

Scientific abstract in English

The abstract (max 8 000 characters including spaces) shall be written as an abstract for a scientific paper, i.e. it shall summarise the various parts of the work:

- Introduction with objective and hypothesis
- Material and methods
- Results
- Discussion and conclusions
- List of scientific papers, if any, which were written during the project period

Introduction

Estimates from the Swedish EPA suggest that there are approx. 80,000 potentially contaminated sites in Sweden. Protection of the soil ecosystem is frequently the major argument for remediation, and the decision to do so is usually based on a simplified risk assessment where actual soil contaminant concentrations are compared to generic guideline values. This may lead to expensive dig-and-dump, where all soil masses with levels above guideline values are removed, but with largely unknown benefits for the soil ecosystem and its function.

APPLICERA was aiming at further develop site-specific environmental risk assessment (ss-ERA) strategies of contaminated soils, focusing on soil functions (SFs) rather than biodiversity. Current ERA tools suffer from a limited understanding on how contaminants affect soil ecosystems and SFs. Aspects such as sampling strategies, identification of appropriate reference samples using SF classification, selection of relevant bioindicators, and consideration of the bioavailable fraction are central topics raised in the project. Approaching these aspects could significantly improve the performance of an ss-ERA.

Specific objectives of APPLICERA:

- Investigate contaminated sites *in situ* to explore how abiotic and biotic indicators can be used to express soil quality
- Explore the environmental risk using a TRIAD, based on chemical, ecological and toxicological indicators, by accounting for inherent variations in soil quality
- Explore and develop an alternative ss-ERA methodology
- Make cost-benefit analysis comparing current and alternative ERA methodologies

Further, within the project the question was raised how the soil ecosystem at contaminated sites should be valued. Is it worth protection, and if so, why? There is a need for a structured way to answer such questions among authorities and other stakeholders.

Materials and Methods

Soil is a complex matrix and as SFs are highly dependent on the soil quality, one of the major challenges in this project was to classify soils based on their inherent (potential) soil quality. For this reason, the tool *SF box* was modified and further developed. This tool uses a minimum set of carefully selected sensitive soil quality indexes to categorize soil samples into different soil quality classes.

To be able to perform a TRIAD, the chemical, (eco)toxicological, and ecological status needs to be characterized. The bioindicators used within APPLICERA were selected based on existing literature and expert judgement within the group, and covered microbiota, micro-, meso-, and macrofauna. Main focus was on the microbiota, which drive key biological processes in the soil, such as decomposition of organic material and nutrient cycling. Thus, the activity, diversity and abundance of microbial communities are considered useful biological indicators for soil quality monitoring. Focus was on communities that drive N-cycle processes due to their high relevance to overall soil ecosystem functioning. For quantification, molecular methods that utilize DNA extracted directly from soil samples were used. However, process rates were also determined using potential activity measurements to reflect the activity of specific N-cycling communities.

Two contaminated sites with historical contamination of polycyclic aromatic hydrocarbons (PAHs) and metals were used for field studies: a railway yard, close to the city Mjölby, and an industrial site (Skönsmon 2:12) close to Sundsvall. At the Mjölby site, 15 sampling points were selected and the influence of depth was investigated by taking samples at three different levels. At the Skönsmon site, samples were taken from topsoil at 50 sampling points.

To further study the relative influence of contamination status vs. soil quality, a controlled field experiment was conducted using lysimeters and two types of contamination. Two natural, non-contaminated agricultural soils from the County of Uppland, with contrasting soil properties (e.g., pH, texture and C/N ratio) were amended with Cu or PAH at three different contamination levels. The aim was to prepare soil contaminated at guidance levels set by the Swedish EPA, corresponding to protecting 10%, 25% and 50% of the soil fauna species. This experiment was conducted over two growing seasons, from spring 2016 to fall 2017.

Results and Discussion

Some studies are still under evaluation. Here we summarize key issues hitherto identified in APPLICERA.

Soil quality has a major influence on SF and the degree to which organisms are affected by PAH and copper contamination. This was demonstrated in the lysimeter experiment and in the Skönsmon field study. Thus, utilization of the *SF Box* tool for classification of soils into quality classes was necessary for a sound ss-ERA, as it provided a scientific basis for evaluating the relative importance of soil quality and contamination level for impact on SFs.

The composition of micro- and mesofauna communities vary dramatically with soil depth. It was therefore challenging to examine the effect of contamination at the Mjölby site, as the effect of sampling depth overrides other factors. The sampling strategy for an ss-ERA is highly critical, and should start with a pre-study of the soil classes (according to *SF box*) and soil contamination at the site to assure that a satisfactorily number of reference (relatively clean) and contaminated samples are available for each soil class.

Existing guidance values are based on total soil concentrations. Our studies showed that it is crucial to include analysis of the bioavailable fraction of the soil contamination, as ss-ERA based on total concentrations may indicate non-relevant (too high) risk resulting in expensive excavations with questionable environmental benefits.

Our Cost-Benefit-Analysis of the Skönsmon case study showed that the APPLICERA-framework may lead to different conclusions about the need for remediation than an ERA based on generic guideline values. Although the APPLICERA-framework implies additional costs associated with extensive

sampling and analyses relative to the generic guideline approach, it provides improved management of contaminated sites with respect to ecological risk, soil quality and prioritization of economic resources. A traditional ERA implied extensive remediation actions of most of the area.

In addition, APPLICERA offered a conceptual clarification regarding what is meant by the protection value of the soil ecosystem, and describes what components this value is comprised of. The soil ecosystem has a value beyond what it provides humans. The soil's intrinsic value is especially important to consider at contaminated sites where the soil has an important function in itself or as part of the whole ecosystem, but where humans have limited use of the soil environment. Furthermore, the time perspective is particularly important to take into account, regarding the instrumental values. It is not only instrumental values for humans (i.e. ecosystem services) that should be considered but also the instrumental values the soil provide other parts of the ecosystem, since nature has a value on its own.

Conclusion

In conclusion, the findings of APPLICERA will contribute significantly to an ongoing project at the Swedish Geotechnical Institute (MARKSYNT), which aims at establishing new guidelines for ERA methodologies based on the SF-box/TRIAD approach. An internal report has been produced that will feed into MARKSYNT.

Dissemination

Larsson M et al. Occurrence and leachability of polycyclic aromatic compounds in contaminated soils: Chemical and bioanalytical characterization. *Science Tot Environ*, 622-623:1476-1484, 2018.

- 10 manuscripts in preparation
- 2 reports, 1 technical note, 2 popular science articles
- 4 master/bachelor theses
- 3 national/ international workshops for researchers, authorities and other stakeholders
- 17 conference presentations