SNOWMAN NETWORK

Knowledge for sustainable soils

Refining approaches to ecological risk assessment for contaminated soils

Introduction

Soil provides humans with a wide range of ecosystem services, from clean air and water to regulation of nutrients; from plant growth control to production of food, fuel and energy[1] Any change in the structure or chemistry of soil may alter the provision of those services. Although it is widely recognised that contamination of soils has important effects on ecosystem service provision[2], the nature and extent of those effects needs further exploration.

Assessing the ecological risk of contaminated soils in Europe and beyond is key to informing long-term land management strategies and limiting the consequences of contamination in a cost effective and environmentally responsible way. Assessment tools are important within this process to ensure that level of risk can be identified, understood and risk factors calculated. Key to understanding the ecological risk associated with contamination is the bioavailability of contaminants, how this varies across a landscape and at scale, and the relationship between availability and uptake by key flora and fauna. This *Policy Brief* synthesises analysis funded by the SNOWMAN network examining two approaches to ecological risks assessment of contaminated soils. They aim to refine and provide further insights as to the toolbox of assessment methodologies and their reliability to help inform decision-makers. It links closely to other projects funded by the SNOWMAN network, in particular INSPECT which considered foraging behaviour and links to contamination risk.

Main findings

Within IBRACS and MUSA different potential methods for improving approaches to ecological risk assessment methodologies were tested and reviewed. The analysis aimed to make improvements in the accuracy and relevance of outputs from ecological risk assessment. The opportunities and limitations are summarised in publications from the key projects:

- Integrating Bioavailability in Risk Assessment of Contaminated Soils: opportunities and feasibilities (IBRACS)
  - http://snowmannetwork.com/wp-content/uploads/Final-report-IBRACS_13-February_revised.pdf

- Integrating Multiple Scale Impact Assessment on Ecosystems for Contaminated site management (MUSA)
  - http://snowmannetwork.com/wp-content/uploads/MuSA_final_report.pdf

Key policy recommendations

- Laboratory and field studies have shown that biological effects are not directly related to the total concentration. Instead, soil organisms respond to the fraction of contaminant that is biologically available.

- Two risk assessment frameworks accounting for contaminant bioavailability were developed and tested; one for metals and one for polycyclic aromatic hydrocarbons (PAHs).

- Improvement in modelling approaches is important and further work is needed to continually improve the robustness and reliability of assessments to inform better understanding of contamination and the risks posed.

- Fully understanding the bioavailability of contaminants and remediation options from a landscape and lifecycle perspective are important to ensure that correct decisions are taken in the interest of public health and environmental quality while avoiding unnecessarily costs to society.

1. Refining risk-assessment approaches to contaminated soils by integrating information on bioavailability

Content and methodology

The IBRACS project funded by the SNOWMAN network was conceived to test, integrate and apply a unified ecological risk assessment framework to contaminated soils. The project's goal was to develop a risk assessment framework, including both analytical tools and reference systems to which the analytical results can be related. The main driver for this being the need to increase the accuracy in the risk assessment of contaminated sites, to inform remediation decision making and ensure costs are also managed and funding is appropriately applied.

In Europe, soil quality criteria (SQC) are based on total concentrations of contaminants. While the total concentration is an indicator of toxicity, laboratory and field studies have shown that biological effects are not directly related to the total concentration. Instead, soil organisms respond to the fraction of the contamination that is biologically available.

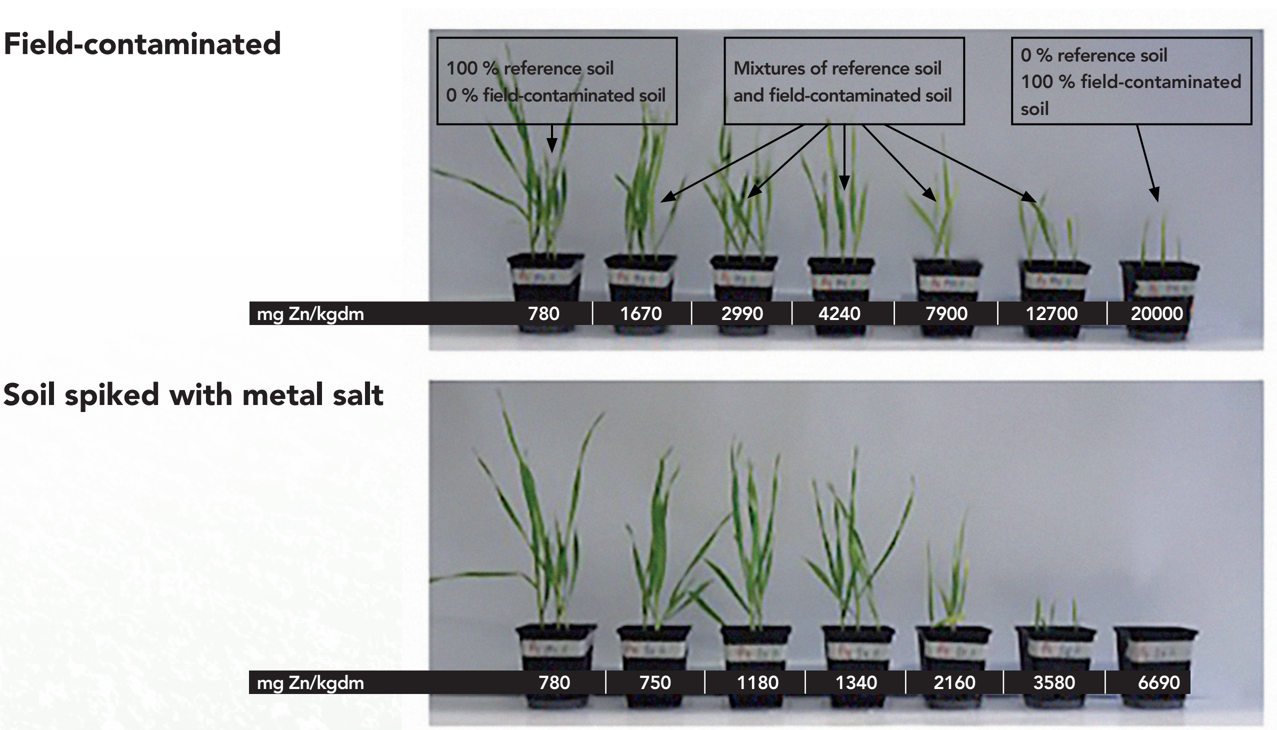

Figure 1.
Above: barley plants grown on mixtures of a field-contaminated soil (Zn: principal metal) and its corresponding reference soil.
Below: The corresponding reference soil spiked with $ZnCl_2$. There is a reduced toxicity of total Zn (aqua regia) in the field-contaminated case compared to the spiked case.

Direct biological tests are highly relevant to the testing of bioavailability but are also costly, time consuming and complicated to perform and evaluate. This limits their use in practical risk assessments. Chemical methods of analysis offer an alternative and are commonly faster, cheaper and easier to commercialise. However, before any chemical bioavailability method can be used in a risk assessment framework, a corresponding reference system based on ecotoxicity test data, i.e. to correlate the biological and chemical tests, must have been developed. Such a framework should relate the measured bioavailable concentration to predefined ecosystem protection goals (e.g. protection of a certain fraction of species).

The overall aim of IBRACS was to provide policymakers with guidelines on how chemical bioavailability tests and results of bioavailability-based risk assessment can be used to inform risk-based management decisions on contaminated land. The analysis:

– reviewed existing risk assessment models in Sweden, Belgium (Flanders, Wallonia) and the Netherlands with focus on bioavailability;
– assessed the ability of established soil extraction and assessment techniques to be used as a proxy to predict toxic responses of plants to exposures of metals (Cu, Ni, Zn) and organic contaminants (PAHs);
– aimed to understand the costs and benefits of bioavailability tests in site specific risk assessment and make recommendations on the integration of chemical bioavailability tests into assessments.

Based on the analysis within the IBRACS study it was proposed that a tiered approach be adopted to ecological risk assessment in order to integrate metal toxicity. At tier 1 this would involve analysing total concentrations of key heavy metals and comparing these to national generic soil limits; by tier 2 this would require site specific sampling and assessment of general soil quality properties (pH, organic carbon and clay content) as well as the fraction of "bioavailable metal" using an isotopic dilution method. This information are being used as input into the soil PNEC calculator[3] to obtain site-specific guideline values. At tier 3 the approach to metal contamination assessment could be integrated into a more extensive site specific ecological risk assessment procedure. The study reviewed the feasibility and practicality of making use of the different assessment tiers in case studies and an examination of existing policy in Wallonia.

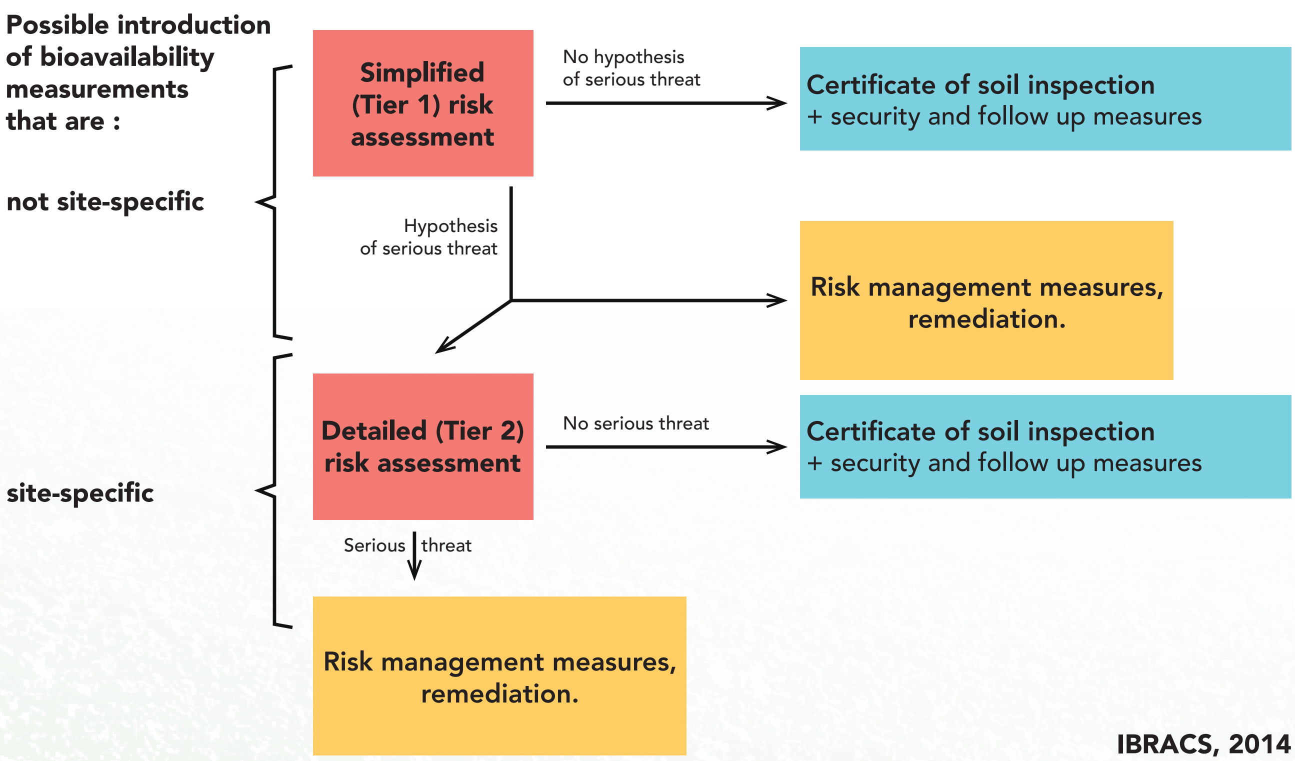

Figure 1. Tiered Risk Assessment from Simplified to Detailed Analysis of Risk

In relation to toxic effects of organic contaminants to soil organisms, specifically PAHs, the study concluded that implementation of methods that determine pore water concentration of free PAHs in risk assessments would greatly improve predictions. An Excel-based tool was developed which can be downloaded free of charge from IBRACS homepage[4]. However, it was recommended that if intake of plants is an important exposure pathway for humans i.e. that food stuffs or animal feed is being sourced from land, then uptake experiments are recommended to be used in site specific risk assessments.

2. Refining risk assessment of contaminated land at multiple-scale

Content and methodology

Land contaminated by metals has health and environmental implications and bring with them a number of risks. Assessing those risks spatially (across landscapes and watersheds) and across different time scales (short and long-term assessments) is essential to ensure adequate remediation strategies beyond site-specific assessments. The MuSA (Integrating Multiple Scale Impact Assessment on Ecosystems for Contaminated site management) project, funded by the SNOWMAN network, has the aim to *'develop an innovative decision support tool for Sustainable Land Management providing ecological risks estimate'* across scales and levels. In particular, the project aims to refine and validate an approach that is able to perform multi-scale assessments of contaminated land by metals on ecosystems. The projects does so through two axis i) by exploring the potential benefits of integrating two existing approaches to contaminated land management – the Ecological Risks Assessment (EcoRA) and the Life Cycle Impact Assessment (LCIA), and ii) by integrating these with further information on the biological availability of metals in soil. The approach proposed was tested within a case study on historically contaminated land and the results presented at a final project workshop.

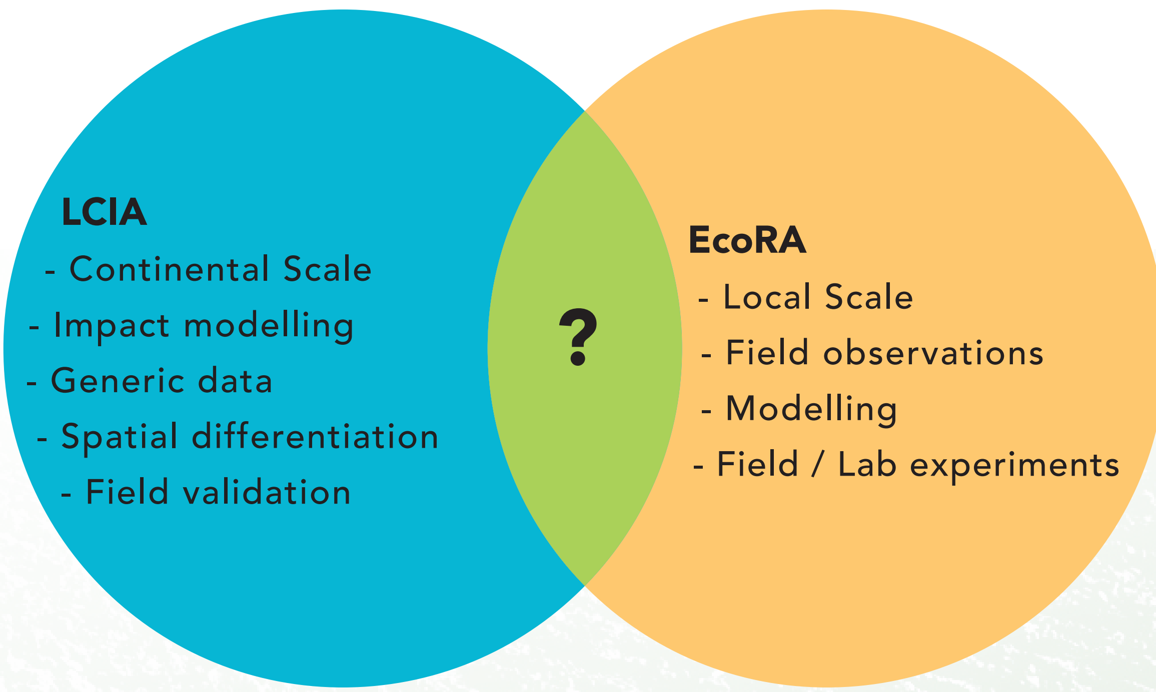

Figure 3. **What is the potential for integration of Life Cycle Impact Assessment (LCIA) and Ecological Risk Assessment (EcoRA)?**

Scoping integration

For selecting an appropriate contaminated land management strategy, both the EcoRA and the LCIA show similar features i.e. they are both multi-level approaches quantifying the environmental burden of human activities. There are, however, also substantial differences for example the consideration of time and spatial scales and the nature of the input data needed. The comparison concluded that the assumptions supporting the models (LCIA) – such as time and spatial scale – and the input data has to be coherent with the field observations (EcoRA). The LCIA should be calibrated with data extracted from field observations, i.e. data on soil composition and organism diversity, and follow a 3-tier approach enabling assessment at more granular scale.

On completion to the MuSA project, due to lack of reliable data the EcoRA and LCIA were found only partially comparable; a fully-developed method is to be validated. Nonetheless, recommendations on how to integrate the two methods and an additional, pilot case study were included. The methodological assessment and case study under the MuSA project have shown potential for integrating the EcoRA and the LCIA in a multi-scale approach.

Overall, the MuSA project was able to provide some insight into how the simultaneous consideration of local and global impacts of contaminated site management can inform decision-makers and stakeholders as to the short and long term effects of management strategies. It also reviewed a number of tools/approaches (LCIA and EcoRA) used in decision-making on contaminated soil management. Further research efforts are identified, with strong recommendations to continue the fruitful exchanges that result from an interdisciplinary approach to assessment.

Conclusions

The IBRACS and MUSA studies identify potential opportunities for improving the environmental robustness of analysis and modelling focused on contaminated land, as well as the toolbox available to decision-makers. In so doing, such action would improve understanding of the processes occurring at a given site and the consequences for the local environment and human health of both the contamination and the decisions taken around remediation.

IBRACS is focused on ensuring that understanding of contamination properly reflects the availability of contaminants and, therefore, that the consequences for flora and fauna is fully understood. MUSA is focused on understanding the consequences for the environment of decisions regarding level of risk and remediation options at different scales. In so doing, both project outcomes should help move towards better understanding of remediation needs and associated consequences. Moreover, application of key principles set out in the studies should support more cost effective decision making both in the long and short term for contaminated land.

About the SNOWMAN network

The SNOWMAN Network is a transnational group of research funding organizations and administrations in the field of sustainable management of soil in Europe. Acting as a Science-Policy-Practice interface, it aims to bridge the gap between knowledge demand and supply.

This policy brief is part of a series presenting the main results of the 17 European research project funded from 2006 to 2015 by the network.

More information on **www.snowmannetwork.com**.

REFERENCES :

1_ *http://www.fao.org/agriculture/crops/thematic-sitemap/theme/spi/soil-biodiversity/soil-ecosystems-services/en/*

2_ **JRC (2016) Soil threats in Europe.**
http://digital.csic.es/bitstream/10261/127158/1/Anaya-et-al_2016_JRC-Soil-contamination.pdf

3_ **PNEC calculator**
http://www.arche-consulting.be/metal-csa-toolbox/soil-pnec-calculator/

4_ **IBRACS homepage**
http://projects.swedgeo.se/ibracs/
Downloads / IBRACS Tool for Estimating the Risk of PAH Pollution in Strong Sorbing, Impacted Soils and Sediments

SNOWMAN Projects

IBRACS Report_
Integrating Bioavailability in Risk Assessment of Contaminated Soils: opportunities and feasibilities
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MUSA Report_
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Full reports available at **www.snowmannetwork.com**

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