ASSESSMENT OF CONTAMINATED SOILS

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Summary

This chapter considers contaminated soil assessments. The assessments are typically conducted to support remedial decisions regarding a site’s risk potential to address whether site remediation is necessary. In the United States, the primary tools for risk characterization are human health risk assessment and ecological risk assessment. These processes employ a tiered approach to evaluate contamination exposure potential and potential adverse effects on human and ecological receptors. Similarities and differences in these processes are discussed with regard to an overall risk characterization. The risk assessment goal is to inform the risk manager of the nature and extent of contamination in the environment, the existing or potential effects on ecological receptors, potential human health risks, and possible changes in site risk or impacts over time. To the extent that science is used to support remedial or risk management decisions, the quality of the decision is contingent on the quality of the risk assessment and the data upon which it is based.

1. Introduction

An assessment of contaminated soil is typically performed to determine the need for remediation, the efficacy of past remediation efforts, or to determine if compensation is required for injuries to natural resources. Such assessments commonly consider impacts of existing contamination on humans or on the environment. The end result may be a determination that contamination poses adverse consequences (hazard assessment), or an evaluation of the probability of realizing adverse consequences where these consequences cannot be directly measured (risk assessment).

The assessment of contaminated soils is commonly driven by the requirements of one or more government regulations. Applicable regulations can vary depending on the origin and type of chemical contamination, the process or industry responsible for the release, the date of the release, and other factors. Regulatory criteria dictate the boundaries and provide the general context for the objectives and technical approach governing the collection and evaluation of information for assessing contaminated soil.

One of the most important federal laws in the United States governing assessment of soil contamination is the Comprehensive Environmental Response, Compensation, and Liability Act, or "Superfund". This act established a national program for responding to the release of hazardous substances into the environment, and it provided the basis for the development of technical guidance for assessing the potential for hazardous substances to adversely impact human health and the environment. The U.S. Environmental Protection Agency (US EPA) has developed both human health risk assessment (HHRA) and ecological risk assessment (ERA) guidance to help meet the "environmental response" part of Superfund.

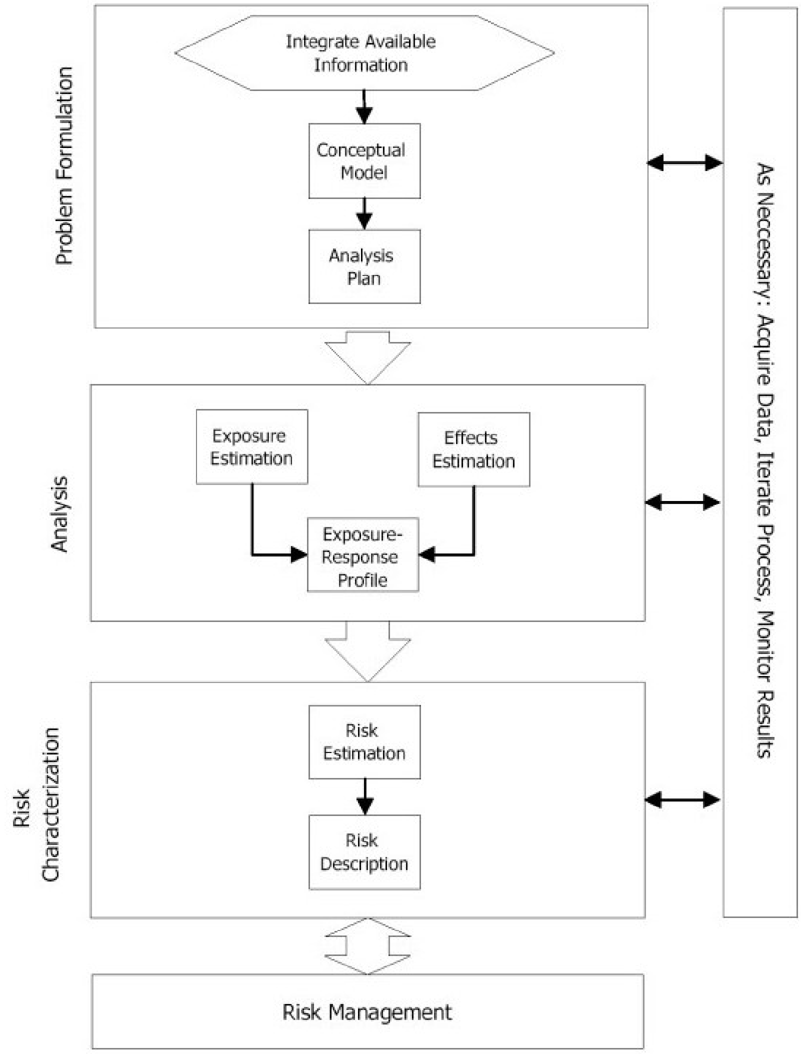

Figure 1: The risk assessment framework employed by the United States Environmental Protection Agency. The framework is based largely on the US EPA process for ecological risk assessment (ERA) although the human health risk assessment (HHRA) process shares many analogous or identical stages. These stages outline the flow of the investigation and emphasize the iterative nature of a risk assessment to incorporate new information.

The US EPA advocates performing HHRA and ERA through three stages. Ecological risk assessment proceeds through (1) problem formulation; (2) the analysis of exposure and effects; and (3) risk characterization. Human health risk assessment has somewhat analogous stages of (1) data collection and evaluation, (2) exposure assessment and toxicity assessment, and (3) risk characterization. In addition to these stages, it should be noted that many HHRAs would also benefit from the explicit inclusion of the concept and process of problem formulation.

Issues related to each of the above stages are revisited as more information is collected on site risks and hazards and initial uncertainties are addressed. Consequently, this is not a rigid, step-wise process with discrete stages but more of a fluid continuum with multiple iterations in the course of an assessment. The process is presented graphically in Figure 1.

The application of ERA and HHRA occurs within the broader context of a site investigation that generally includes project scoping, sampling of environmental media, analysis of chemical data from environmental samples, and evaluation of remedial alternatives. Under Superfund, this is referred to as the Remedial Investigation/Feasibility Study. The remedial investigation focuses primarily on site characterization to support selection of remedial action objectives. The feasibility study is concerned with evaluating the remedial alternatives that might be employed to achieve these objectives. The major components of the remedial investigation are the collection and analysis of field data and the development of a baseline risk assessment, where the term "baseline" signifies conditions prior to implementing any remedial actions.

2. Risk Assessment

The assessment of contaminated soils typically progresses through a series of stages, from simple, highly conservative assessments to resource intensive, complex, and more realistic evaluations. This approach can be characterized as the risk management continuum (Figure 2), as adapted from the soil screening process developed by US EPA. The risk management continuum emphasizes the concentration of constituents in soil although there are other factors considered in risk management like the cost/feasibility of the remedy and public/regulatory acceptance of the remedy. Although the risk management continuum is a simplified presentation it does show the progressive stages for an assessment where each stage requires more resources (time, materials) than the preceding one. This tiered approach facilitates the identification of risk drivers by eliminating those sites or toxicants and pathways that are not cause for concern. In this way, resources can be allocated to focus on higher priority sites or on more important chemicals at a site.

To briefly illustrate the tiered approach to risk assessment, consider an ecological evaluation of arid grassland soil contaminated with heavy metals (see *Speciation of Heavy Metals and Radioisotopes*) and high explosive organic compounds (see *Organonitrogen Compounds*). If no obvious ecological impacts were apparent, the initial evaluation, typically referred to as a screening assessment, would compare representative (e.g., average) soil concentrations to chemical-specific, soil toxicological benchmarks; i.e., chemical concentrations below which adverse effects are unlikely. Relative to high explosives, there is extensive toxicological literature on metals. It is therefore likely that toxicity benchmarks exist for the metals of interest and a simple comparison may indicate that site metals are unlikely to pose an adverse impact to site biota. If metals were the sole contaminants of interest at the site, the screening assessment would indicate that further evaluation is unwarranted. But assessment of the high explosives is problematic because we lack good toxicity information for many of these compounds. If benchmarks do not exist for high explosives of interest, further assessment is warranted to address uncertainties around this data gap. Issues relevant to advanced tiers of an assessment are explored further in the sections that follow.

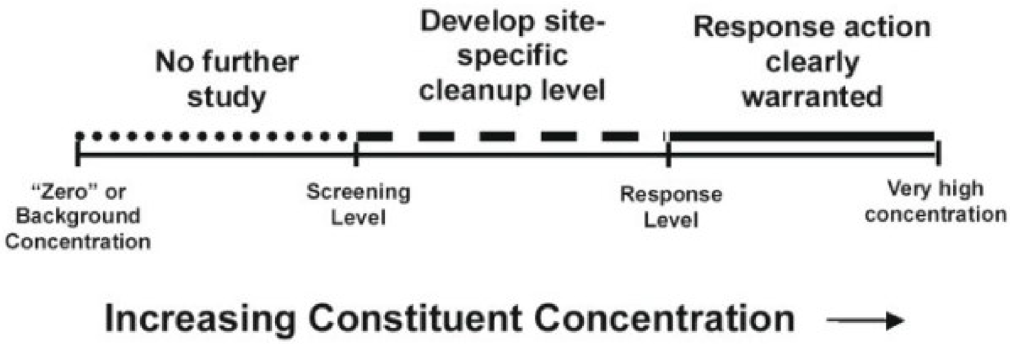

Figure 2: Risk management continuum based on the US EPA soil screening level guidance that illustrates how screening levels are used to eliminate sites from further study or make remediation decisions

While sites can be eliminated from further consideration in the screening assessment, this possibility represents one extreme end of the risk management continuum. The other extreme involves sites where cleanup is obviously needed. At sites like this, it would be an unwise expenditure of resources to carry out a detailed site assessment if all stakeholders agree that immediate remediation is warranted. For sites in between these extremes, it is important to note that taking a tiered approach to assessment can be viewed negatively. For example, the public may perceive that a site is being studied endlessly without a clear objective. This pitfall can be addressed with a consistent and transparent tiered-assessment approach and by showing the public cases where problems were identified and remediated.

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Biographical Sketches

James T. Markwiese is a biologist with special emphases in chemistry, microbiology and toxicology. He received his Ph.D. in Zoology and Physiology with Statistics minor, M.S. in Biology with Hazardous Waste Management minor and B.S. degrees in both Zoology and Environmental Biology with Psychology and Chemistry minors. He studied at the National Science Foundation's Center for Microbial Ecology on an NSF fellowship and won the Society of Environmental Toxicology and Chemistry's doctoral fellowship for his dissertation work. Jim is currently integrating his knowledge of environmental chemistry and biological processes in solving environmental problems for clients across the country. In addition to his risk assessment work for the Los Alamos and Argonne National Laboratories and the US Navy (San Francisco Bay Area and the Quantico Marine Base), Jim has extensive experience reviewing quality assurance project plans for the US EPA through the Superfund Innovative Technology Evaluation program and he is particularly interested in developing assessment tools and approaches for arid and semiarid ecosystems.

Randall T. Ryti is a Senior Scientist at Neptune and Company, Inc. with broad interests in environmental statistics, chemistry, and toxicology. Dr. Ryti holds a Ph.D. in Biology from the University of California San Diego and has over twenty years of experience in basic and applied environmental problems. His current interests include application of risk assessment tools to environmental decision-making, interpretation and presentation of complex environmental data, and arid ecosystems risk assessment evaluation and interpretation. Randy has assisted in the planning, decision logic, and statistical design for environmental restoration projects at numerous Federal facilities, and for many of these projects, he developed cost-based statistical approaches that assisted the decision-maker in achieving an acceptable cost/risk balance.

Ralph Perona specializes in assessing human health risks associated with exposure to chemical and radiological contamination in environmental media. As a human health risk assessor, Ralph provides decision support for evaluating and managing complex environmental problems requiring the integration of numerous disciplines including data analysis, exposure assessment, chemical fate and transport among environmental media, toxicology, and uncertainty analysis. His knowledge of the relationships among the different facets of an environmental investigation allows him to develop practical conceptual site models to assist in problem definition, sampling design, and interpretation of data analysis and risk assessment results. Ralph has provided assistance to clients including the Los Alamos National Laboratory, the New

Mexico Environment Department, the Department of Defense, Westinghouse Hanford, and private clients in the U.S. and Canada. Ralph holds a M.S. in Environmental Health and a B.S. in Food Science. He is experienced in the use of many types of software for performing risk and dose modeling of chemicals and radionuclides in various environmental media and has developed independent models for benchmarking and interpreting commercially available software.