly Gat, Fritz H. Frimmel and Gudrun Abbt-Braun
- 4.6. The effect of organic matter from brown coal on bioavailability of heavy metals in contaminated soils299**
Piotr Skłodowski, Alina Maciejewska and Jolanta Kwiatkowska
- 4.7. Use of activated carbon for soil bioremediation309**
Galina K. Vasilyeva, Elena R. Strijakova and Patrick J. Shea
- 4.8. Adsorption of anions onto sol-gel generated double hydrous oxides.....323**
Natalia I. Chubar, Valentyn A. Kanibolotskyy, Volodymyr V. Strelko, Volodymyr S. Kouts and Tetiana O. Shaposhnikova
- 4.9. Xenobiotic pharmaceuticals in water and methods to prevent their appearance in drinking water: Photolytic and Photocatalytic Degradation of Pharmaceuticals339**
Fritz H. Frimmel and Tusnelda E. Doll

| | |
|---|------------|
| 4.10. UV/VIS light-enhanced photocatalysis for water treatment and protection | 351 |
| Jan Hupka, Adriana Zaleska, Marcin Janczarek, Ewa Kowalska, Paulina Górska and Robert Aranowski | |
| 4.11. New horizons in purification of liquids: Novel colloidal and interfacial strategies to remove hazardous molecules, viruses and other microorganisms from water | 369 |
| Dinesh O. Shah and Monica A. James | |
| 4.12. Fly ash-organic byproduct mixture as soil amendment | 387 |
| Kenneth S. Sajwan, Siva Paramasivam, Ashok K. Alva and Shivendra V. Sahi | |
| 5. Biosystems for Non-Destructive Remediation and Immobilization of Pollutants in Soils, Sediments and Detoxification of Industrial Wastes | |
| 5.1. Phytoremediation and phytotechnologies: a review for the present and the future..... | 403 |
| Nelson Marmiroli, Marta Marmiroli and Elena Maestri | |
| 5.2. Constructed wetlands and their performance for treatment of water contaminated with arsenic and heavy metals | 417 |
| Ulrich Stottmeister, Sasidhorn Buddhawong, Peter Kuschik, Arndt Wiessner and Jürgen Mattusch | |
| 5.3. Disposal of sewage effluent and biosolids in eucalyptus plantations: a lysimeter simulation study | 433 |
| Pinchas Fine, Nir Atzmon, Fabrizio Adani, and Amir Hass | |
| 5.4. Phytoremediation of explosives in toxic wastes | 455 |
| Thomas Vanek, Ales Nepovim, Radka Podlipna, Anja Hebner, Zuzana Vavrikova, Andre Gerth, Hardmuth Thomas and Stanislav Smrcek | |
| 5.5. Floating aquatic macrophytes as a decontamination tool for antimicrobial drugs..... | 467 |
| Cinzia Forni, Caterina Patrizi and Luciana Migliore | |

| | |
|--|------------|
| 5.6. Plant tolerance to heavy metals, a risk for food toxicity or a means for food fortification with essential metals: the <i>Allium Schoenoprasum</i> model | 479 |
| Avi Golan-Goldhirsh | |
| | |
| 6. Assembled Plant and Microbial Technologies for Bioremediation of Pollutants | |
| | |
| 6.1. Ecoremediation. Cooperation between plants and soil microorganisms, molecular aspects and limits | 489 |
| Michel Tissut, Muriel Raveton and Patrick Ravanel | |
| | |
| 6.2. Anaerobic dehalogenation of halogenated organic compounds: novel strategies for bioremediation of contaminated sediments..... | 505 |
| Max M. Häggblom, Donna E. Fennell, Young-Beom Ahn, Beth Ravit, and Lee J. Kerkhof | |
| | |
| 6.3. Molecular tools for microbial remediation - contaminants uptake, metabolism and biosensing | 523 |
| Eliora Z. Ron | |
| | |
| 6.4. Role of mycorrhizal fungi in phytoremediation and toxicity monitoring of heavy metal rich industrial wastes in Southern Poland | 533 |
| Katarzyna Turnau, Elzbieta Orłowska, Przemysław Ryszka, Szymon Zubek, Teresa Anielska, Stefan Gawronski and Anna Jurkiewicz | |
| | |
| 6.5. Biodegradation of petroleum hydrocarbons by keratinolytic fungi | 553 |
| Krzysztof Ulfig, Wioletta Przysaś, Grażyna Płaza and Korneliusz Miksch | |
| | |
| 7. Management strategies for large-area contaminated sites | |
| | |
| 7.1. Integrated management strategy for complex groundwater contamination at a megasite scale | 567 |
| Grzegorz Malina, Janusz KrupaneK, Judith Sievers, Jochen Grossmann, Jeroen ter Meer and Huub H.M. Rijnaarts | |

| | |
|--|------------|
| 7.2. Management options for regionally contaminated aquifers: a case study at Bitterfeld, Germany | 579 |
| Holger Weiss, Birgit Daus, Susanne Heidrich, Arno Kaschl, Mario Schirmer, Peter Wycisk, Jochen Grossmann and Martin Keil | |
| Subject Index | 591 |

PREFACE

In every respect, human development and human security are closely linked to the productivity of ecosystems. Our future rests squarely on their continued viability.

UNDP, UNEP, World Bank, World Resources Institute: *World Resources 2000-2001. People and Ecosystems. The Fraying Web of Life.*

1. OBJECTIVE OF THE BOOK

Soil, surface waters/sediments and shallow unprotected groundwater aquifers are interrelated compartments of the environment that are particularly easy to compromise, sensitive to short- and long-term pollution and directly affect sustainability of ecosystems and human health. Routine human activity such as application of fertilizers and pesticides in agriculture and forestry, or wet and dry deposition of atmospheric pollutants emitted from industrial plants, waste disposal and other practices adversely affect soil and water quality that already increasingly suffers from mismanagement in many areas. The predominant sources of pollution result in non-point contamination that is particularly difficult to reduce and control. Wars, accidents and natural emergency cases such as catastrophic floods that occur partly due to anthropogenically disturbed global water balance also add to overall increase of diverse contaminant loads in soil and water. Beneficial properties of some bulk waste materials such as biosolids (sewage sludge), biowaste (e.g. municipal waste composts) or fly ash from coal combustion

encourage applying these waste to land as a source of nutrients and organic matter, or as a soil amendment. All these human activities result in soil being a sink for all possible chemicals, also new ones, that belong to many groups of xenobiotics - organic compounds such as halogenated organics (AOX), linear alkylbenzene sulfonates (LAS), Di(2-ethylhexyl)phtalate (DEHP), nonylphenol and ethoxylates (NPE), polychlorinated biphenyls (PCBs), polychlorinated dibenzo-dioxins and furans (PCDD/F), organotins (MBT, DBT, TBT), and various pharmaceuticals. Heavy metals and metalloids, and some organic compounds, e.g. polycyclic aromatic hydrocarbons (PAH) that occur in nature but in much lower concentrations, are also of particular concern due to their persistence and toxicity. There is growing evidence of mutagenicity, genotoxicity and endocrine disruption impact of many chemicals on soil and aquatic organisms – primary receptors of soil and water contaminants - and their declining biodiversity. Other organisms – participants of the food web, including humans – have been also endangered.

During the history of human development and industrial revolution, mankind for a longer time ignored warning signs that its activity might damage the capacity of ecosystems to sustain us. Now, at the beginning of the third Millennium we are much more aware of our utter dependence on the productivity of ecosystems that is largely determined by the quality of their essential compartments: soil and water, and of the costs of their degrading and restoration. We also know much more about the processes that govern the fate and migration of contaminants in the environment. Nevertheless, we still know surprisingly little to be able to answer the basic question set up in the special millennial edition of the World Resources Report, *World Resources 2000-2001* (UNDP-UNEP-World Bank-World Resources Institute, 2000): "How best can we manage ecosystems so that they remain healthy and productive in the face of increasing human demands?" And how best can we manage soil and water resources to keep them healthy and productive?

We inherited a huge number of contaminated sites that have to be efficiently and cost-effectively restored, of different size and origin. We still continue to make mistakes in view of current benefits, and ignoring the precautionary principle and our limited knowledge. The development of this knowledge to enable correct prognosis of environmental behavior, bioavailability and impact of chemicals on living organisms is a priority task for better environmental management.

The data on long-term environmental behavior of many xenobiotics and efficient methods of their control are still scarce. Also data on heavy metals of anthropogenic origin are insufficient, in particular with respect to metals mobility, bioavailability and its alteration in time. New concepts and approaches in science that merge biology and chemistry will provide better simulation of contaminant bioavailability in real soil and aquatic systems, and thus a better basis for correct decisions.

A prerequisite of sound ecosystem management decisions is monitoring of soil and waters that should provide reliable data for solid scientific assessment and its validation, and for supporting and verifying environmental management decisions.

Another emerging task of soil and water screening/monitoring comes from the hazards of eco-terrorism, as these compartments are particularly easily available for an attack, consisting of hazardous chemical, microbiological and biochemical poisoning of water. The specific nature of ecoterrorist's attack requires application of specific techniques, in particular identifying unknown substances and mixtures, type of hazardous action, as well as the extent of acute toxicity and its spatial and temporal extinction. Such topics as advanced "field" and "on-site" analytical techniques, optical sensors and immunochemical-based methods, the miniaturization of instrumentation to permit its use in a field setting for screening/ monitoring is of particular timeliness and urgent need.

In all cases, soil and water monitoring tools should provide an early warning, to prevent, intercept or minimize contamination before the environmental damage proceeds too far.

Minimization of potential of soil and water contamination, also due to use of waste materials such as sewage sludge and other biosolids for soil amendment requires source control of contaminants' emission not only from large industries, but also from small artisan enterprises. For this purpose, simple and inexpensive methods, preferably with use of abundant waste materials, e.g. as efficient and cost-effective sorbents of pollutants may be used. In this way the contaminant loads in sewage sludge from municipal treatment plants could be efficiently reduced, therefore reducing also sewage sludge (biosolids) non-point pollution potential to amended soils. In turn, the opportunities that are brought about by application of many rapidly developing techniques such as permeable reactive barriers for either cutting off the accessibility of reagents causing generation of hazardous contaminants, or reacting with hazardous substances that results in bonding, or decomposing, or transforming them into non-hazardous substances are not yet fully utilized. Many novel solutions might be found in this area, or already known solutions might find a new area of application. Permeable reactive barrier techniques and new sorbents might be equally applicable both for prevention of pollution through control of contaminant generation or transformation them into non-hazardous compounds, but also for efficient remediation of soil and/or water contamination or neutralization of an acute toxicity that might result from accident or eco-terrorism. In all cases, the mechanism of action is of the first priority, but optimization of technical construction/application details are of no lesser importance for assuring efficiency and cost-effectiveness. In the permeable reactive barriers, and other preventive/remediation measures, a number of novel integrated physicochemical and biochemical methods can be used.

The remediation solutions for water/sediments and soil pollution should be focused on non-destructive methods that would allow preservation of soil properties during and after decontamination. One such non-destructive method is phytoremediation, i.e. selection of the best contaminant scavengers applicable in the relevant environment and climatic conditions. for contaminant uptake by plants from water/sediment/soil.

Remediation of soils, water/sediments and groundwater contaminated by complex mixtures of organic pollutants and heavy metals is one the greatest challenges facing environmental restoration. There is therefore a significant demand for environmentally safe and economically feasible technologies for treatment of contaminated ecosystems. Although fundamental and applied studies have provided many novel treatment technologies, we must improve the means to bridge between research and practice, and means to combine different capabilities.

Microbial biotransformations of organic contaminants have been widely observed in soils and sediments, while heavy metal contaminants may be immobilized by the action of metal-reducing bacteria or through sulfide precipitation by sulfate-reducing bacteria. Microbial processes are especially attractive, since biodegradation can result in complete mineralization of organic contaminants or lead to significant reduction in their toxicity. Plant based technologies, phytoremediation, are of interest in the ability of plants sequester contaminants on the one hand, and enhance microbial activities in their root zone, on the other. Accelerated in situ decontamination and/or detoxification through stimulation of desirable microbial and plant-mediated processes can shorten the time frame needed for site remediation, thereby reducing the costs of long term monitoring. Remediation that exploits these natural in situ biological processes, combined with in-place containments, potentially avoids redistribution of the contaminants.

The objective of this book is to summarize and critically assess the current status, development trends and needs of three basic defensive elements that safeguard the quality and environmental safety of soil and water/sediments: early warning monitoring, protection and remediation measures, with particular regard to the viability of methods and technologies, i.e. easiness-to-use, reliability, cost-effectiveness, high efficiency and non-destructive character of remediation that is of particular importance considering the scale of application.

The priority aim of the book is to contribute to the improving maintenance of ecosystems, and specifically to summarize and add to information on how best to protect our soils and aquifers, prevent movement and mobilization of pollutants and how to enhance their degradation and/or immobilization. The remediation solutions for soil pollution are focused on non-destructive methods that would preserve soil properties during and after decontamination.