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Brief Communication

The upcoming European Soil Monitoring Law: An effective instrument for the protection of terrestrial ecosystems?

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Abstract

Soils are a precious resource consistently placed under several threats and urgently in need of protection within a regulatory framework at the European level. Soils are central to the provision of environmental services as well as human existence on earth. The need to protect soil has been identified by several recent European strategies and fortunately, a specific European regulation for soil protection is on the way—the European Soil Monitoring Law (formerly: Soil Health Law). However, efforts need to ensure that the upcoming Soil Monitoring Law closes gaps between existing regulations for chemicals and acknowledges current European strategies for environmental protection and sustainability. This brief communication started from a fruitful discussion among SETAC Global Soils Interest Group members on a recent public consultation on the newly proposed Soil Monitoring Law of the European Commission and highlights critical points focusing on the chemical pollution of soils. We emphasize urgent needs such as the essential definition of a “healthy state” of soils; the implementation of a suitable set of indicators and quality standards for the description of physical, chemical, and biological states of soils; the enforcement of the “polluter-pays” principle; and the establishment of a Europe-wide monitoring program. Results from monitoring need to be fed back into regulatory frameworks, including the regulation of chemicals. Guidance documents for the risk assessment of chemicals are outdated and need to be updated. Finally, actions need to be taken to foster healthy soils, stop biodiversity decline, and ensure the functioning of ecosystem services for future generations. *Integr Environ Assess Manag* 2023;00:1–6. © 2023 The Authors. *Integrated Environmental Assessment and Management* published by Wiley Periodicals LLC on behalf of Society of Environmental Toxicology & Chemistry (SETAC).

KEYWORDS: Chemical risk assessment; Environmental quality standards; Regulatory framework; Soil monitoring; Soil protection

BACKGROUND AND PROBLEM DEFINITION

Soil is a precious but finite and nonrenewable resource. Soils are essential for food supply and serve as a primary filter of water resources, guaranteeing and maintaining water

quality as well as providing several other ecosystem services. Healthy soils support healthy ecosystems, which is also reflected in the myriads of life within, ranging from micro to macro scale and contributing to over 25% of the planet's overall biodiversity (Food and Agriculture Organization of the United Nations [FAO], 2020, van Gestel et al., 2021).

However, soils are constantly impacted by multiple stressors such as land sealed or used for settlements and infrastructure or the exposure to pollutants following industrial and agricultural use. Soil contamination, due to diffuse as well as point source pollution, combined with other stressors, such as unsustainable exploitation and climatic change, has led to downward trends for key soil parameters (FAO, 2020).

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Recent European strategies under the European Green Deal (COM/2019/640) acknowledge the need for action to protect soils with key strategic initiatives and respective new legislative framework proposals, such as the European Soil Strategy for 2030 (COM/2021/699) and the proposed Soil Monitoring Law (COM/2023/416 final, formerly, Soil Health Law), the Farm to Fork Strategy (COM/2020/381) with the Sustainable Use Regulation (COM/2022/0196), the Biodiversity Strategy for 2030 (COM/2020/380) with the Nature Restoration Regulation (COM/2022/304 final), and finally the overarching Zero Pollution Ambition (COM/2021/400). These legislative initiatives recognize the intrinsic value of soils as well as the need to balance economic objectives with the protection of soils as valuable resources supporting life on earth.

Even if several country-specific regulations for soil protection—often focusing on specific issues—are implemented at the Member State level (FAO, 2023), a comprehensive European regulation for soil protection has been lacking so far. However, a specific and legally binding European Soil Monitoring Law has been published in July 2023 by the European Commission (COM/2023/416 final) and might be implemented after discussions within the European Parliament and of the Council in 2025. Nonetheless, several scientific and regulatory actions still need to be taken to design and implement a legally binding framework for soil protection.

OBJECTIVES OF THE LAW AND IMPLEMENTATION OPTIONS

Definition of a “healthy state” of soils

The aim of the European Commission to reach 100% healthy soils by 2050 (COM/2021/699) needs to acknowledge different options and definitions for different land uses, habitats, and soil types. Sealed areas used for settlements, infrastructure, or industry would need a specific approach compared to nearly undisturbed natural areas within strictly protected habitats. Although land use in Europe is very diverse, most surfaces are used for agricultural production (42%) as well as forests (37%) (EC, 2022a). Agricultural sites are threatened by multiple chemical contaminants, such as the direct application of fertilizers and plant protection products, resulting in the disturbance of soil biodiversity (Alengebawy et al., 2021). To acknowledge the impact of land uses and still be able to formulate protection and restoration targets for different soil types, maximum permissible deviations from a “healthy” soil state could be outlined (Pieper et al., 2023), for example, for soils under agricultural use. It is important that the definition of healthy soils is based on parameters and states typical for soils at least under sustainable use practices, rather than on already degraded soils.

Soil types and their associated edaphic properties also need to be considered when defining “healthy” soils; for example, sandy areas are completely different compared to

peaty areas in terms of their typical and healthy biological, physical, and chemical parameter values and ranges.

The definition of a “healthy” state should be linked to habitat and soil types and should be described by the physical, biological, and chemical conditions of the soil (EC, 2022b).

Develop and implement indicators to assess the current state of soils

A suitable set of biotic and abiotic indicators describing the state of soils is urgently needed for the assessment. A suitable toolbox of indicators and thresholds for soil health assessments was recently published (Baritz et al., 2022). The suggested set includes indicators and critical limits for organic carbon, nutrient loss (N and P), acidification, pollution, biodiversity, erosion, compaction, and sealing. Indicators and thresholds are linked to climatic regions, soil textures, and land use types. The suggested indicator “pollution” also includes organic chemicals, which are further elaborated upon in the following paragraphs.

Identify chemical substances with high priority for soils

As suggested by the EU Soil Strategy, a list of priority substances shall be available by 2024. In Europe, 454 active substances of plant protection products are currently approved (EC, 2020). Some of these substances have up to 20 metabolites and some of the latter are the real “active ingredient.” Besides active ingredients, formulated products include surfactants and additives that influence their efficacy and potentially the product's toxicity. Tank mixes and the application spray series can lead to complex mixtures of fresh and older residues of active substances and additives in soils over time. Moreover, unapproved substances are authorized for emergency uses (e.g., neonicotinoids) and legacy chemicals occur in polluted soils. Soils are also impacted by other sources and chemicals, for example, due to local or diffuse contamination including residues from industrial activities, fertilization by manure, sewage sludge, and reused sewage treatment plant water containing pharmaceuticals and biocides residues, as well as from the atmospheric deposition of chemicals.

To focus on substances of emerging concern, sale amounts, use frequencies, and substance properties like the degradation profile, ecotoxicity, and human toxicity, consideration of emergency authorizations, as well as legacy chemicals, should also be required.

High toxicity to nontarget organisms and/or humans in combination with high persistence in soils is crucial for the identification of substances of high priority for soils. Ideally, such substances should be monitored regularly and their use should be severely restricted or limited, for example, by controlling sales and specifying maximum specific loads per unit area.

Readily degradable compounds may also severely impact soil health, due to longer than anticipated persistence in soil, and potentially sustained toxicity, depending on the product coformulants or tank mixtures.

Very toxic substances to the environment should be monitored, possibly in combination with application data. This is relevant so as to avoid erroneously linking effects on soil organism communities to other applied (persistent) chemicals that are still detectable in the soil at sampling times.

Define and implement environmental quality standards (EQS) for chemical pollution

Some Member States have already derived risk-based reference values for several chemical compounds in soil (Baritz et al., 2022; Carlon, 2007). However, legally binding quality standards for chemicals in soil are rare.

Substances bearing high toxicity toward humans and/or the environment as well as showing high persistence should be prioritized when deriving EQS for chemical pollution. Soil quality standards are needed for regulated and legacy chemicals, such as plant protection products, biocides, pharmaceuticals, and other industrial chemicals. Moreover, since several chemicals may coexist in the soil, the assessment of the effects of chemical mixtures on nontarget organisms should also be considered.

Environmental quality standards should be harmonized at the European scale by building and developing on existing frameworks and values already developed by Member States, while remaining flexible to regional and national needs. In fact, a possible workaround and initial step could be a concerted effort to harmonize at the European scale existing soil quality standards among different Member States. However, because soils are naturally heterogeneous, the process of setting values at the European scale will be challenged by several practical issues, due to differences in background levels, land use types, and chemical bioavailability depending on the soil type and climatic differences.

Stricter protection of soils might be useful and necessary in nature conservation areas, whereas chemical burdens in agricultural landscapes might be acceptable at a different tolerable deviation level. Because organisms and organic matter in soils are at the basis of terrestrial trophic networks, including pollinators, birds, and mammals (Potapov et al., 2022), EQS need to account not only for all soil biota but also the interconnected functional framework. Defining EQS for chemical pollution of soil could be used to determine whether contaminant remediation is required or a good status has been reached.

Define and implement indicators for biodiversity

Due to the heterogeneous nature of the soil matrix and the multitude of soils under different climatic and land use conditions, not to mention the range of possible (chemical) stressors, particular attention needs to be paid to the selection of indicators describing soil biodiversity, as also suggested by the European Environment Agency (Baritz et al., 2022).

As stated by FAO (2020), soils provide >25% of the total worldwide biodiversity. Moreover, soil organisms are an important intermediate element in the food web for

different species at higher trophic levels. However, there is still a knowledge gap about the effects and impact of pollution on soil food webs. This gap persists despite the contribution of data from open databases, describing the presence and abundance of soil species, such as “Edaphobase” (Burkhardt et al., 2014).

In frameworks protecting nature and the environment, like the Flora and Fauna Habitat Directive (Directive 92/43/EEC) and the Red Lists for treated species of IUCN, soil invertebrates are poorly represented, which is not surprising as the knowledge and conservation state of soil organisms are mostly unknown (Köninger et al., 2022).

Given that the goals of the Soil Strategy are to reverse soil biodiversity loss and protect or restore soil health, it is important to establish causality and link observed effects to particular stressors. By doing this, sustainable soil management is possible and the current downward trends observed in soils can be reversed. Currently, the chemical occurrence in soils is barely monitored and information about soil biological components, particularly in-soil communities, is largely missing. To protect soil biodiversity and functions, a combined approach is favorable, including data on chemical occurrence and respective EQS observed in biological tests. To this end, in-field records of organism groups (e.g., abundances and species richness for earthworms), microbial communities, and ecosystem functions (e.g., organic matter degradation), combined with the ecotoxicological laboratory endpoints, could be used, in essence adapting a triad approach combining chemical, ecological, and ecotoxicological lines of evidence to determine levels of risk and establish causality between different potential environmental stressors.

To describe the effects on in-soil organisms in natural fields, a reference healthy status needs to be defined. Knowledge of earthworms is fairly significant and some Member States in Central Europe have gathered data on abundance as well as species richness in different habitats (Phillips et al., 2021). An indicator describing expected abundances as well as species richness could be implemented, for example, for Central Europe in the short term and should be used as a starting data set to describe in-field communities. Further indicators for other taxa are needed and should be developed and implemented. They should be able to describe expected values for abundance and species richness for other organisms, like collembolans or mites. Standardization of sampling methods and interpretation of results are also needed.

Adapt the regulatory framework for chemicals

The legislative framework for regulated chemicals is separated into several regulations, such as either regulating the placement of plant protection products on the market (EC 1107/2009) or biocides (EU 528/2012) on the market. Each regulation is designed to assess and amend only one single substance for one intended use, resulting in so-called “regulatory silos” (Sousa et al., 2022). In reality, several inputs of chemicals may occur in soils. Agricultural sites are

sprayed several times within one growing season by more than one plant protection product (Knillmann et al., 2021). Recent monitoring studies show the occurrence of several plant protection product residues in soil samples (Riedo et al., 2021; Silva et al., 2019). Additionally, biocides, pharmaceuticals (Biel-Maeso et al., 2018; Grenni et al., 2018), and other chemical residues might impact the same fields through fertilization or irrigation by reclaimed wastewater (FAO/WHO, 2019). Contaminants can also bio-concentrate and translocate into plants (Barra Caracciolo et al., 2022).

The exposure to mixtures of pesticides and other contaminants to soils and soil biota has been well reported (Bopp et al., 2019; Panico et al., 2022), but is currently not regulated (McCarty et al., 2018). Mixtures of chemical residues with emerging pollutants such as microplastics (Dolar et al., 2021) and nanoparticles need to be better studied and, depending on study results, possibly regulated. To achieve this aim, several initiatives (e.g., the NORMAN network) are actually working to gather such information (Dulio et al., 2020). Currently, the different regulatory frameworks do not consider the multiple exposure of soils to different chemicals and therefore do not assess the current reality of soil organisms being exposed to mixtures of chemicals.

Implement the “polluter-pays” principle

The European Union should oblige its Member States to implement the polluter-pays principle (Ronchi et al., 2019), although some inconsistencies in environmental law are present (Schmidtchen et al., 2021). Denmark is presently the only European Member State applying the principle, with a pesticide tax implemented since 1996. In all other European Member States, society bears the external costs of the application of plant protection products (e.g., biodiversity loss or drinking water contamination). This could be avoided if the sale of chemicals is combined with a tax or levy, depending on the products' toxicology or ecotoxicology as well as its chemical fate and persistence in the environment. A recent analysis suggests implementing a European-level tax or taxes implemented by each Member State (Möckel et al., 2021). This action would allow consistency across Member States, making it possible to steer the use of chemicals in terms of their toxicity toward human health, ecosystems, and persistence, and reach reduction targets set in European strategies, as well as in regulations (e.g., Sustainable Use Regulation).

Establish a Europe-wide monitoring program

Finally, to evaluate trends, as well as to plan restoration and mitigation measures, European monitoring programs on the state of soils (Orgiazzi et al., 2022) should be further implemented and expanded in the short term. A European monitoring program should be representative in terms of (i) climate conditions, (ii) different soil types, and (iii) land use types within the European Union. The physical, chemical, and biological state of soils should be monitored in order to

reach the aims of the European Soil Strategy for 2030 and the provisions of the proposed Soil Monitoring Law.

Besides other parameters like loss of organic carbon, soil erosion, acidification, soil compaction, nutrient sate, soil biodiversity, soil sealing, land take, and soil monitoring should be used to gather data on multiple pathways of chemical contamination, overarching the different regulatory frameworks. It is necessary to consider underlying risk assessment scenarios in terms of the analyzed soil layer, intended use of the chemical, exposure pattern, and all other assumptions made during the establishment of environmental thresholds. In order to compare different monitoring programs and to feed back into the prospective regulation of chemicals, the analyzed soil should include several soil depths to fully characterize the distribution of contaminants and to link the results to environmental effects, fate, and possible threats to groundwater.

Tools are needed that describe the appropriate chemical analytical measures and define target priority substances. Monitoring results need to be combined with indicator thresholds for soil pollution and biodiversity to display trends over time and define priority actions for remediation or soil protection at a site-specific scale. Tang et al. (2021) developed a global map of pesticide risk based on the expected occurrence of pesticides in combination with ecotoxicological thresholds and the occurrence of sensitive areas. Andres et al. (2022) worked on the development of a chemical indicator for terrestrial systems and applied it in a case study on the risk of pesticides for soil organisms in Czechia. A similar approach could be used for other chemicals by using monitoring data to identify sites with high priority for remediation.

Results from monitoring should be fed back to the regulation process of chemicals, allowing Member States to develop action plans to reduce soil chemical pollution. Creating a publicly available database would help to share the results of monitoring activities, as designed by the European Soil Observatory.

Finally, information from soil monitoring should be used to design, establish, and implement remediation and/or restoration measures. Efficacy of remediation and restoration measures need to be monitored and—if needed—adjusted.

OUTLOOK

The implementation of a legally binding Soil Monitoring Law is a positive step in the right direction. However, several actions must be taken to design and implement a legally binding framework for soil protection that will actually be protective. We urgently need a holistic approach that bridges upstream regulations, including the “one substance—one assessment principle” on chemicals and the downstream upcoming soil regulation, which should also tackle mixtures of chemicals. The definition of a “healthy state” of soils should be able to cover different land use types as well as different soil types under different environmental conditions. As this is a challenging task, tolerable deviations from a healthy status under different land uses could help

tackle the variability in the field. Chemical pollution is one major threat toward soils and soil biodiversity. Thresholds and indicator values need to be implemented and monitored within a legally binding framework for soils. It is our hope that the Soil Monitoring Law will foster and be a driver for further research and protection of the tremendous biological diversity and functionality of soils.

AUTHOR CONTRIBUTION

Pia Kotschik: Visualization; writing—original draft; writing—review and editing. **Juliska Princz:** Writing—review and editing. **Claudia de Lima e Silva:** Writing—review and editing. **Mathieu Renaud:** Writing—review and editing. **Mireia Marti-Roura:** Writing—review and editing. **Bonnie Brooks:** Writing—review and editing. **Silvia Pieper:** Visualization; writing—review and editing. **Ingrid Rijk:** Writing—review and editing. **Mike Simini:** Writing—review and editing. **Sandrine Andres:** Writing—review and editing. **Björn Scholz-Starke:** Writing—review and editing. **Paola Grenni:** Writing—review and editing.

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CONFLICT OF INTEREST

The authors declare no conflicts of interest.

DATA AVAILABILITY STATEMENT

Publicly available data from Eurostat <https://ec.europa.eu/eurostat/data/database> and the FAO portal <https://www.fao.org/soils-portal/soilex/en/> were used. Data are available upon request from the corresponding author Pia Kotschik (pia.kotschik@uba.de).

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SUPPORTING INFORMATION

The Supporting Information depicts a chart showing the need for effective soil protection.

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