

# Geochemical Soil Atlas of Switzerland – Distribution of Toxic Elements

Jolanda E. Reusser\*, Maja B. Siegenthaler, Lenny H. E. Winkel, Daniel Wächter, Ruben Kretzschmar, and Reto G. Meuli

**Abstract:** Chemical elements such as copper and molybdenum are essential for animal and human health but may become toxic at elevated concentrations depending on the exposure and intake rate. Other elements such as mercury pose a threat to human health at already low concentrations. The soil acts as the main source of these elements for plant uptake and is thus driving accumulation along the food chain. However, in Switzerland, no nationwide information on elemental distributions in soils has existed up to now. The geochemical soil atlas of Switzerland will fill this gap by presenting the concentration ranges and the spatial distribution of 20 elements in the topsoil. In this summary, we present the methodological approaches and some main findings of the atlas with a focus on toxic elements as well as elements that can be or are toxic at higher concentrations.

**Keywords:** Geochemistry · Soil chemistry · Soil contamination · Soil mapping · Trace elements

**Jolanda E. Reusser** is an environmental engineer and received her PhD on the speciation of phosphorus compounds in soil using nuclear magnetic resonance spectroscopy at ETH Zurich. She worked as a postdoctoral researcher on the ‘Geochemical Soil Atlas of Switzerland’ project within the Swiss Soil Monitoring Network (NABO) at Agroscope, Zurich-Reckenholz. Currently, she is employed as a postdoctoral researcher in the group of Inorganic Environmental Geochemistry at ETH Zurich and in the group of Soil Quality and Soil Use at Agroscope.

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**Lenny H. E. Winkel** is an Associate Professor of Inorganic Environmental Geochemistry at ETH Zurich and Eawag. She obtained her PhD in Geochemistry at ETH Zurich in 2006. After postdoctoral appointments in France, UK, and Greece, in the frame of an EU project, she was awarded a SNSF professorship in 2011 and promoted to Associate Professor at ETH Zurich in 2018. Her current research is aimed at understanding the processes controlling the biogeochemical cycling and environmental distribution of trace elements through a combination of field, lab, and modelling approaches.

**Daniel Wächter** holds an engineer (FH) degree in Environmental Engineering from the University of Applied Sciences (ZHAW). He recently transitioned to a role as a Data Management Specialist at the Swiss Competence Center for Soil (KOBO), part of the Bern University of Applied Sciences, starting in August 2023. Prior to this, he worked at Agroscope, Zurich-Reckenholz, where he was responsible for quality assurance within the Swiss Soil Monitoring Network (NABO).

**Ruben Kretzschmar** is a soil scientist specialized in environmental soil chemistry and mineralogy. He received his PhD in 1994 at North Carolina State University, NC, USA, and has been a Professor of Soil Chemistry in the Department of Environmental Systems Science at ETH Zurich since 1999. His recent research focused on the speciation and bioavailability of trace elements in redox-affected soils and their coupling to major elements such as iron, manganese, sulfur, and carbon.

**Reto G. Meuli** is a physical geographer specialized in soil science. After receiving his PhD from ETH Zurich in 1997 on ‘Geostatistical analysis of regional soil contamination by heavy metals’, he worked as a soil- and contaminated site specialist in Switzerland. From 2008 to 2023, he was the head of the research group Swiss Soil Monitoring Network (NABO) at Agroscope, Zurich-Reckenholz. He was also a board member of the Soil Science Society of Switzerland (2010–2022), of which he was President in 2012–2014.

## 1. Soil – Source of Essential and/or Toxic Elements

Elements such as calcium and magnesium are essential for organisms, others like mercury and cadmium can pose a health threat even at low concentrations.

The plant uptake from the topsoil (0–20 cm) is considered an important driver for the enrichment of essential and/or toxic elements in animal and human nutrition. In soils, elements originate from various sources, such as weathering of the bedrock or inputs from atmospheric deposition, and are influenced by different mobilisation and immobilisation processes<sup>[1]</sup> (Fig. 1).

The quantity of an element taken up by plants not only depends on its chemical form and bioavailability but also on its total concentration in soil. Total element concentrations exhibit great spatial variability due to the various sources and sinks. The spatial distribution of elements in soils can be assessed and visualised in geochemical soil atlases, for example, the geochemical soil atlas of England and Wales<sup>[2]</sup> or the geochemical soil atlas of Europe,<sup>[3]</sup> in which Switzerland is represented by 17 sampling sites. Based on the spatial distribution, regions with low concentrations of essential elements or toxic concentrations of elements can be defined. Therefore, geochemical soil atlases serve as a basis to develop measures for soil protection and protection of plant, animal, and human health in specific areas. Furthermore, important back-

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# Geochemical Processes In Soil And Groundwater Geoproc 2002 Research Report

**Agnes C. Rola, Herminia Arocena-  
Francisco, Jennifer P. T. Liguton**



## **Geochemical Processes In Soil And Groundwater Geoproc 2002 Research Report:**

**Winning the Water War** Agnes C. Rola, Herminia Arocena- Francisco, Jennifer P. T. Liguton, 2004 The British National Bibliography Arthur James Wells, 2003 **American Book Publishing Record**, 2004 *Globaler Wandel und regionale Entwicklung* Reinhard F. Hüttel, Rolf Emmermann, Sonja Germer, Matthias Naumann, Oliver Bens, 2011-05-30 In dem Band werden die Auswirkungen des globalen Wandels hinsichtlich der Nutzung der Ressourcen Wasser und Boden analysiert und mögliche Anpassungsstrategien diskutiert Auch wenn diese Fragen am Beispiel der Region Berlin Brandenburg untersucht werden haben die Autoren ihre Analysen und Empfehlungen bewusst so ausgestaltet dass sie auf vergleichbare Regionen übertragen werden können Mit ihrer interdisziplinären Perspektive bietet diese Untersuchung eine erste Orientierung für die Entwicklung geeigneter Anpassungsstrategien **5th ICEG Environmental Geotechnics** Hywel R. Thomas, 2006 *Geochemical Processes in Soil and Groundwater* Horst D. Schulz, Astrid Hader, 2003-12-09 The central scientific question of the priority program was to improve the knowledge of geochemical processes in seepage and groundwater with the specific aim to quantify the impact of human influences From the very beginning the priority program was restricted to those questions that could be handled within the limited period of six years Hence we concentrated on three groups of substances Natural organic substances anthropogenic organic substances i.e. PAK BTEX PCB as well as metals relevant to the environment This volume has two slightly different objectives First of all it represents the international conference GeoProc2002 which took place in Bremen from March 4-7 2002 a meeting that was designed specifically to address the subject of geochemical processes in seepage and groundwater Over six years the German Science Foundation DFG funded priority program 546 Geochemical Processes with long term effects in anthropogenically affected seepage and groundwater The results of 6 years of research were presented at the GeoProc2002 conference and therefore this book also represents the conclusion of this priority program **Geochemical Processes, Weathering and Groundwater Recharge in Catchments** O.M. Saether, P. de Caritat, 2020-08-19 Geochemical Processes Weathering and Groundwater Recharge in Catchments is a specialist book concerned with the natural processes taking place where water interacts with minerals and organic matter at the earth's surface in soils or within aquifers It focuses on the all important interface between the hydrological and geochemical cycles in terrestrial ecosystems and is thus particularly relevant to understanding the environment The book is intended primarily as a reference text for graduate students in Earth Sciences Hydrology or Environmental Sciences but will be a useful introduction to those studying Chemistry Biology or Forestry Studies Geochemical Processes Weathering and Groundwater Recharge in Catchments presents an overview of the current status of knowledge of catchment studies with an outline of the challenges of future research Geochemical Processes Horst D. Schulz, Georg Teutsch, 2002 **Geochemical Processes, Weathering and Groundwater Recharge in Catchments** Ola M. Saether, Patrice de Caritat, 1997 Geochemical Processes Weathering and Groundwater Recharge in Catchments is a

specialist book concerned with the natural processes taking place where water interacts with minerals and organic matter at the earth's surface in soils or within aquifers. It focuses on the all important interface between the hydrological and geochemical cycles in terrestrial ecosystems and is thus particularly relevant to understanding the environment. The book is intended primarily as a reference text for graduate students in Earth Sciences, Hydrology or Environmental Sciences but will be a useful introduction to those studying Chemistry, Biology or Forestry Studies.

*Geochemical Processes: Weathering and Groundwater Recharge in Catchments* presents an overview of the current status of knowledge of catchment studies with an outline of the challenges of future research. *Geochemical and Hydrologic Processes and Their Protection* Sidney Draggan, John J. Cochrane, Richard Morrison, Council on Environmental Quality (U.S.). Interagency Subcabinet Committee on Long-term Environmental Research, 1987-06-11. In 1984 the Conference on Environmental Quality the Environmental Protection Agency and the National Science Foundation convened a series of panel meetings to discuss long term environmental issues. *Environmental Impacts on Human Health* is the result of that prestigious conference. Drawing on contributions from nationally recognized scientists and experts from industry and government this collection of papers will help to redirect long term environmental research and development. The book addresses four topic areas: surface and groundwater processes and pollution; land soil processes and pollution; atmospheric oceanic processes and pollution; and multimedia toxic substance hazardous waste research.

*Groundwater Geochemistry* William J. Deutsch, Randy Siegel, 2020-11-25. *Groundwater Geochemistry: Fundamentals and Applications to Contamination* examines the integral role geochemistry plays in groundwater monitoring and remediation programs and presents it at a level understandable to a wide audience. Readers of all backgrounds can gain a better understanding of geochemical processes and how they apply to groundwater systems. The text begins with an explanation of fundamental geochemical processes followed by a description of the methods and tools used to understand and simulate them. The book then explains how geochemistry applies to contaminant mobility, discusses remediation system design, sampling program development and the modeling of geochemical interactions. This clearly written guide concludes with specific applications of geochemistry to contaminated sites. This is an ideal choice for readers who do not have an extensive technical background in aqueous chemistry, geochemistry or geochemical modeling. The only prerequisite is a desire to better understand natural processes through groundwater geochemistry.

*Geochemical Processes* Horst D. Schulz, Georg Teutsch, 2002-12-25. This book is a result of the Priority Programme 546 run by the Deutsche Forschungsgemeinschaft. It presents the various ideas, concepts and conclusions that resulted from this Programme on the subject of geochemical processes with long term effects in anthropogenically influenced drainage and ground water.

*Surface and Ground Water, Weathering, and Soils* J.I. Drever, 2005-11-21. Volume 5 has several objectives. The first is to present an overview of the composition of surface and ground waters on the continents and the mechanisms that control the compositions. The second is to present summaries of the tools and methodologies used in

modern studies of the geochemistry of surface and ground waters The third is to present information on the role of weathering and soil formation in geochemical cycles weathering affects the chemistry of the atmosphere through uptake of carbon dioxide and oxygen and paleosols preserved soils in the rock record provide information on the composition of the atmosphere in the geological past Reprinted individual volume from the acclaimed Treatise on Geochemistry 10 Volume Set ISBN 0 08 043751 6 published in 2003 Present an overview of the composition of surface and ground waters on the continents and the mechanisms that control the compositions Provides summaries of the tools and methodologies used in modern studies of the geochemistry of surface and ground waters Features information on the role of weathering and soil formation in geochemical cycles Contains information on the composition of the atmosphere in the geological past Reprinted individual volume from the acclaimed Treatise on Geochemistry 10 volume set *Geochemistry, Groundwater and Pollution* C.A.J. Appelo,Dieke Postma,2004-06-24 Building on the success of its 1993 predecessor this second edition of *Geochemistry Groundwater and Pollution* has been thoroughly re written updated and extended to provide a complete and authoritative account of modern hydrogeochemistry Offering a quantitative approach to the study of groundwater quality and the interaction of water minerals **Groundwater Geochemistry** William J. Deutsch,Randy Siegel,2013 This book offers an introduction to the geochemical processes in the subsurface that produce the composition of groundwater found in an aquifer It covers the basic processes from mineral dissolution and precipitation to adsorption desorption an understanding of which provides investigators with the knowledge to interpret the chemical evolution of groundwater and the tools to develop practical effective remediation methods The book also discusses the application of geochemical modeling for natural and contaminated sites Completely updated this second edition includes several new chapters and a new glossary

**Contaminant Geochemistry** Brian Berkowitz,Ishai Dror,Bruno Yaron,2009-09-02 Combining earth science subsurface hydrology and environmental geochemistry this book provides a comprehensive background for those interested in the protection and sustainable management of the subsurface environment The reader is introduced to the chemistry of contaminants which usually disturb the natural equilibrium in the subsurface as a result of human activity One focus of the book is on contaminant reactions in soil solutions Discussions on case studies are provided Heterogeneous Processes of Geochemical Migration V. S. Golubev,Artemii Artashesovich Garibiants,Artemii Artashesovich Garibiants,1971 The problem of the geochemical migration of elements has received wide attention in the works of V I Vernadskii and A E Fersman 1 2J Vernadskii considered geochemistry to be the science of the history of chemical elements on the earth their distribution and move ments in space and time and their genetic relations IJ Geochemical migration was defined by Fersman as the movement of chemical elements in the earth s crust leading to their dissemination or concentration The views of Vernadskii and Fersman on the migration of elements have received added support and development in connection with successes in physics chemistry biology and other sciences According to Fersman the earth is looked upon as a cosmic body

characterized by common origin and Similarity of composition with the sun the planets meteorites and other bodies of the solar system The scale and trend of geochemical migration of elements in the earth are determined by the initial state of terrestrial matter its thermal history and the scale of time The rules of elemental migration are determined by internal and external factors Fersman distinguishes five groups of internal factors i e Groundwater Geochemistry William J. Deutsch, 2003 Groundwater Geochemistry Fundamentals and Applications to Contamination examines the integral role geochemistry plays in groundwater monitoring and remediation programs and presents it at a level understandable to a wide audience Readers of all backgrounds can gain a better understanding of geochemical processes and how they apply to groundwater systems The text begins with an explanation of fundamental geochemical processes followed by a description of the methods and tools used to understand and simulate them The book then explains how geochemistry applies to contaminant mobility discusses remediation system design sampling program development and the modeling of geochemical interactions This clearly written guide concludes with specific applications of geochemistry to contaminated sites This is an ideal choice for readers who do not have an extensive technical background in aqueous chemistry geochemistry or geochemical modeling The only prerequisite is a desire to better understand natural processes through groundwater geochemistry Geochemical Processes in a Transition Zone Between Surface Water and Acidic, Metal-rich Groundwater Shawn Gavin Benner, 1994

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