Critical Physical Geography

# The Field Guide to Mixing Social and Biophysical Methods in Environmental Research

Edited by
Rebecca Lave and Stuart Lane

https://www.openbookpublishers.com



All external links were active at the time of publication unless otherwise stated and have been archived via the Internet Archive Wayback Machine at https://archive.org/web

Any digital material and resources associated with this volume will be available at https://doi.org/10.11647/OBP.0418#resources

Critical Physical Geography: Interdisciplinary Approaches to Nature, Power and Politics Vol. 1
ISSN (print): 3049-7469
ISSN (digital): 3049-7477

ISBN Paperback: 978-1-80511-366-9
ISBN Hardback: 978-1-80511-367-6
ISBN Digital (PDF): 978-1-80511-368-3
ISBN Digital eBook (EPUB): 978-1-80511-369-0
ISBN HTML: 978-1-80511-370-6

DOI: 10.11647/OBP.0418

Cover image: Stuart N. Lane, When the "environment" tries to tell you that you are measuring the wrong thing (2023), all rights reserved
Cover design: Jeevanjot Kaur Nagpal

# 41. Soil toxicological analysis

*Salvatore Engel-Di Mauro*

## Definition

Soil toxicological analysis refers to the interpretation of laboratory and/or field tests done on soil samples to determine the concentrations of organic and/or inorganic substances or elements that, depending on the form, intensity, and duration of exposure, may lead to the premature mortality or adverse health effects for humans and/or other beings or compromise ecosystem functions (see Malone, Chapter 16). Soil toxicology is associated with biophysical research, especially at the intersections of the environmental, health, soil, biological, and ecological sciences.

## The basics of soil toxicological analysis

The objective of soil toxicological analysis is to determine the potential harm for given levels of different substances pre-existing or accumulated in soils. It is an assessment of toxicity arising from human impacts, which have become primary causes of soil contamination. As part of the analysis, one must control for toxicity levels originating from material out of which soils formed (geogenic sources) and/or added to soils over time from non-human sources. A main part of the analysis consists in identifying which soil and related ecological components hold what amount of which toxic substance, namely, soil mineral particle surfaces (especially clays and amorphous minerals), soil organic matter, soil water, soil air, and organisms living in and on soils (e.g., bacteria, earthworms, fungi, plants). This helps determine which organisms

 https://doi.org/10.11647/OBP.0418.41

could be most affected, the residence time and potential fate of different chemicals, the degree of availability and accessibility of the different substances for different organisms, among other issues related to toxicological assessment. Chemical and physical tests on soil samples are ideally supplemented by biological assays, developing models from dose-response tests on a variety of organisms to evaluate the degree of human health hazard or wider ecological ramifications.

## Soil toxicological analysis in depth

Many kinds of substances or elements exist that can be harmful to us or other organisms. Harmful substances or elements are broadly classified as heavy metals or metalloids, solvents and vapours, radiation and radioactive materials, dioxins and furans, and pesticides. Toxic substances released by organisms are categorised according to the organism releasing such substances. There are many other environmental sources of harmful substances or elements, such as volcanic eruptions (e.g., hydrogen sulphide), large fires (e.g., polycyclic aromatic hydrocarbons from wood combustion), or sedimentary strata (e.g., lead from pozzolanic ash deposits). However, most soil toxins, degradable and persistent, originate from industrialised production systems since at least the late 1700s.

Determining whether and when a substance or element is toxic (soil-polluting) presents some challenges. It generally depends on the amount and characteristics of a substance or element, environmental conditions, the species (or type of organisms) considered, the level of accessibility to specific organisms, and how easily the toxin can be assimilated into (the dose) and expelled from an organism's body. A substance or element is considered a soil contaminant when it has the potential to undermine organisms' health or the functioning of an ecosystem. Soil contamination is when the concentration of an element or substance is higher than background levels, while soil pollution implies levels deemed harmful for humans, a given set of organisms, and/or an ecosystem.

Results of toxicological analysis are typically compared to established soil quality standards and/or soil screening levels that often vary among and even within countries (see Malone, Chapter

16 for related issues). These standards and screening levels specify concentrations for different elements and substances deemed to pose risks to human and/or other organisms' health and/or to ecosystem functioning based on assumed forms and degree of exposure and known toxicity data. Soil-borne contaminant exposure pathways include inhalation, ingestion, and skin absorption. The relative importance of each varies over time and space since, especially in areas frequently impacted by human activities, there are also indirect forms of exposure, such as consuming food produced on polluted soils or contaminated by lodged soil particles from polluted soil.

Exposure pathway processes are complicated by synergistic and/or antagonistic interactions among pollutants and by variable soil environmental conditions (e.g., reduction-oxidation reactions, pH, microbial activities, root exudates, etc.) that can temporarily attenuate, amplify, or neutralise pollutants or, in the case of organic pollutants, degrade them to harmless or at times even more toxic by-products. Given pathway variability and contingency, additional investigations on exposure and bioaccessibility should be conducted to evaluate hazard levels and risk, which must also be related to degrees of vulnerability and capacity in an affected community.

## Why is soil toxicological analysis important?

Determining soil toxicity levels is basic to general assessments of mainly terrestrial environment pollution levels. Soil toxicological analysis helps detect sources of contamination impacting other processes like air quality, food systems/webs, water supplies, and near-coastal ecosystems. It is thereby important to efforts promoting human and/or other organisms' health as well as ecosystem functioning. As terrestrial environmental pollution may be hidden intentionally, or simply not known about, soil toxicological analysis may be important in identifying instances of environmental injustice.

## Relationship of soil toxicological analysis with other methods

Soil toxicological analysis necessitates, at the very least, an understanding of the characteristics and dynamics particular to the contaminated or polluted soils. Yet the interpretation of findings requires studying of wider ecological and social context and implications. This is because a substance or element found in soil is toxic in relation to the characteristics of the organism or organisms considered, to the biophysical interactions within and beyond soil that accentuate or attenuate a contaminant's diffusion and accessibility to organisms, and to the specific circumstances or environmental conditions lived by the organism or organisms affected. These factors need to include social relations that result in some people being exposed more than others to soil-borne toxicities.

A decisively influential factor, often ignored, is the social setting of the scientific investigation, from conception through interpretation of results and policy recommendations. Such activities are always shaped by social background and position, as in any human endeavour, so there ought to be explicit critical self-reflection relative to the political ramifications of findings, the way in which data are divulged, and with whom such data are shared. Hence, an evaluation of soil toxicological analysis from a critical social science perspective is important.

Further, given that biophysical interactions affecting contamination processes in most cases involve human action, studying the social forces behind the introduction and spread of contaminants in soils is necessary to address contaminant sources and effects. At a minimum, social science methodologies such as participatory approaches (see Mokos, Chapter 36), questionnaire surveys and/or interviews (see Johnston and Longhurst, Chapter 32; Winata and McLafferty, Chapter 43), and studies of local land use histories aid in evaluating contamination sources and differential health effects and vulnerabilities (as linked to social relations of power and modes of oppression). Equally important are perspectives and methodologies from other biophysical sciences. For instance, ecological research on local biological communities can reveal potentials for ecosystem cascading effects and geochemical investigations can help distinguish environmental from human sources of contaminants. Put differently, soil toxicological analysis alone cannot form the basis of toxicity assessment without perspectives and methodologies from the social sciences and other biophysical sciences.

## Ethical issues and soil toxicological analysis

When studying the levels of toxicity in soils, there are at least four major issues to keep in mind, aside from considerations of other organisms' populations' survivability and overall ecosystem functioning. The first is gaining the confidence of those who might be impacted by soil toxicity and communicating with them in an accessible language (Malone, Chapter 16). Workshops focused on sharing technical knowledge are critical. A second issue is that there should be discretion about results. The form and extent of data disclosure should be discussed with the community directly affected before any soil sampling occurs, and the researcher must be careful to avoid harming the community with their findings (e.g., when findings of contamination are used to justify paving over a community garden and appropriating the land for other uses). To avoid this, the researcher should make sure they are informed about local concerns and power relations and consult frequently with the communities implicated in their research. A third concern is the potential for creating undue alarm relative to results, which can undermine the well-being of a community directly affected. Results should always be considered in relation to other pollution sources and health hazards, and to existing soil pollutant exposure levels, which may be minimal. This is linked to a fourth ethical matter of providing guidance on exposure mitigation or avoidance, which should be discussed from the beginning with the community involved.

## Issues to be aware of in using soil toxicological analysis

Total element or substance data do not denote the level or form of exposure, nor the proportion of the pollutant concentration that is bioavailable (that is, in forms that can be accessed by an organism) and bioaccessible (that is, that can be metabolised and bioaccumulated). The amount of bioavailability and bioaccessibility depends on soil characteristics, varying physico-chemical conditions, and soil ecological processes, as well as on the pollutants' characteristics and how organisms are exposed and vulnerable to them. In terms of human health, social relations of power affect the degrees of vulnerability to differing exposure levels and capacity to reduce exposure (Malone, Chapter 16). Hence, total concentrations may be above soil quality standards or screening levels and nevertheless be relatively harmless. Other factors must be investigated to determine the level of hazard and risk.

Toxicity data do not encompass all organisms and cannot address the social processes involved in the kind and level of exposure. Toxicity data are incomplete, especially relative to the tens of thousands of industrially produced compounds in existence. It may sometimes be necessary to carry out additional studies to evaluate the levels of toxicity for a substance or element in a soil.

Because soils are comprised of dynamic sets of interactions and processes that vary over time and space, it is essential to obtain up to date and geographically detailed information on the main soil properties that affect the extent of a pollutant's toxicity (e.g., bioavailability and bioaccessibility). This implies carrying out analyses on soil characteristics beyond just the substances or elements being studied.

As a result of the above, pollutant toxicity levels vary over time and space according to changing soil and wider ecological and social conditions. Results of soil toxicological analyses cannot be assumed to be applicable beyond the spatio-temporal scale of the study. Studies focused on human health, sampling, and analyses over decades and in multiple areas provide much greater confidence about pollutant effects.

## Suggested further reading

Some open-source overviews of soil toxicological analysis include:

*Agency for Toxic Substances and Disease Registry*, https://www.atsdr.cdc.gov/index.html.
This is a public agency of the United States that provides a searchable catalogue with detailed information on the characteristics of substances and elements toxic to humans.

*European Chemicals Agency* , https://echa.europa.eu/search-for-chemicals.
A searchable database for substances and elements falling under European Union regulations, which tend to be stricter than in the United States.

FAO and UNEP. 2021. *Global Assessment of Soil Pollution—Summary for Policy Makers* (FAO), https://doi.org/10.4060/cb4827en.
The publication includes overviews of soil contaminants and their health and ecological effects in ways that are accessible to a lay readership.

*Pesticides Property Database*, http://sitem.herts.ac.uk/aeru/ppdb/en/.
An online searchable pesticides database, hosted by the University of Hertfordshire (UK), providing human health and ecotoxicological data.

# References cited

Alengebawy, A., S.T. Abdelkhalek, S.R. Qureshi, and M.Q. Wang. 2021. 'Heavy metals and pesticides toxicity in agricultural soil and plants: Ecological risks and human health implications', *Toxics*, 9.3.

Brevik, E.C. and L.C. Burgess. 2013. *Soils and Human Health* (CRC Press).

Davis, L.F., M.D. Ramírez-Andreotta, and S. Buxner. 2020. 'Engaging diverse citizen scientists for environmental health: Recommendations from participants and promotoras', *Citizen Science: Theory and Practice*, 5.1, pp. 1–27.

Longhurst, R. and Johnston, L., Chapter 27, this volume. 'Focus groups.'

Mokos, J., Chapter 36, this volume. 'Participatory methods.'

Ramírez-Andreotta, M.D., R. Walls, K. Youens-Clark, K. Blumberg, K.E. Isaacs, D. Kaufmann, and R.M. Maier. 2021. 'Alleviating environmental health disparities through community science and data integration', *Frontiers in Sustainable Food Systems*, 5.

Winata, F. and McLafferty, S., Chapter 43, this volume. 'Survey and questionnaire methods.'