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Soil health index in remediation of contaminated sites. Approach and application

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Summary. - The soil health index is an approach for assessing the ecological potential of a soil. The index is based on a physical, chemical, and biological characterization and rating of soil conditions. The approach is flexible, permits comparisons amongst soils with widely different properties and contaminant levels, and it can be adapted to site specific conditions. The rationale and development of the index are documented in this report along with sample handling, assessment methods, and quality assurance practices. Standardized reporting formats have also been developed for compiling and presenting the findings. An interpretive guide is included for the reporting formats and how to apply the results to site specific conditions.

Key words: soil, ecotoxicity testing, remediation, contaminated sites.

Riassunto *(L'indice di qualità del suolo per il recupero di siti contaminati. Approccio e applicazione).* - L'indice di qualità del suolo è un metodo che consente di valutarne il potenziale ecologico. L'indice è basato su una caratterizzazione fisica, chimica e biologica e su una valutazione delle condizioni del suolo. Il metodo è flessibile e consente confronti fra suoli aventi proprietà e livelli di agente contaminante molto differenti e può essere adattato alle condizioni specifiche del sito. In questo lavoro viene riportata la metodologia dell'indice nonché come trattare i campioni e le pratiche di controllo di qualità. Per la raccolta e la presentazione dei risultati sono stati sviluppati modelli di raccolta dati standardizzati. E' inclusa inoltre una guida interpretativa per i modelli di raccolta dati e per come applicare i risultati alle condizioni specifiche dei siti.

Parole chiave: suolo, test ecotossicologici, recupero, siti contaminati.

Introduction

The use of biology to collect data when assessing remediation of contaminated sites can be a valuable tool [1]. It is an ideal complement to chemical data information when making remediation decisions. The health index approach is applicable in the remediation process of contaminated sites as a mapping tool, which can be used to guide further toxicity and chemical analysis. It can also assess the effectiveness of remediation techniques and be used as a monitoring tool.

The soil health index is a biological approach for assessing the ecological potential of a soil or a contaminated site. The index is based on physical, chemical, and biological characterizations and ratings of soil sample conditions. The contaminated soils are always compared to relative non-toxic control soils from the site. The approach is flexible, permits comparisons amongst soils with widely different properties and contaminant levels, and it can be adapted to site specific conditions. Within this flexibility is the option to scale up the index for large sites, scale it down for small sites, or vary the test species selection to modify the approach from a soil index to a sediment index.

Soils are complex systems and there are many factors that affect the availability of contaminants in soil [2]. In North America, current site assessment practice is starting to incorporate a small biological component, but still relies heavily on chemical criteria regulations. When only using chemical criteria to assess a site, several key issues are raised. Chemical criteria identifies and analyzes for individual contaminants and does not address potential interactive effects such as synergistic, additive, or negative effects of compounds together. This is a key issue as there is rarely a single contaminant of concern at a site. Also the bioavailabilty of contaminants is not addressed. The contaminant levels may exceed chemical criteria but the availability of that contaminant to test species in the environment may be low or not available at all. When assessing chemical criteria, samples are usually only analyzed for a limited number of contaminants due to budget and cost. It is impossible to analyze for all the potential contaminants in the environment, which could number in the millions, if not billions of permutations of compounds. Chemical criteria also do not address how those contaminants will affect ecosystem structure and function.

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Chemical criteria may not be the most effective tool especially at sites where you do not know what your contaminants might be and you cannot test every sample for every contaminant. There also might be natural impairment at a site that is not chemical, but physical. For example a soil may have a naturally low pH that can inhibit the microbe population [3].

The health index approach provides the tool to deal with this by analyzing a clean control site and comparing all samples to it to account for natural impairment. The health index incorporates this by not only comparing sites to a clean non-toxic site, but by including a biological component and by analyzing for chemical and physical parameters as well.

Methods

The health index approach incorporates an abiotic and biotic component. The abiotic analyzes for parameters that might affect an organisms physiological tolerances such as pH, electrical conductivity, and particle size. The biological assessment takes a multiple trophic level approach testing the sample against different levels of the food chain so that effects are less likely to be missed.

Multiple species are used in each of the different trophic levels tested to further strengthen the test design. Due to varying species sensitivities within a trophic level, the goal is to include at least two from each level. The trophic levels that are analyzed for soils are microbes, plants, invertebrates, and community processes such as CO_2 evolution in soil from the microbial community [1, 2, 4-7]. Other endpoints can easily be incorporated such as a human health component [8].

Once the test design is established the samples are processed for testing. Similar to the design of using multiple species from multiple trophic levels, more than one media is tested for each sample. The solid phase tests expose the test organisms to the sample as received and any soil bound contaminants. An aqueous extract of the sample is made to test any water-soluble toxicity that may simulate water run off or leachable toxicity from the sample. A methanol extract is also performed to test for non-polar hydrophobic organic contaminants that might not get extracted by the aqueous extract.

When dealing with contaminated sites the larger the sample size, the more representative the data. Due to the volume of tests that are performed on each sample, screening level exposures are used. This involves running each test at a single treatment level. This method of testing generates a large number of data for each sample and can be incorporated in to a mapping design of the contaminated site. There is also a significant quality assurance component to the test design that includes analyzing replicates and duplicates of sample to ensure accuracy and precision of the testing as well as running the appropriate controls. Negative controls are run to ensure that test criteria is met and positive controls are run on the test organisms to ensure that they meet established performance criteria.

Once the testing has been concluded, each test result is ranked on a normalized scale of 1 to 5 for each test. Values of one are considered toxic and values of five are non-toxic and there are degrees of toxicity in between. Once the individual tests have been ranked the values are averaged across the trophic levels to yield single ranked values for each level. Then the trophic level values are averaged and a single health index value is obtained for each sample. This single value is between 1 and 5 and reflects all components of the health index.

Discussion

When interpreting the results for the samples, the first step is to compare the samples to the control site and identify any areas where the physiological tolerances of the organisms may have been stressed to explain the results. Next look at the trophic level responses. Was one trophic level more sensitive than others that would indicate trends in the responses? For example, the contaminant might be toxic to microbes, but not phytotoxic. Within each trophic level it is important to look for individual species sensitivity. Was one species overly sensitive to the potential contaminant?

The interpretation of the health index can be used to identify patterns and trends in the data. The test design is such that absolutes are not defined but that a weight of evidence is provided to ensure that ecological potential is assessed. The health index may be used to map out areas of concern with toxicity and in this application the biological data can be used to guide chemical analysis. It is not designed to replace chemical analysis, but used as a tool to complement chemical analysis. It can be used as a monitoring tool to measure the progress and effectiveness of remediation programs as well as form part of a risk based management tool for risk assessments where contaminated sites cannot be remediated to below chemical criteria.

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