Development of a Metals Toxicity Protocol for Biosolids

This project was initiated to provide a low-cost, user-friendly procedure for evaluating potential toxicity resulting from amending soils with biosolids from municipal wastewater treatment plants. The resulting report serves as a reference manual for various toxicity testing procedures. Moreover, this research addresses the challenges researchers face in assessing biosolids samples and conveys useful insights from the research team regarding lessons learned in designing and conducting biosolids research.

Although the protocol developed cannot be used to declare an entire biosolids application site free of potentially adverse human health and environmental effects, it can help utilities monitor the presence of specific toxicants in biosolids samples from amended soils.

A Better Test

Bioassays for the evaluation of contaminated soil have gained widespread attention over the past 20 years. U.S. EPA has recognized the need to incorporate biological assays in predicting soil toxicity, as research using biological tests has clearly demonstrated that chemical analysis alone is not sufficient. This project's research approach endeavored to develop a protocol using plants and lower organisms to provide a credible mechanism for monitoring potential toxicity and to help protect public health and the environment.

The research approach was conducted in two phases. In phase one, laboratory-based studies were investigated to develop an integrated assessment procedure composed of a series of bioassays. Toxicity was evaluated using standard tests including earthworm mortality, growth, and reproduction; seedling germination and root elongation; microbial respiration; and nematode mortality and reproduction. Toxicity evaluations were then selected or modified from these existing procedures and applied to biosolids samples from municipal wastewater treatment plants. Additionally, chemical extractants were selected to provide semi-quantitative data on potential toxicity of specific chemicals. Chemical lability tests for metals were employed including water soluble, exchangeable, and metals extractable by the physiologically based extraction test (PBET).

Nearly 60% of all biosolids are being recycled through land application each year in the United States.

Twenty municipal wastewater treatment plants, from geographically diverse locations throughout the United States, provided biosolids samples for the initial screening of toxicity. From the data gathered, biosolids from four of the twenty utilities were selected for further evaluation, as they showed the most promise for indicating inhibition. A fifth utility was selected out of the 20 as a control, because biosolids produced from this facility did not have a significant adverse effect in the three assays. In addition, two soils with historically excessive applications of high-metal biosolids were evaluated.

BENEFITS

- Provides a protocol for monitoring the presence of specific toxicants in biosolids-amended soil samples from land application sites.
- Serves as a reference manual for various toxicity testing procedures.
- Informs researchers of the challenges in assessing biosolids samples and the nature of tests available to address those challenges.
- Conveys useful insights regarding lessons learned in designing and conducting biosolids research.

RELATED PRODUCTS

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This research can help utilities monitor the presence of specific toxicants in biosolids samples from amended soils.

Toxicity Breakdown

In phase two, a matrix of biosolids, biosolids-treated soils, and untreated soils from the seven sites selected in phase one were collected and analyzed for toxicity and target contamination.

Contaminants examined were zinc, copper, nickel, chromium, arsenic, cadmium, lead, and coplanar polychlorinated biphenyls (PCBs). The chemical and physical properties of the soils and biosolids subsamples were determined. Toxicity was assessed using a variety of tests: a) earthworm biomass b) seed germination; c) microbial respiration; and d) nematode survival. Chemical lability was also evaluated and shown to be correlated to bioavailability.

Research results determined whether biosolids application induced toxicity in the target organisms attempted to establish the cause of the toxicity, and identified three procedures that could be used as a low-cost, user-friendly protocol to help utilities monitor potential toxicity in land-applied biosolids.

Chemical extractions were able to detect slight increases in labile metal concentrations only for soils receiving applications of five years or more and significantly higher metal concentrations in soils treated with high-metal biosolids. Single applications had no impact on metal concentrations.

Although all target organisms were sensitive to reference toxicants, the bioassays were not able to detect any residual toxicity in amended soils. Some toxicity was observed in a small number of the amended soils, but no patterns emerged. Nearly all of the observations could be attributed to transient soil properties induced by biosolids amendment such as slight depression of pH and elevated salinity. None of the metal concentrations was excessive and most would not be considered elevated relative to background concentrations. In addition, a beneficial response of enhanced microbial respiration due to the presence of biosolids was observed.

Thus, the application of biosolids in compliance with U.S. EPA's Rule 503 for the short term (single year) did not demonstrate a pattern of toxicity to target organisms in the utilities studied. Additionally, long-term application of compliant biosolids did not result in toxic soils. However, soils with a history of application of non-compliant biosolids (i.e., excessive metal concentrations) did induce some toxicity as determined by several of the ecotoxicity tests.

Chemical extractants were selected that were sensitive enough to detect slight increases in metal concentrations in the biosolids-amended soils. Metal concentrations were low, but the sensitivity of the extractants indicates that they can be used to help monitor metal accumulation in soils. Coplanar PCBs were not detected in the biosolids.

A New Protocol

The product of this research is the Metals Toxicity Protocol for Biosolids-Amended Soils. This protocol is a series of three bioassays: microbial respiration, earthwormbiomass, and seed germination. With pictures and step-by-step instructions, the protocol conveys how to sample soils, prepare samples, conduct the three metals toxicity assays, and interpret the results. Although this protocol cannot be used to declare an entire biosolids application site free of potentially adverse human health and environment effects, it can help utilities monitor the presence of specific toxicants in biosolids samples from amended soils.

In the course of this research, the research team also learned lessons that will be useful to future biosolids researchers, such as consideration for when and where test samples are taken. For example, being able to repeatedly sample biosolids at different times of the year would have added to the team's understanding of the temporal range of properties. Similarly, field sampling was not designed to enable the quantification of spatial variability. Although samples were taken at multiple sites within the field, the samples were combined and homogenized to accommodate the original design.

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