Chapter 8
Scoping and Conducting Ecological and Human Health Risk Assessments At Superfund Mine Waste Sites

8.1 Introduction.

The purpose of this chapter is to highlight some of the unique issues related to risk assessments at abandoned mine waste sites and to provide some guidance to help address these issues. Baseline risk assessments for site investigations provide a basis for risk management decisions. Although risk management decisions help determine the scope of the risk assessment, they should not influence the analytical process utilized in the evaluation. For example, scientific elements of the dose-response evaluation will remain consistent throughout all risk assessment activities. Risk assessments are also conducted to support removal actions that reduce excess risks to health to acceptable levels. This chapter furnishes Site managers and other federal, state, and local authorities with a summary of key issues relevant to mine waste site risk assessments as well as a compilation of references to other helpful resources. In some cases, cleanup activities can be implemented without conducting a baseline risk assessment.

8.2 Supporting Guidance Documents.

EPA Risk Assessment Guidance for Superfund (RAGS), including Volume 1 parts A[1], B[2] and C[3] D[4], and a supplemental volume[5], provide a broad, conceptual framework for conducting human health risk assessments at CERCLA sites. These concepts, while originally developed to address risk assessment issues during CERCLA action, are appropriate to consider in evaluating risk at non-CERCLA sites. Guidance for conducting ecological risk assessments may be found in the Ecological Risk Assessment Guidance for Superfund[6] (ERAGS), the EPA Guidelines for Ecological Risk Assessment[7], the field and laboratory reference guide[8], and in Appendix F of this document. EPA's Office of Emergency and Remedial Response supplies copies of the *ECO Update* intermittent bulletin series of supplemental ecological risk assessment guidance on specific technical and procedural issues. General EPA guidance

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[1] U.S. Environmental Protection Agency (EPA). 1989. *Risk Assessment Guidance for Superfund: Volume 1 - Human Health Evaluation Manual, Part A: Baseline Risk Assessment*. EPA/540/1-89/002.

[2] U.S. Environmental Protection Agency (EPA). 1991. *Risk Assessment Guidance for Superfund: Volume 1 - Human Health Evaluation Manual, Part B: Development of Risk-based Preliminary Remediation Goals.* EPA/540/R-92/003.

[3] U.S. Environmental Protection Agency (EPA). 1991. *Risk Assessment Guidance for Superfund: Volume 1 - Human Health Evaluation Manual, Part C: Risk Evaluation of Remedial Alternatives*. EPA/540/R-92/004.

[4] U.S. Environmental Protection Agency (EPA). 1998. *Risk Assessment Guidance for Superfund: Volume I Human Health Evaluation Manual, Part D, Standardized Planning, Reporting, and Review of Superfund Risk Assessments*. Office of Emergency and Remedial Response, Publication 9285.7-01D

[5] U.S. Environmental Protection Agency (EPA). 1991. *Risk Assessment Guidance for Superfund: Volume 1 - Human Health Evaluation Manual, Supplemental Guidance: Standard Default Exposure Factors.* OSWER directive 9285.6-03.

[6] U.S. Environmental Protection Agency (EPA). 1997. *Process for designing and conducting ecological risk assessments*. EPA/540-R-97-006, June 5, 1997.

[7] U.S. Environmental Protection Agency (EPA). 1998. *Guidelines for Ecological Risk Assessment*. EPA/630/R-95/003F.

[8] U.S. Environmental Protection Agency (EPA). 1989. *Ecological Assessment of Hazardous Waste Sites: A Field and Laboratory Reference*. EPA/600/3-89/013.

documents that address risk-related issues include Superfund Accelerated Cleanup Model (SACM) information[9], guidance addressing data useability in risk assessments[10], data quality objectives[11], and risk characterization[12].

Other guidance specific to particular issues or regions may be obtained through regional offices. Contact the regional EPA office associated with a given site to determine if regional guidance is available, as well as to determine the appropriateness and applicability of utilizing guidance documents from other regions on particular issues. For example, OSHA and related work place regulations (e.g., ACGIH, NIOSH) do not apply to environmental contamination, exposure to non-workers, or to workers outside of their controlled job setting. EPA and OSHA have an MOU on this subject and some regions have guidance for handling joint occupational and environmental exposures and resulting risks. Reference and guidance documents are also available from other federal agencies (e.g., USGS) and from various state agencies (e.g., California Environmental Protection Agency).

Contact information and electronic versions of some EPA publications are available online through the world wide web at http://www.epa.gov and new publications are available from the U.S. EPA Office of Research and Development at http://www.epa.gov/ORD/whatsnew.htm.

8.3 Overview of Mine Waste Site Risk Assessment Features

Several features of mine waste sites may be unique among hazardous waste sites and should receive consideration in the baseline risk assessment. This section addresses issues which are relevant to both ecological and human health risk assessment.

8.3.1 Site Characteristics

Physical Features. Features prevalent at many mine waste sites that may influence the approaches taken in the risk assessment include the size of the site, current and future land uses, the number of contaminants present, media contaminated, and the vertical and horizontal extent of contamination. Mine waste sites may occupy areas comparatively larger than those of other hazardous waste sites. Two examples of influences on the risk assessment are: (1) A large area is more likely to include greater portions of a particular terrestrial organism's home range and to possibly include more than one type of ecosystem and (2) Some former mine sites are current residential areas while others are very remote and have little likelihood of becoming residential.

Contaminant Distribution. Contamination is commonly ubiquitous across mine waste sites and includes a large volume of contaminants. Such widespread contamination often requires multiple pathway exposure evaluations in the risk assessment. It may be helpful to identify and focus on contaminants and/or exposure pathways that will drive the risk assessment; however,

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[9] U.S. Environmental Protection Agency (EPA). 1994. *Risk Assessment Tools for the Superfund Accelerated Cleanup Model.* Office of Solid Waste and Emergency Response. November. PB94963226.

[10] U.S. Environmental Protection Agency (EPA). 1992. *Guidance for Data Useability in Risk Assessment, Parts A and B.* Office of Solid Waste and Emergency Response. Directive 9285.7-09A&B. (PB92963356 and PB92963362.)

[11] U.S. Environmental Protection Agency (EPA). 1993. Data Quality Objectives Process for Superfund Interim Final Guidance. EPA/540/R-93/071.

[12] U.S. Environmental Protection Agency (EPA). 1995. Memoranda from Carol Browner regarding *EPA Risk Characterization Program/EPA Risk Characterization Policy and Guidance*. Office of the Administrator. March 21.

each contaminant of concern must be addressed and associated risks must be characterized to ensure that planned cleanup activities will be comprehensive. In some cases, this process may involve a screening-level risk assessment which precedes a more in-depth risk assessment.

8.3.2 Comprehensive Risk Assessment Considerations

Several issues are comprehensive because they are important in both ecological and human health risk assessments. This section discusses three such important issues: 1) Background Contaminant Concentrations, 2) Exposure Pathways, and 3) Bioavailability.

Defining Background. Naturally high background concentrations of metals are an important consideration at mine sites. Chapter 7 discusses background sampling in the initial sampling and analysis plan; the EPA Data Useability Guidance, cited earlier in this chapter, may also be consulted for assistance with planning a background sampling design. To ensure that appropriate "reference area" locations are chosen for background sampling, risk assessors must consider both natural and anthropogenic contributors. A background sampling location should usually be upwind and upstream of the site, and must have soil characteristics and related properties similar to those at the site. If several different types of soil or habitats are present at the site, more than one set of background data may need to be gathered to ensure that appropriate comparisons are made. A nearby watershed, unimpacted by mining, may provide an opportunity to collect background samples.

Natural background concentrations of metals in mining areas may occasionally be elevated above risk-based values or regulatory criteria and standards. Risk-based values are those concentrations at or above which an unacceptable human health or ecological effect may occur. Regulatory levels, including applicable or relevant and appropriate requirements (ARARs, discussed in Chapter 7) may or may not be risk-based values. If naturally occurring background concentrations exceed risk-based or regulatory values, the risk assessment may separately present risks caused by site contributions from natural background levels. The risk assessment should always present cumulative risk estimates. This enables risk managers to gain perspective and make better cleanup decisions.

Anthropogenic contributors to a background sampling site should be similar to those connected with the mine waste site. Both site samples and background samples should be representative of the areas under consideration. For example, if a busy highway runs through a proposed background sampling area, the same or a similar highway should be associated with the mine waste site to account for leaded gasoline deposition. Locations which reflect obvious contributions of human activities, such as roadsides, drainage ditches, storm sewers or the like, could be judged as inappropriate for collecting background samples. These areas may reflect secondary sources of contamination and not be representative of the greater area under consideration. In rare cases, a roadway contaminated during the transport of mining materials may be an area of concern. It is important that the intended applications of the background data in the risk assessment are determined early in the process to ensure that an adequate number of samples over an appropriate area and in a relevant pattern are collected to allow, as applicable, for spatially relevant and statistically significant results. Usually, per ERAGS Appendix D (Statistical Considerations), a 1-tail t-test is adequate to compare background with site concentrations, provided that independent representative samples from proper locations are evaluated. EPA guidance on the determination of inorganic content in soils and sediments[13] is also available.

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[13] U.S. Environmental Protection Agency (EPA). 1995. Engineering Forum Issue: Determination of Background Concentrations of Inorganics in Soils and Sediments at Hazardous Waste Sites. Office of Solid Waste and Emergency Response. December. EPA/540/5-96/500.

Exposure Pathways and Sources. Risk assessments at mine waste sites commonly require evaluation of exposures from multiple sources and exposure via multiple pathways. Multiple pathway assessments for terrestrial ecological receptors may include surface water ingestion, incidental ingestion of soil, or ingestion of contaminants taken up by plants. For human health assessments, multiple exposure pathways may include dermal contact with soil or water, incidental ingestion of soil or dust, inhalation of dust, and ingestion of ground or surface water. Multiple contaminant sources, such as nearby off-site tailings piles and roadways constructed of slag or waste rock, may also contribute to risks incurred by mobile populations with large home ranges as well as human beings that live and play in various areas of the site. Concurrent occupational and residential exposures are particularly relevant for those contaminants that are encountered both on the job and at home. Exposure sources may also include exposures from lead-based household paints and occupational metal exposures. Such analyses may later support multi-media risk reduction options strategies. EPA recommends the development and use of a conceptual site model (as described in RAGS, Section 3.6) to link releases from contaminant sources to environmental media which will be contacted by potential receptors under current and future land-use scenarios.

Bioavailability. When estimating the internal dose of a given contaminant, several factors are evaluated: source exposure concentration, intake rate, and the fraction of contaminant which is biologically available to that organism. Considerations of the particle size and mineralogy, the oxidative state of the metal, physical accessibility (e.g., whether or not it is encased by another compound which is not able to be broken down by an organism's digestive system) can modify an organism's internal dose. Data for assessing bioavailability may come from animal testing or from validated laboratory (*in vitro*) procedures. Only tests with biological systems can provide bioavailability values. Other non-animal experimental procedures may provide information regarding "bioaccessibility," or the potential for uptake based on physical or chemical features. TCLP, EP-TOX, chemical equilibrium computer models and other non-animal tests provide little useful information about bioavailability in living systems. In 1997, industry-initiated research was begun to evaluate the use of *in vitro* methods; however, scientific peer review and validation have not been completed at this writing. For lead exposure estimates, EPA's Technical Review Workgroup for Lead (TRW) can provide the latest estimates of bioavailabilty.

With respect to human exposure, bioavailability can be defined as "absolute" or "relative". It is important for the bioavailability units of measure to properly correspond to the toxicity units of measure. Consult your regional risk assessor for a complete explanation of these terms and how they affect the risk assessment.

8.4 Ecological Risk Assessment

Understanding the ecological risk posed by a mine site is critical to making sound cleanup decisions. For a CERCLA cleanup Section 300.430(e)(2)(I)(G) of the NCP states that during Remedial Investigations and Feasibility Studies, "environmental evaluations shall be performed to assess threats to the environment, especially sensitive habitats and critical habitats of species protected under the Endangered Species Act." In addition, as described in Chapter 7, numerous federal and state statutes and regulations concerning environmental protection contain potential ARARs for Superfund sites.

Mine sites are unique from other sites in ways that can influence the size, scope, and detail to adequately characterize ecological risks. These sites can cover large areas and often affect large portions of eco-regions. In historic mining districts mine site impacts can contribute to degraded environmental conditions throughout a watershed. Moreover, they may be located in more remote areas, on federally owned land that is otherwise relatively pristine. Guidance on

the role of natural resource trustees is particularly applicable for mine waste sites[14]. Mine waste sites are contaminated primarily with heavy metals and may also be impacted by operational contaminants including cyanide, acids, and PCBs. These sites may to be located in areas with soil and waters containing high background levels of metals and low pH that can complicate interpretation of soil, sediment, and surface water sampling results. Furthermore, cleanup options tend to be limited by the magnitude of problems and physical alterations to the landscape.

The following sections discuss ecological risk assessment issues associated with mine waste site investigations. For a more complete discussion of the ecological risk assessment process, and some suggestions regarding methods for approaching specific situations, consult the ERAGS, as well as Appendix F of this handbook. Helpful examples of ecological risk assessments prepared for large mine sites include: Bunker Hill in Idaho, Kennecott (terrestrial) in Utah, Sulphur Bank Mercury in California, Carson River Mercury in Nevada, and California Gulch (aquatic) in Colorado.

8.4.1 Identification of Potential Chemical and Physical Stressors

The major threat to the environment from mine sites is heavy metal contamination, including "acid mine drainage". See also Chapters 2 and 3 for an overview of mine site operations and a discussion of mine waste site activities that contribute to ecological and human health risk. Physical habitat alteration may also adversely affect environmental receptors. Sections 8.4.3 and 8.4.4 discuss some of these alterations and potential impacts. Additionally, Section 8.3.2 discusses background concentrations and is relevant to ecological as well as human health risk assessment. Background concentrations may be used in the determination of contaminants of potential concern for a site. Site contaminant concentrations may also be compared to toxicity-based reference values.

Some metals commonly found at mine waste sites such as zinc, iron, copper, and manganese are essential micronutrients for both wildlife and humans; they can be, however, toxic at higher levels. Bio-accumulation of metals presents greater problems for fish and wildlife at higher trophic levels, but this usually only occurs with organic metals such as methyl mercury.

8.4.2 Problem Formulation

Ecological risk assessments require clear definitions of the receptors and transfer pathways being assessed. Identifying impacts common to mine waste sites and placing them into a Conceptual Site Model facilitates a focused and efficient ecological risk assessment. For each functional unit, relevant assessment endpoints must consider spatial and temporal issues.

Spatial Issues. The large size and potential ecological complexity of a mine waste site may require assessment of several functional ecosystems. Both the relative and absolute magnitude of the contaminated area and of smaller specific areas that are critical to site ecosystems should be examined. The impacts of small scale contamination on highly valued habitats (e.g., tailing piles in wetlands or streams) and of broad scale contamination on other habitats should each be evaluated. Key elements associated with the spatial scale include multiple types of releases (e.g., tailings, drainage, smelting dross and emissions) and associated transport mechanisms. Home ranges are a critical spatial concern. Different types of home ranges (e.g., hunting areas, roaming areas) may be considered based on the way a given organism is likely to encounter mine waste contaminants (e.g., food chain exposure or

[14] U.S. Environmental Protection Agency (EPA). 1992. *ECO Update: The Role of Natural Resource Trustees in the Superfund Process.* Volume 1. Number 3. Office of Emergency and Remedial Responses. PB92963369.

incidental soil ingestion). Selected home ranges must be compared with identified contaminated areas.

Temporal Issues. Ecological parameters are controlled by temporal factors. Seasonal events such as snowmelt, runoff, and swollen creeks and rivers can serve as major energy inputs that mobilize contaminants and contribute to higher levels of transported solids. Low flow, high temperature periods should be evaluated as times of likely contaminant-motivated stress to organisms, which may result in increases to organism metabolism and contaminant concentrations. Receptor foraging behaviors can vary during migration and spawning times. The analysis should consider receptor behaviors and life stages which may adversely enhance toxicity. For example, salmon eggs are more sensitive to toxicity from metals than adult fish.

Endpoints. Endpoint selection will direct planning of the ecological risk assessment and help place results in context. Identification of potential endpoints may be initiated with a description of the general functional groups in the ecosystem. Environmental media and exposure routes of mine waste contaminants should be identified during preparation of the Conceptual Site Model. Toxicological modes of action for site-specific contaminants of concern should also be considered. Based on this information and the spatial and temporal issues identified above, species and processes, within identified functional groups, that appear to be most valued, most sensitive, or that meet other site-related criteria (e.g., organisms that are hunted or fished, threatened or endangered raptors) can be selected for evaluation in the risk assessment. Final selection species and process assessment endpoints and measurement endpoints involves additional considerations.

Careful selection of "assessment endpoints" will help define subsequent supporting measurements. Each assessment endpoint will associate with one or more measurement endpoints to facilitate evaluation of exposure and risk. Choice of endpoints should be reflective of the complexity (e.g., organism interdependence) and diversity (e.g., variety of plants, animal and aquatic life) of the ecosystem. Risks to threatened and endangered species may be assessed through their incorporation into the Conceptual Site Model. Other decisions which should be made prior to data collection include definition of data objectives, explicit measurement selection, establishment of acceptable levels of uncertainty, and data quality control and analysis procedures. Since background metals concentrations at mine waste sites tend to be high, it is important to define a "significant risk level".

8.4.3 Characterization of Ecological Effects

Terrestrial Impacts and Risks. At some sites (e.g., Bunker Hill in Idaho), air transport of particulate matter from smelting operations and acid emissions (SO_2, NO_2 derived from H_2SO_4 and HNO_3) resulted in widespread contamination of surrounding soils, vegetation loss and stress, via acid rain and phytotoxicity, over hundreds or thousands of acres. Soils with high residual metal levels may not support native vegetation. Sites also may have large areas of degraded or lost vegetation following massive physical alterations of terrain and subsequent erosion. Vegetation coverage may serve as one measurement endpoint when evaluating an area's ability to support herbivorous terrestrial organisms. Vegetative loss may itself serve as an assessment endpoint for evaluating the overall ecological state of the site with soil metal concentration as one of its supporting measurement endpoints. Increased levels of zinc in soils can cause a decrease in microbial levels and in lichen growth. Decreased lichen growth can indicate the soil's ability to sustain vegetation. Risk to other terrestrial-linked receptors should be taken into account, even if the receptor's home range extends beyond the site boundaries.

Aquatic Impacts and Risks. Extensive degradation of aquatic ecosystems has occurred at many mine waste sites. Degradation of riparian vegetation has resulted in bank destabilization, erosion and sedimentation of water bodies. Run-off from tailings piles often lowers the pH of surface waters and increases levels of metals in sediments and the water column. Metal precipitates are often formed from acid mine drainage which adsorb to sediments and disrupt the benthic community. Run-off events from snow melt and storms can result in pulses of acids and toxic substances at critical life stages for resident fish and invertebrates. High acidity from mine acid drainage or storm water run-off at mine waste sites results in mobilization of metals in water, potentially causing detrimental effects to the aquatic community including fish kills. If fish tissue samples are to be used as a measurement, an adequate supply of fish for sampling should be verified at the time of assembling the sampling and analysis plan. At the older mine waste sites, tailings sometimes were dumped directly into surface waters or washed into surface waters in the initial years of mining operations. The concentration of metals in waste piles tends to be higher at older sites because the older methods of ore processing were not as efficient. At many mine waste sites, it is difficult to identify the key sources and events which cause continued contamination of surface waters. Other aquatic issues to consider include effects on benthic invertebrates and related impacts via the food chain, food chain exposures to aquatic birds and mammals, bioavailability of contaminants in sediments, chemical, and physical properties of the water that influence contaminant toxicity.

8.5 Human Health Risk Assessment

The following section discuss human health risk assessment issues associated with mine waste sites. The intent of this section is to highlight issues not specifically addressed in RAGS and other guidance.

8.5.1 Contaminants of Potential Concern

Human health risk assessments at mine waste sites focus primarily on issues addressing risks to humans from heavy metals and process chemicals. Heavy metals such as lead, zinc, copper, arsenic, cadmium and mercury as well as radionuclides, PCBs, and cyanide have been identified in soils near mine waste sites. Contamination may occur via wind blown dust, the use of mine wastes for landscaping, road building or foundations for home building, transport by surface waters or spillage during mining activities. Comparison of measured contaminant concentrations to undisturbed background concentrations and preliminary remediation goals may help to identify site-specific contaminants of potential concern. Some EPA regional offices have developed lists of preliminary remediation goals based on default assumptions for screening purposes. Contact your regional risk assessor for more information. There is also a soil screening levels guidance document available[15].

Lead. Up to the current time, lead has been the an important contaminant of concern at Superfund mine waste sites associated with residential use. EPA guidance[16] recommends the cleanup goal of a soil lead concentration such that a child would have an estimated risk of no more than 5% of exceeding a blood lead concentration of 10 g/dl. In August 1998, EPA issued clarification to the 1994 Revised Interim Soil Lead Guidance for CERCLA sites and RCRA Corrective Action Facilities. The full text can be found at the following web page: http://www.epa.gov/epaoswer/hazwaste/ca/index.htm#p&g.

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[15] U.S. Environmental Protection Agency (EPA). 1994. Soil Screening Guidance. Office of Solid Waste and Emergency Response. EPA/540/R-94/101.

[16] U.S. Environmental Protection Agency (EPA). 1998. *Clarification to the 1994 Revised Interim Soil Lead Guidance for CERCLA Sites and RCRA Corrective Action Facilities* (a.k.a. "The Lead Directive"). Office of Solid Waste and Emergency Response. August. Directive # 9200.4-27. EPA/540/F-98/030.

The July 14, 1994 OSWER directive (The Lead Directive) indicates that a level of 400 ppm lead in soil be used as a level of contamination above which there may be enough concern to warrant site-specific study of risks. The EPA utilizes the Integrated Exposure Uptake Biokinetic (IEUBK) Model[17] to predict blood lead concentrations in children chronically (longer than 90 days) exposed to lead contaminated sources including soil, food, water, dust, air and drinking water, and to develop agency guidance. The IEUBK Model is discussed in the following section on Exposure Assessment, 9.5.2.

EPA has a Technical Review Workgroup (TRW) with expertise in the field of lead risk assessment. The TRW is comprised of senior scientists from multiple EPA regions and program offices (e.g., OSWER, NCEA and OPPTS). The TRW is supported by OSWER and its work is directed by TRW members. The TRW can be contacted through regional risk assessors and provides support for the use of the IEUBK model as well as assistance in other lead risk assessment issues.

In addition to the TRW, EPA has established the Lead Site Workgroup (LSW), composed of risk managers and risk assessors from the Regions and Headquarters, as a resource to develop agency guidance on risk management issues, and to provide the Regions with site specific consultations[18]. Through the efforts of the LSW, the Clarification to the 1994 Revised Interim Soil Lead Guidance for CERCLA Sites and RCRA Corrective Action Facilities was issued. The Lead Site Consultation Group (LSCG), composed of Division Directors and senior managers from Regions and Headquarters provides general direction to the LSW. The LSW and the LSCG can be contacted through regional Mine Sites Coordinators or through regional OSWER contact persons who address risk issues.

Guidelines regarding lead-based paint hazards in housing are available from HUD[19]. When evaluating indoor dust for its potential to contribute to lead exposure it is important to evaluate the contribution of lead based paint. It is particularly important to evaluate the presence of lead-based paint in older communities. The LSW is preparing risk management position papers which also provide guidance for the evaluation of soil and dust exposures when lead-based paint may be present.

Other Metals. Not all mine waste sites have lead as the primary contaminant of potential concern. It is not unusual for several metal contaminants to be present. Arsenic, cadmium, mercury and antimony may also be present. Although not a metal, cyanide may be a contaminant due to its use as a process chemical.

Radionuclides. Examples of radionuclides and their decay products that may be present at mine waste sites include thorium, radium, radon, and uranium. The risk assessment should not include the risk to background levels of radiation. Only the incremental risk to the contaminants must be considered. Further information for determining PRGs for radionuclides is provided in RAGS part B.

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[17] U.S. Environmental Protection Agency (EPA). 1994. *Guidance Manual for the IEUBK Model for Lead in Children.* Office of Solid Waste and Emergency Response, Washington, DC. EPA/540/R-93/081.

[18] U.S. Environmental Protection Agency (EPA). 1996. Memorandum from Stephen D. Luftig regarding *Administrative Reforms for Lead Risk Assessment*. Office of Solid Waste and Emergency Response. April 17.

[19] U.S. Department of Housing and Urban Development (HUD). 1995. *Guidelines for the Evaluation and Control of Lead-Based Paint Hazards in Housing.* June.

Organics. Organics may include VOCs (e.g., TCE), SVOCs (e.g., PAHs), PCBs, and fuel oil constituents. Volatile organics can introduce the inhalation pathway via exposures directly on site or from ground water transport to shower water supply. Individuals may be exposed to organics via ingestion or dermal contact with contaminated water or soil. Although organic contaminants are not usually dominant at mine waste sites, when they are present they may introduce significant risks that must be considered in the assessment. PCBs and asbestos may also be present at abandoned facilities.

8.5.2 Exposure Assessment

This section discusses some unique issues associated with assessing exposures to humans at mine waste sites. Exposure pathways and sources include inhalation of fugitive dust, soil ingestion, dermal contact with soil, indirect exposure through plant and animal uptake (and subsequent consumption by humans or animals), and ingestion of and dermal contact with contaminated ground water. Risk assessors may find useful information for assessing indirect exposures in RCRA guidance[20]. Mining pits, shafts, and boreholes may provide conduits through which groundwater contaminants migrate from shallow to deep aquifers that may contaminate drinking water. Recreational surface waters used for fishing and swimming can be contaminated from storm water run-off, leaching from waste piles and ground water to surface water migration routes. Plumbing, occupational exposure, and home hobbies should also be assessed as potential sources of lead in evaluating overall community exposure potential, as well as the individual level.

Measurement of Indoor Dust and Outdoor Soil and Dust. Much of the exposure to site-related metals may occur from contact with indoor dust, and outdoor soil and dust. In sites with current residential use, site specific characterization of contaminants in indoor dust may provide valuable information regarding the sources of contamination and significantly influence remedial or removal activities. For example, the presence of lead-based paint, if determined to a source of contamination, could affect remedial or removal activities.

The Integrated Exposure Uptake Biokinetic Model (IEUBK). The U.S.EPA uses the IEUBK model to predict childhood blood lead concentrations at lead contaminated sites. The IEUBK uses a predictive, integrated, multi-source and multi-exposure route approach to estimate the probability of exceeding user-chosen blood lead concentrations. The model results assist the site manager in developing final cleanup goals which are protective of the typical child. The model provides soil lead concentrations that represent the 95% upper confidence limit on the mean soil lead concentration goal. The IEUBK model should not be used for predicting blood lead concentrations in populations other than children who may be chronically (greater than 90 days) exposed to lead contamination. The TRW (or regional risk assessor) should be consulted to ensure the consistent and appropriate use of the IEUBK model. The LSW has prepared risk management position papers to provide guidance to ensure consistent management at mine waste sites.

The 400 ppm level of concern, presented in the Lead Directive, was derived using the IEUBK model in conjunction with a set of default assumptions. Site-specific data or default parameters under appropriate circumstances may be substituted. Contact the TRW (or regional risk assessor) for assistance.

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[20] U.S. Environmental Protection Agency (EPA). 1994. Exposure Assessment Guidance for RCRA Hazardous Waste Combustion Facilities, Draft. April. EPA/530/R-94/021.

Estimating Adult Exposures. A methodology for assessing adult lead exposures is available[21]. In this methodology, soil/dust exposures to the adult female are evaluated and the blood lead concentration in the fetus of the pregnant adult female are estimated.

8.5.3 Toxicity Assessment

Because mine waste sites can be very large and contaminant concentrations heterogeneous, several different exposure scenarios may be indicated. Based on current or proposed site use, it may be appropriate to develop exposure point concentrations which permit evaluation of acute as well as chronic toxicity. In EPA Superfund risk assessments both cancer and non-cancer health effects should be evaluated for all contaminants as well as the risks of exposures to mixtures. Guidance is available for applying toxicity values from EPA's Integrated Risk Information System (IRIS)[22] on the World Wide Web at the following address: http://www.epa.gov/iris/.

8.5.4 Health Studies

In addition to baseline risk assessment activities or removal risk assessment activities, mine waste sites may have coinciding epidemiologic or human health studies. Such studies do not replace the need for risk assessment, and are only useful where the data provide sufficient resolution for documenting both the presence and absence of exposure or adverse health. Results of human health studies may be used in developing a site cleanup strategy responsive to the community's health protection needs. Occasionally, the results of community health studies may reveal an imminent health threat and trigger a removal action. Health studies have been conducted by the PRP, the Agency for Toxic Substances and Disease Registry (ATSDR), local health districts, and state health departments.

If a related health study is to be conducted, EPA should be involved in both the design of the study and the final interpretation of study results. During the scoping of the health study plan, the community's ability to implement a health program should be taken into consideration. All technical (but not managerial) analyses associated with the health study should generally undergo peer review. In lead risk assessments, structural equation modeling of the health study results may help distinguish the contributions of different sources of human exposure. However, structural equation modeling is resource and time intensive; it contains variability and uncertainty, and potential benefits should be carefully weighed against the cost before proceeding. Structural equation modeling may also discriminate among various activities which influence human activity patterns and therefore exposures. For example, health intervention and education, or even an increased awareness of contamination, commonly result in avoidance behaviors (e.g., increased hand washing and dust removal or using alternate play areas) which could result in decreased exposure. Although these are neither consistent nor permanent remedies for reducing or eliminating exposures, such activities can influence the results of health studies and may be identified by structural equation modeling.

In some cases, results from health studies based on children's blood lead analyses have not been the same as IEUBK model predictions. There are several adequate scientific explanations for this observation which the risk manager may choose to verify through further investigation. The TRW or regional risk assessor can provide assistance in both the design of blood lead studies and in further investigations. Health studies for lead exposures have been conducted for the following Superfund mine waste sites: Bunker Hill in Idaho, Coeur d'Alene

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[21] U.S. Environmental Protection Agency (EPA). 1996. *Methodology for Assessing Risks Associated with Adult Exposure to Lead in Soil.* Technical Review Workgroup for Lead. Office of Solid Waste. October.

[22] U.S. Environmental Protection Agency (EPA). 1993. *Use of IRIS Values in Superfund Risk Assessment.* PB93963360.

Basin in Idaho and California Gulch in Colorado. Health studies for arsenic exposures have been conducted at Anaconda site in Colorado and Asarco/Tacoma site in Washington state (these sites included smelters).

8.6 Probabilistic Analysis

All risk assessments, both ecological and human health, should present an analysis of uncertainties associated with the risk evaluations. One approach to quantitatively address uncertainties is probabilistic analysis. Monte Carlo simulation, a type of probabilistic analysis, produces multiple risk descriptors instead of single numerical values to provide a range of risk estimates. Monte Carlo simulation calculates outcomes based on those situations with inherent variability and informational uncertainty. It also can present the degree of uncertainty quantitatively. Probabilistic analyses should only be applied when critical parameters have valid distributions of values available and when the parameters of concern effect a significant impact (as determined through sensitivity analysis) upon the risk results. A sensitivity analysis of parameters and range values should be presented. A primary difficulty in using probabilistic analyses in risk assessment is the ability to identify relevant databases for the development of appropriate distributions. Some guidance on the use of probabilistic analyses in risk assessment is available from EPA[23] [24]; regional guidance may also be available.

8.7 Risk Characterization

The risk characterization section of the risk assessment encompasses the presentation of ecological and human health risks in the context of their magnitude, significance, uncertainty, and implications for current and future site uses. It is a critical point in directing remedial action plans and hence, must be comprehensive and clear. The EPA Administrator's 1995 memoranda on risk characterization, cited above, explain these concepts in more detail. These memoranda also recommend that risks be provided in terms of a range from average exposures to upper bound exposures.

8.8 Risk Communication

A plan for risk communication should be developed simultaneously with scoping and work plan development. The plan should not only consider residents, landowners, and trustees, but should also include other stakeholders in federal, state and local agencies (including EPA regional offices). Information regarding community relations is provided in Chapter 6 of this document. Because PRPs may be involved in CERCLA activities in more than one EPA region, communication among site managers and risk assessors in different regions is important.

Communication strategies should be further coordinated between EPA and the PRPs. In some cases the PRPs may sponsor a health study on area workers or community residents. In such situations, it is essential that communication of risk and health information provided simultaneously by EPA and the PRP should strive to minimize confusion and stress on the recipients of this information.

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[23] U.S. Environmental Protection Agency (EPA). 1992. Memorandum from F. Henry Habicht regarding *Guidance on Risk Characterization for Risk Managers and Risk Assessors.* Office of the Administrator. Washington, DC. February 26.

[24] U.S. Environmental Protection Agency (EPA). 1997. *Guiding Principles for Monte Carlo Analysis*. EPA/630/R-97-001, March 1997.

8.9 Removal Actions

Risk assessments that support removal actions are usually separate from the baseline risk assessment for the longer term cleanup decisions; however, such risk assessments may help to direct, and possibly become a part of, the baseline risk assessment which supports the remedial investigation. Because the time frame of a removal action is rapid, so is the accompanying risk assessment. Consequently it commonly focuses on one or a limited number of contaminants and exposure pathways. It may account for only a human receptor group or only ecological receptors, or it may address both together. For example, risk of a catastrophic or a large scale event affecting critical ecological habitat may require immediate action, supported by an abbreviated but adequate risk assessment. For large and complex sites, once a removal action and supporting risk assessment are completed, in most cases a baseline risk assessment will be required for the overall site.

The decision to implement a removal action or a remedial (long term) action is a risk management issue. Although not part of risk assessment, information regarding educational and health intervention programs are included here because it specifically addresses the exposure and toxicity issues discussed in this chapter. Educational and health intervention programs can be an integral part of site management strategies. If communities are educated they can help to protect themselves while final cleanup actions are selected and implemented. Therefore local and state health departments should be consulted early in the process to recommend strategies for achieving early risk reduction. ATSDR can also be a partner in these efforts.

8.9.1 Health Effects

The health effect of concern for a removal action may be based on a chronic health effect that adversely affects a large number of people (or ecological receptors) or a particularly sensitive group (e.g., young children). It is also possible that the health effect of concern for a removal action may be based on acute adverse health effects requiring more immediate medical intervention. In contrast, the baseline risk assessment conducted during the remedial investigation may need only to focus on a long term health effect. At present, EPA does not have a database that provides acute human health toxicity criteria analogous to the Integrated Risk Information System (IRIS), which provides chronic human health criteria. Site managers and risk assessors should determine if particular acute toxicity criteria have already been adopted in their region, or may coordinate with regional toxicologists to develop their own criteria, or consult with the Superfund Technical Support Center at the National Center for Environmental Assessment in Cincinnati.

8.9.2 Risk Management Considerations

During the initial scoping, work plan development and sampling and analysis plan for the removal action risk assessment, the site manager and risk assessor should consider needs for risk evaluations which may follow the removal activity. To the extent possible, removal, site investigation, and long term cleanup activities should be coordinated and complementary. This will help to avoid redundancy, promote efficient use of resources, and ensure that no contaminants or exposures are inadvertently omitted from the risk evaluation.

In planning these efforts, recognize that education and health intervention programs have limits. They cannot protect everyone, and the protective benefits can be lost if the program should become ineffective. Such programs are best utilized early in the process of mitigating risk at a site. In general, EPA recommends that engineering controls be the principal tool for risk reduction for final site management strategies because it provides a more permanent response than ordinary reclamation activities or transient behavioral modifications. Local health officials

can be instrumental in identifying particular segments of the community that may be the most vulnerable. They can help focus targeted cleanup actions where education and health intervention cannot be relied upon to provide the needed protection to vulnerable members of the community. Health intervention can be an important component of an overall site management strategy.

8.10 Sources of Additional Information

Additional information on the risk assessment process can be found at various EPA websites, including http://www.epa.gov/oerrpage/superfund/programs/risk/index.htm, which discusses risk assessment in the Superfund program. On this webpage there are links to webpages that discuss human health risk assessments, ecological risk assessments, the “tools of the trade”, and forms to contact EPA with specific questions.

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