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Ecological Risk Assessment for Soil Toxicity Opens Ways for Soil Management

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Abstract

Soil ecosystems are incredibly complex with great heterogeneity in physical, chemical and biological characteristics and are considerably influenced by factors such as geology, topography, climate and anthropogenic activities. Soil toxicity and bioaccumulation tests can be important tools for decision makers, whether in approving registration requests or in assessing contaminated sites and remedial action plans. Soil toxicity test can also be used for long term monitoring programs or to assess the success of clean-up projects.

Keywords: Ecological risk; soil; factors; toxicity.

1. Introduction

Standardized toxicity tests for soil microbes, plants, invertebrates, birds, and mammals were reviewed for their ability to assess the toxicity of chemicals in soils, and for their inherent limitations and usefulness in assessing contaminant hazard to the environment. Many approaches to performing ecological risk assessments have been proposed and used to support environmental management [1-4]. The soil profile is a description of the vertical cross sections of the soil that naturally occur in layers or horizons. These layers or horizons result from soil formation and uniquely characterize the physico-chemical nature of individual soils [5-9]. Ecological risk assessment estimates likelihood that adverse ecological effects may occur or are occurring as a result of exposure to one or more stressors [2]. Applicable guidance for conducting ecological risk assessment includes [1, 2].

2. Ecological Risk Assessment

Predicting the adverse effects of chemicals in soil requires a conceptual framework upon which to organize and quantify the potential for risk. The first phase of the ecological risk assessment, *Problem Formulation*, is a planning phase. The environmental problem is characterized in terms of exposure and effects and the ecological risk assessment is systematically planned based on the data available and the information needed to complete the assessment. Existing data is acquired and compiled and an assessment of additional data needs is made. Policy and regulatory issues are explored. The feasibility, objectives and scope of the ecological risk assessment are determined particularly in relation to any site-specific factors. The second phase, *Analysis*, is composed of two subactivities, the characterization of exposure and the characterization of ecological effects. The exposure characterization step predicts or measures the spatial and temporal distribution of the stressor and identifies its co-occurrence or contact with the ecological components of concern. The ecological effects characterization step identifies and quantifies the adverse effects resulting from the stressor, and where possible, establishes a cause-and-effect relationship. The end results of the Analysis phase are an exposure profile and an ecological effects profile.

The third and last phase, risk characterization, is an integration phase where the exposure and effects profiles developed in the second phase are integrated to estimate the potential risk or likelihood of adverse ecological effects associated with exposure to the stressor. The risk may be described qualitatively, quantitatively, or both depending upon the data, but should describe the risk in terms of the assessment endpoint identified in the problem formulation phase. It includes a summary of the uncertainties and assumptions made during the assessment, the strengths and weaknesses of the assessment, and the ecological significance of the identified risks in terms of type, magnitude, spatial and temporal patterns, cause and effect relationships and likelihood of recovery. Ancillary data sorted on a weight-of-evidence basis may also be included. The third phase should provide a complete picture of the analysis, the uncertainty and the results, and should pave the way for science-based risk management decisions.

In addition to the three main phases of the ecological risk assessment, interactions between risk managers and risk assessors are dispersed frequently throughout the assessment process. These discussions were integrated in the framework in order to ensure that the risk assessment will result in information relevant to the risk management requirements and that the risk assessment is ecologically relevant. In addition, early and repeated involvement in the risk assessment process will assist in ensuring that the risk manager has full and complete understanding of the assessment’s conclusions, assumptions and limitations.

3. Soil Parameters

Soils should be collected from the field following strict quality control/quality assurance (QA/QC) guidelines and standardized collection procedures. In addition to measuring the mass of chemicals of concern in each sample, other soil measurements and characteristics should be quantified. Depending on the purpose of the test and to select appropriate reference or control soils, the following parameters should be measured in each sample: pH, moisture content/soil porosity, bulk density, total organic matter/total organic carbon, soil type and texture (sand, silt, clay), grain size/mineralogy, cation exchange capacity, exchangeable cation concentrations (potassium, calcium, sodium, magnesium), salinity (as assessed by electrical conductivity), macronutrient levels (nitrogen, phosphorous).

4. Control or Reference Soils

A common feature of soil toxicity tests is the use of negative, reference, and positive controls. Control groups are generally prepared and subjected to the exact experimental conditions as the treatment groups. They are used for a variety of purposes to ensure the integrity of the test system, including: 1) to measure the acceptability of the test, 2) to ensure the health and quality of the test organisms in general, and to ensure that no shifts in test organism sensitivity has occurred, 3) to ensure that test conditions (e.g., organism handling, husbandry and environmental parameters) are suitable for the test, and 4) to provide a basis or comparison for interpreting the results. The use of negative, reference, or positive treatment groups is required in some tests and only recommended in others. The use of positive control groups is often required only periodically, depending upon the frequency that the test is conducted in a particular laboratory in order to verify the sensitivity of the test organism. Regardless, the use of positive or negative treatment groups should also be addressed in the test protocol.

When collecting soils from the field and performing toxicity tests, it is critical that an appropriate reference site(s) is selected. Soil parameters (e.g., pH, grain size, organic matter, nutrient levels and others discussed above) should be as closely matched as possible. Otherwise, these parameters may influence the outcome of the test to a greater extent than the chemical contamination itself. It is also important to select an appropriate reference site to obtain “clean” soils which can be used to proportionally dilute site soils for establishing site-specific soil toxicity effects levels. We recommend range-finding or pre-sampling/analysis of site and proposed reference soils to determine whether an adequate reference site exists nearby the contaminated site of interest.

5. Conclusion

Soil toxicity test is based on the understanding that soil microorganisms play a critical role in soil health by breaking down and transforming organic matter. Interference in these biochemical processes could adversely affect nutrient cycling and soil fertility. This assay measures the effect of chemicals of interest on carbon transformation in aerobic surface soils under laboratory conditions favorable to microbial metabolism. Soils are treated, homogenized and incubated in the dark at room temperature for up to 100 days. Soils are periodically sampled and glucose-induced respiration rates measured as carbon dioxide released or oxygen consumed. Results are compared against control samples or a dose-response is prepared. Changes in respiration reflect changes in size and activity of microbial communities through both chemical stress and carbon starvation. Table 1 indicates critical Phases of the Ecological Risk Assessment Process.

Table 1: Critical Phases of the Ecological Risk Assessment Process.

Phases	**Parameters**	**Explanation**
Phase I	Problem Formulation	Determine stressor characteristics (e.g. type, intensity, duration, frequency, timing, scale); determine the ecosystem potentially at risk; evaluate existing data of ecological effects; select appropriate endpoints, considering ecological relevance, policy goals and societal values, susceptibility to the stressor; develop a conceptual model, working hypothesis regarding how the stressor might affect the ecological components of the ecosystem
Phase II	Analysis	Characterization of exposure: Characterize the stressor, in terms of distribution or pattern of change; characterize the ecosystem; analyze the potential exposure; develop an exposure profile Characterization of ecological effects: Evaluate the relevant effects data; analyze the ecological response in terms of stressor –response determinations or extrapolations and causal evidence evaluation; develop a stressor-response profile
Phase III	Risk Characterization	Estimate the risk; integrate the stressor-response and exposure profiles; identify uncertainty in the analyses; describe the risk; summarize the risk assessment; interpret the ecological significance

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