CHAPTER 2

RISK EVALUATION DURING THE FEASIBILITY STUDY

The FS generally is a two-step process of evaluating remedial alternatives: (1) screening, if necessary, and (2) a more detailed analysis for those alternatives that pass the screening. The RI/FS Guidance provides information on conducting the FS and describes all of the evaluations that are performed. Some of these evaluations pertain to human health risk, and the guidance in this chapter assists in these evaluations. (Ecological effects of remedial alternatives — not discussed in RAGS/HHEM Part C — also must be considered during the FS.)

2.1 RISK EVALUATION DURING DEVELOPMENT AND SCREENING OF ALTERNATIVES

The overall objective of the development and screening of alternatives is to identify an appropriate range of waste management options, some of which will be analyzed more fully in the detailed analysis phase. This process usually takes place relatively early in the RI/FS process, during project scoping (before the baseline risk assessment is completed).

The NCP specifies that the long-term and short-term aspects of three criteria — effectiveness, implementability, and cost — should be used to guide the development and screening of remedial alternatives. At screening, those alternatives that are clearly unacceptable in terms of effectiveness or implementability or are grossly excessive in cost may be eliminated from further consideration.

Consideration of effectiveness involves evaluating the long-term and short-term human health risks — among other factors — associated with a remedial alternative. The criteria of implementability and cost are not related to risk and, therefore, are not discussed in this document.

2.1.1 CONSIDERATION OF LONG-TERM HUMAN HEALTH RISKS

The long-term human health risks associated with a remedial alternative are those risks that will remain after the remedy is complete (i.e., residual risks). Evaluating long-term risks might ideally include an assessment of the risks associated with treatment residuals and untreated wastes (for a treatment-based remedy), or an evaluation of the remedy's ability to provide protectiveness over time (for a containment-based remedy). This approach might simply involve comparing estimates of the final concentrations that a remedy is expected to achieve in a medium with the PRGs for those chemicals in that medium. At the screening stage, however, this evaluation typically is based on professional judgment and the experience of the CERCLA program staff. Quantifying residual risks during screening generally is not necessary. For example, a technology may be evaluated during screening for its potential to treat the classes — or treatability groups — of chemicals present at the site (e.g., volatile organics, halogenated organics, non-volatile metals) rather than its ability to meet chemical-specific PRGs. See Section 2.2.1 for additional information on long-term risks associated with remedial alternatives.

2.1.2 CONSIDERATION OF SHORT-TERM HUMAN HEALTH RISKS

The short-term human health risks associated with a remedial alternative are those risks that occur during implementation of the remedial alternative (e.g., risks associated with emissions from an onsite air stripper). Because some remedies may take many years to complete, some "short-term" risks may actually occur over a period of many years. Populations that may be exposed to chemicals during remedy implementation include: (1) people who live and work in the vicinity of the site and (2) workers who are involved in site remediation. As with the consideration of long-term risks, this evaluation is based primarily on many simplifying assumptions and on professional judgment at the screening stage and is intended to identify alternatives with clearly unacceptable short-term risks. See Section 2.2.2 and Appendices A and D for additional information on evaluating alternatives for short-term risks during screening and development of alternatives.

2.2 RISK EVALUATION DURING DETAILED ANALYSIS OF ALTERNATIVES

The overall objective of the detailed analysis of alternatives is to obtain and present the information that is needed for decision-makers to select a remedial alternative for a site. This detailed analysis usually takes place during the later stages of the RI/FS process (i.e., near the end of or after the baseline risk assessment, when PRGs may have been modified). As discussed previously, two of the balancing criteria assessed during the detailed evaluation — long-term effectiveness and short-term effectiveness — involve an evaluation of risk. In addition, these criteria are considered in evaluating the criterion of overall protection of human health and the environment.

The risk evaluations of remedial alternatives involve the same general steps as the baseline risk assessment: exposure assessment, toxicity assessment, and risk characterization. The box on this page discusses the connection between the baseline risk assessment and the risk evaluations of remedial alternatives.

The guidance provided in this section assists in assembling and using available site-specific information for the purpose of completing the detailed analysis of remedial alternatives, specifically the evaluation of criteria that pertain to human health risks. The box on the next page lists several sources of information that can be used in the risk evaluations that are conducted during the RI/FS. The box on page 14 addresses the question of whether a quantitative evaluation is needed. The case studies at the end of this chapter provide examples of a qualitative and a quantitative evaluation of long-term and short-term risks during the detailed analysis.

CONNECTION BETWEEN THE BASELINE RISK ASSESSMENT AND THE RISK EVALUATION OF REMEDIAL ALTERNATIVES

A risk evaluation of remedial alternatives follows the same general steps as a baseline risk assessment. Detailed guidance on each step is provided in RAGS/HHEM Part A, which must be reviewed and understood by the risk assessor before a risk evaluation of remedial alternatives is conducted. Note, however, that the baseline risk assessment typically is more quantitative and requires a higher level of effort than the risk evaluation of remedial alternatives. Other differences (and similarities) are listed below.

Evaluate Exposure (Part A — Chapter 6)

- The source of releases for the baseline risk assessment is untreated site contamination, while the source of releases for the evaluation of remedial alternatives is the remedial action itself (plus any remaining waste).
- Exposure pathways associated with implementation of remediation technologies may include some pathways and populations that were not present (or of concern) under baseline conditions.
- The evaluation of short-term exposures associated with remedial alternatives may consider a number of different releases that occur over varying durations.

Evaluate Toxicity (Part A — Chapter 7)

- The risk evaluation of remedial alternatives often involves less-than-lifetime exposures that require appropriate short-term toxicity values to characterize risk or hazard.
- The risk evaluation of remedial alternatives may include an analysis of chemicals that were not present under baseline conditions (i.e., created as a result of the remedial alternative).

Characterize Risks (Part A — Chapter 8)

- A risk evaluation of remedial alternatives generally considers risks to onsite workers, as well as risks to the surrounding community.
- There are additional uncertainties involved in evaluating risks of remedial alternatives that are not considered in the baseline risk assessment (e.g., confidence in performance of remedies and patterns of predicted releases, confidence in attainment of clean-up levels).

SOURCES OF INFORMATION FOR RISK EVALUATIONS DURING THE FS

Baseline Risk Assessment. Much of the data collected during the baseline risk assessment can also be used to calculate the long-term residual risk associated with a remedial alternative. Some of the data may be applicable to calculation of risks during the remedial action. Some of the information from the baseline risk assessment that may be useful for analyzing the risks associated with the remedial alternative includes:

- exposure setting, including exposed populations and future land use (RAGS/HHEM Part A, Section 6.2);
- exposure pathways, including sources of contamination, chemicals of concern, fate and transport of chemicals after release, and exposure points (RAGS/HHEM Part A, Section 6.3);
- general exposure considerations, including contact rate, exposure frequency, and duration (RAGS/HHEM Part A, Section 6.4);
- exposure concentrations, including monitoring data, modeling results, and media-specific results (RAGS/HHEM Part A, Section 6.5);
- estimates of chemical intake (RAGS/HHEM Part A, Section 6.6);
- toxicity information (e.g., changes/additions to Integrated Risk Information System [IRIS] and Health Effects Assessment Summary Tables [HEAST]) (RAGS/HHEM Part A, Chapter 7);
- quantitation of risks (RAGS/HHEM Part A, Section 8.6); and
- uncertainties associated with toxicity assessment, exposure assessment, and baseline risk characterization (RAGS/HHEM Part A, Sections 6.8, 7.6, and 8.5).

Treatability Studies. Treatability investigations are site-specific laboratory or field studies, performed either with laboratory screening, bench-scale, or pilot-scale study (see Section 5.3 of the RI/FS Guidance). Generic studies for technologies (e.g., those performed by a vendor) can also contain useful information. Treatability studies may provide risk-related data such as (1) information on short-term emissions and (2) information on removal efficiencies of a technology. This information may be especially useful when considering innovative technologies. *Guide to Conducting Treatability Studies under CERCLA* (under development by EPA's Risk Reduction Engineering Laboratory) provides a three-tiered approach to conducting treatability studies during screening, selection, and design of remedial alternatives. Chapter 5 of the RI/FS Guidance, especially Section 5.6, provides information on evaluating the applicability of the treatability study results (e.g., determination of usefulness, documentation, usefulness of residual information, application of laboratory/ bench/pilot studies to full-scale system).

Feasibility Studies or Other Analyses for Comparable Sites. If a risk evaluation of one of the alternatives being considered was conducted during the FS (or later stages) for a site with similar wastes and similar conditions, some of the information that was developed may be helpful in characterizing the short-term or long-term risks associated with that alternative. This type of information should be examined carefully to determine whether the analyses are appropriate for the site currently being evaluated. Differences in the types of hazardous substances present, characteristics of environmental media, meteorological conditions, locations of receptors, or other factors could result in large differences in the risk evaluation.

The Engineering and Technical Support Center of EPA's Risk Reduction Engineering Laboratory (513-569-7406 or FTS 684-7406) can provide information concerning treatability studies and evaluations of remedial technologies.

FACTORS TO CONSIDER WHEN DECIDING WHETHER A QUANTITATIVE RISK EVALUATION IS NEEDED

The decision of whether to conduct a quantitative or qualitative risk evaluation depends on: (1) whether the relative short-term or long-term effectiveness of alternatives is an important consideration in selecting an alternative and (2) the "perceived risk" associated with the alternative. The perceived risk includes both the professional judgment of the site engineers and risk assessors and the concerns of neighboring communities. Some factors that generally lead to a higher perceived risk are as follows:

- close proximity of populations;
- presence of highly or acutely toxic chemicals;
- technologies with high release potential, either planned or "accidental";
- high uncertainties in the nature of releases (e.g., amount or identity of contaminants released) such as might exist with use of certain innovative technologies;
- multiple contaminants and/or exposure pathways affecting the same individuals;
- multiple releases occurring simultaneously (e.g., from technologies operating in close proximity);
- multiple releases occurring from remedial actions at several operable units in close proximity; and
- releases occurring over long periods of time.

If consideration of these (or other) factors leads to a high perceived risk for an alternative, a more quantitative evaluation, including emission modeling and/or detailed treatability studies, may be helpful in the decision-making process. For example, if one alternative considered for a site involves extensive excavation in an area that is very close to residential populations, then a more quantitative evaluation of short-term risks may be needed to evaluate this alternative. In addition, other factors, such as available data and resources, may affect the level of detail for these risk evaluations.

2.2.1 EVALUATION OF LONG-TERM HUMAN HEALTH RISKS FOR DETAILED ANALYSIS

Evaluation of the long-term human health risks associated with a remedial alternative involves: (1) evaluating residual risk and (2) evaluating the alternative's ability to provide protection over time.

Evaluate Residual Risk. Because PRGs generally are based on chronic human health risk considerations (e.g., ARARs such as maximum contaminant levels (MCLs), or risk-based concentrations), they usually provide the standard to use to evaluate long-term health risks. When site engineers are developing alternatives and determining whether a technology is capable of achieving PRGs, they are in effect evaluating residual risk. (Therefore, the results from using RAGS/HHEM Part B and other guidance on remediation goals are very important for this part of the analysis.)

Most of the time it will be sufficient for the detailed analysis to indicate whether or not an alternative has the potential to achieve the PRGs, rather than to quantify the risk that will remain after implementation of the alternative. If more detailed information concerning long-term risk is needed to select an alternative (e.g., to determine the more favorable of two otherwise similar alternatives), then it may be useful to determine whether one alternative is more certain to achieve the PRGs than the other, whether (or to what extent) one may be able to surpass (i.e., achieve lower concentrations than) the PRGs, or whether one may be able to achieve the goals in a shorter time.

Certain remedial technologies (e.g., incineration) may produce new contaminants that were not present at the site under baseline conditions. The risks associated with these additional substances generally should be evaluated. Another consideration in evaluating the residual risk associated with some alternatives is the level of confidence in the ability of the remedy as a whole to achieve the site engineers' predictions. For some technologies (e.g., ground-water extraction and treatment technologies), past experience has indicated that, in some situations, it may be difficult or impossible to achieve the predicted goals. This information on the uncertainty associated with an alternative may be an important factor in selecting a remedy.

After the individual technologies comprising a remedial alternative have been examined separately, then the alternative as a whole should be examined to determine the extent to which it meets the PRGs for all of the contaminated media and all of the contaminants of concern. Even if PRGs will be met, potential cumulative effects on human health due to multiple contaminants, media, or exposures may need to be considered. If an alternative will not meet the PRGs for all media or contaminants of concern or if cumulative effects are a concern, this information should be highlighted in the presentation of the results of the detailed analysis.

Evaluate Protectiveness Over Time. Evaluating whether an alternative is likely to maintain the specified level of protectiveness over time (often referred to as "permanence") involves using expert engineering judgment. In particular, if an alternative relies on engineering or institutional controls to reduce or eliminate exposure to contaminated media, then the ability of these controls to maintain protectiveness should be considered. These types of remedies provide protection by reducing or eliminating exposure to hazardous substances rather than eliminating the hazardous substances or reducing their concentrations, volumes, or toxicity. Failure of such remedies could lead to an increase in exposure and therefore an increase in risk. For example, if a remedy includes the capping of contaminated soils, then the potential future exposures due to cap failure include direct contact with soils and the leaching of contaminants to ground water. The worst-case situation of complete containment system failure is unlikely to occur, however, because five-year reviews (see Section 3.4) are conducted at all sites where wastes are managed onsite above concentration levels that allow for unrestricted use and unlimited exposure.

2.2.2 EVALUATION OF SHORT-TERM HUMAN HEALTH RISKS FOR DETAILED ANALYSIS

Short-term health risks generally include any current baseline risks plus any new risks that would occur while implementing the remedy. As discussed previously, the evaluation of potential short-term risks involves the same general steps as in the baseline risk assessment. These steps, however, generally will not be conducted in the same level of detail for the FS.

Other important points concerning level of effort should be emphasized here. For example, the Resource Conservation and Recovery Act (RCRA) has performance standards for many commonly used CERCLA remedial technologies (e.g., incineration). The risks associated with many of these technologies were analyzed in developing these standards, and the standards were set such that the risks associated with operation of the technology would be acceptable. Therefore, a detailed evaluation of the risks associated with RCRA-regulated technologies generally would not be necessary. On the other hand, depending on site-specific factors such as the toxicity of site contaminants and the proximity of populations, a more detailed evaluation of short-term risks may indeed be appropriate.

Detailed analyses may also be appropriate for less-characterized technologies (e.g., innovative technologies). In addition, alternatives with multiple short-term releases or substantial baseline risks may need a more detailed evaluation to determine whether cumulative risks are expected to be within acceptable levels.

Of special note is that the short-term risk evaluation for remedial alternatives during the detailed analysis includes an evaluation of the potential for short-term risks to two groups of individuals: (1) neighboring populations (which include onsite workers not associated with remediation) and (2) onsite workers associated with remediation.

Appendices A through D provide information that can be used when a more quantitative evaluation of short-term risks is needed to support the selection of a remedy. Chapter 8 of RAGS/HHEM Part A also provides guidance on characterizing short-term risk.

Evaluate Short-term Exposure. A qualitative exposure assessment for remedial alternatives during the detailed analysis generally involves — just as in the baseline risk assessment, but in a less quantitative manner — using the concept of reasonable maximum exposure (RME) to evaluate release sources, receiving media, fate and transport, exposure points, exposure routes, and receptors associated with a particular alternative.

An important difference between the baseline risk assessment and the risk evaluation of remedial alternatives involves exposure sources. For the baseline risk assessment, the source of exposure is untreated site contamination. For remedial alternatives, however, the potential sources of exposure are the releases that result from the implementation of remedial technologies. In addition, some remedial alternatives (e.g., incineration, biodegradation) may result in new chemicals that were not previously assessed for the site.

The first step of the exposure assessment involves identifying the types of releases associated with a particular waste management approach. During the detailed analysis, methods for mitigating potentially significant short-term releases should be examined, and releases that are expected to be most difficult to control should be highlighted.

Appendices A and D of this guidance each contain two matrices that should assist in characterizing the releases that may occur during remedy implementation. Exhibit A-1 provides a brief description of common remedial technology processes, and Exhibit A-2 summarizes potential releases to different media during the normal operation of various technologies. Exhibit D-1 provides a summary of releases associated with radiation remedial technologies, and Exhibit D-2 includes a qualitative estimate of the potential short-term risks posed by a radiation remedial technology.

After the releases and their receiving media have been identified, the next step of the exposure assessment is to determine whether major exposure pathways exist. Characterizing site-specific exposure pathways involves identifying:

- the general fate and transport of the contaminants that are released from the technology (e.g., downwind transport);
- the potential exposure points and receptors (e.g., nearby downwind residents); and
- potential exposure routes (e.g., inhalation).

Exhibit 2-1 illustrates an example of an exposure pathway for a remedial alternative. More detailed information concerning exposure pathways is available in Chapter 6 of RAGS/HHEM Part A. The flow charts contained in Exhibit 6-6 of Part A are particularly useful in determining the populations potentially exposed by releases into a particular medium. Transfers of contaminants from one medium to other media also are addressed.

At this point, a quantitative exposure assessment — if needed — would involve (in addition to identifying release sources, exposure routes, and exposure points):

- quantifying releases;
- evaluating environmental fate and transport;
- determining exposure point concentrations; and
- calculating intakes.

All of these steps are discussed in Chapter 6 of RAGS/HHEM Part A.

Throughout the short-term exposure assessment, the assessor must continually ask whether the potential exposure warrants the level of quantitation being used. At times, the answer may not be known until the end of the exposure assessment. For example, if short-term exposure was estimated to be very similar to long-term exposure, it would not be necessary to expend resources to obtain the short-term toxicity information needed to quantitatively characterize risk.

A major difference between the exposure assessment conducted during the baseline risk assessment and the one conducted during the risk evaluation of remedial alternatives is the evaluation of the timing and duration of releases. Because a number of different activities will take place during implementation, it is likely that the quantities of hazardous substances released to the environment will vary over time. For example, as seen in Exhibit 2-2, one remedy can have several distinct phases, each with different exposure potentials. It may be important to determine the sequence of events and likely activities at each phase of the remediation, so that the exposure point can be evaluated for each phase. This will also ensure that appropriate short-term exposure durations are identified and that the potential for releases to occur simultaneously and thus result in cumulative risk is considered. As seen in

EXHIBIT 2-1

ILLUSTRATION OF AN EXPOSURE PATHWAY FOR A REMEDIAL ACTION

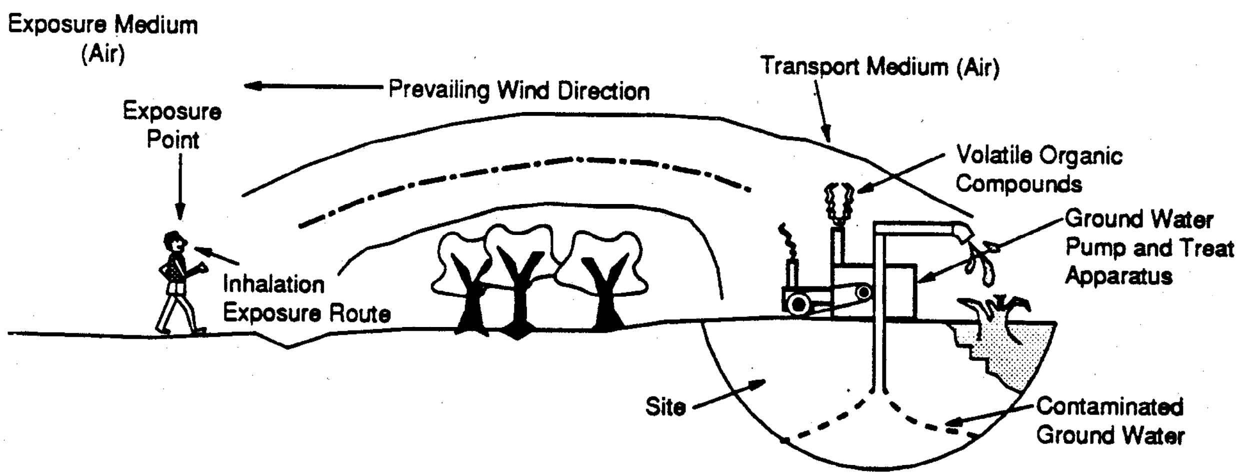


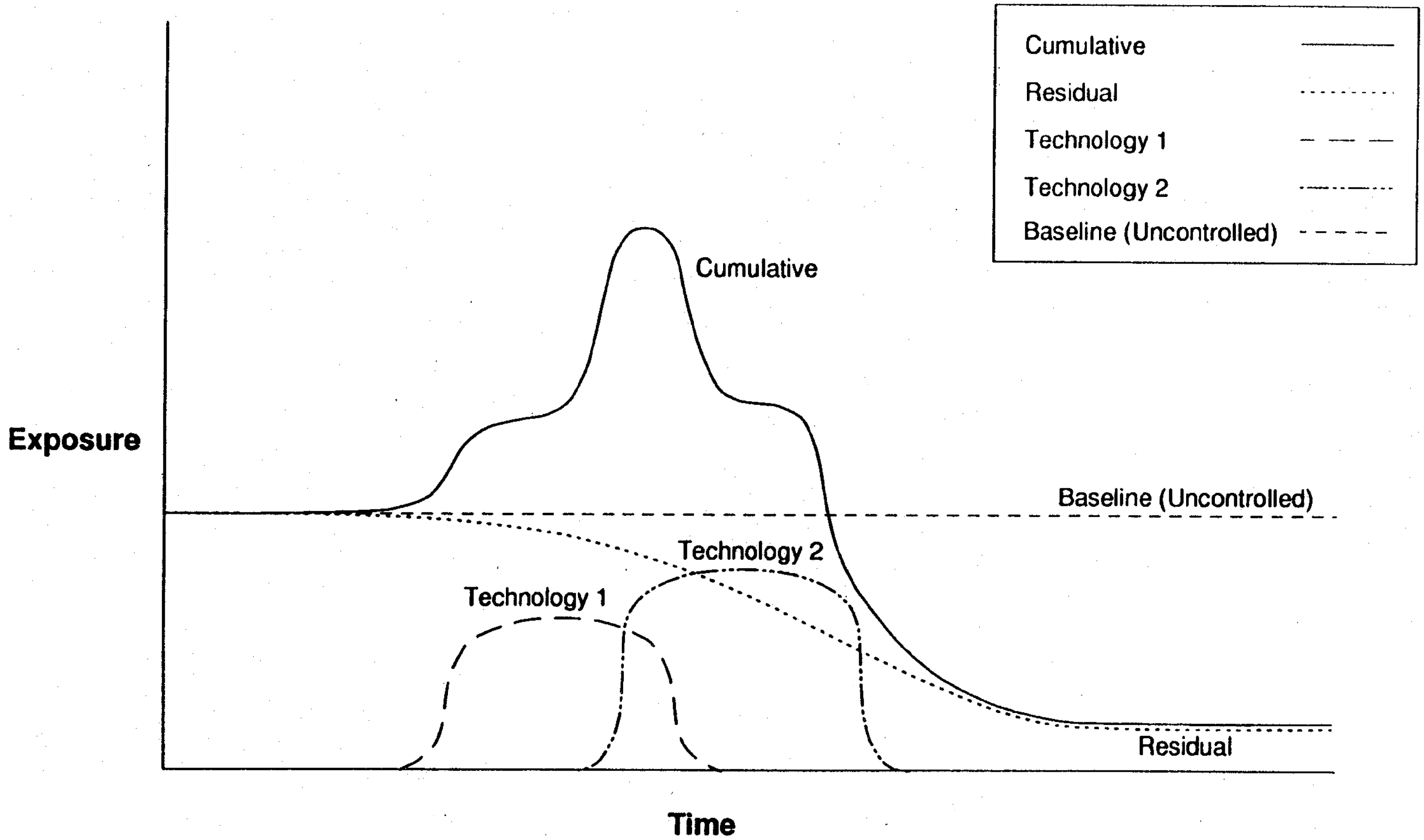
Exhibit 2-2, this issue is complicated by the possible presence of baseline exposures.

Appendix B provides references — organized based on several important categories of remedial technologies — that can be consulted to quantify the release of and therefore exposure to contaminants. The information in Appendix B includes a brief discussion of considerations in release modeling and monitoring, a list of key technology-related parameters generally needed as inputs for models (e.g., meteorological conditions, operation characteristics, soil/media characteristics), an annotated list of primary references, and a list of additional references.

Evaluate Short-term Toxicity. The releases that may occur during implementation of a remedial alternative, and hence the exposure-point concentrations, generally last for varying durations and correspond to less-than-lifetime exposures. Consequently, any toxicity values used to evaluate the risks from these shorter exposures must correspond to the duration of the release (or exposure). Three exposure durations, in addition to longer-term exposures, may be of concern at CERCLA sites undergoing remediation: single exposure events (minutes, hours, or single day), very short-term exposures (up to two weeks), and short-term exposures (two weeks to seven years). Note that the chronic toxicity values for noncarcinogenic effects used most frequently in the baseline risk assessment may not be appropriate without modification for exposures of less than seven years (otherwise they may be unnecessarily conservative).

EXHIBIT 2-2

ILLUSTRATION OF CUMULATIVE EXPOSURE FROM MULTIPLE RELEASES



Note: The graph illustrates how nearby populations at some sites could be exposed to both residual risks <u>and</u> risks from remediation technologies. The cumulative exposure illustrated is the sum of residual exposure and exposures associated with releases from Technologies 1 and 2. This exhibit is for illustration purposes only and is not meant to imply that this level of quantitation is neccesary or even desired.

Appendix C contains information concerning the use of short-term toxicity values. RAGS/HHEM Part A provides additional information on assessment of contaminant toxicity. As discussed in Appendix C, the Superfund Health Risk Technical Support Center (TSC) should be consulted in all cases where short-term toxicity values are needed.

Characterize Short-term Risks to the Community. During risk characterization, exposure and toxicity information is brought together to provide a measure or indication of the magnitude and timing of short-term health risks (if any) from the remedial alternatives. As discussed previously, risk assessors may choose to characterize the short-term risks to the community (i.e., persons who live or work in the vicinity of the site) quantitatively for some sites and qualitatively for others. When short-term risks are not expected to be a problem for a site, a more qualitative evaluation generally is appropriate. In these cases, a qualitative evaluation of the magnitude, duration, and/or likelihood of the exposures and risks should be conducted, and assessors could describe short-term risks in a qualitative manner relative to the results of the baseline risk assessment.

A quantitative evaluation of short-term risks is most likely to be useful when the types, levels, and/or availability of hazardous substances are expected to change significantly as a result of remediation. If quantitative exposure estimates and toxicity data are available, then a more quantitative risk characterization may be conducted. The quantitative method that is used to characterize these risks depends in part on the toxicity values that have been identified. Some of these toxicity values (e.g., subchronic reference doses) must be combined with the results of the exposure assessment (i.e., intakes). The results of risk characterizations using this type of toxicity value will be of the same type as those generated in the baseline risk assessment: hazard quotients (or indices) or excess individual lifetime cancer risks. If the toxicity values incorporate exposure assumptions (e.g., as in one- and ten-day health advisories), then these values are compared with exposure concentrations to determine whether the risks are above acceptable levels. Appendix C provides additional information on short-term toxicity values.

Cumulative effects from multiple releases or multiple chemicals should also be considered, if possible. If the risk characterization is qualitative, then a discussion of the potential for cumulative risks from multiple chemicals and/or exposure pathways (e.g., due to simultaneous implementation of several remedial technologies) should be provided. If the results of the risk characterization are more quantitative (e.g., cancer risks and hazard quotients), then the information concerning duration and timing of releases can be used to calculate the cumulative risks or hazard indices for those releases that will occur at the same time and affect the same populations. If the results of the quantitative risk characterization are comparisons with short-term toxicity criteria, then the total exposure concentrations can be calculated for releases that occur at the same time and affect the same populations. These total exposure concentrations then can be compared to the short-term toxicity criteria. See Chapter 8 of RAGS/HHEM Part A for additional guidance on characterizing short-term human health risks.

Characterize Short-term Risks to Workers. Worker health and safety issues should also be considered during the development of the FS. The Worker Protection Standards for Hazardous Waste at 40 CFR 311 and 29 CFR 1910.120 establish requirements for worker protection at CERCLA sites, including requirements for planning (i.e., health and safety plans, and emergency response plans), training, and medical surveillance. Although the standards encompass areas that are not directly related to worker risk (e.g., illumination and sanitation), they also specify requirements in areas that are directly relevant to worker health risks. Specifically, once a remedy is selected, the Worker Protection Standards require that implementation of that remedy proceed with the following risk-related considerations:

- site characterization and analyses prior to commencing remedial activities, specifically risk identification (see 29 CFR 1910.120(c));
- proper use of engineering controls, work practices and personal protective equipment (PPE) for employee protection (see 29 CFR 1910.120(g)); and
- preparation of emergency response plans that specify how the site employees will be protected while responding to onsite

emergencies that may occur (see 29 CFR 1910.120(l)).

It is important to note, however, that factors not associated directly with hazards particular to a given site (e.g., risk of accidents during offsite motor vehicle transport) are not usually considered during the FS, but instead should be addressed prior to remediation in the site health and safety plan.

The exact nature of the assessment of worker safety issues for a remedial alternative will vary with each site. For many types of sites and remedial alternatives, the risks to workers will be well-characterized and will not require much additional site-specific analysis. These issues will be addressed in more detail in the site-specific health and safety plan. Thus, a qualitative assessment of worker risk is appropriate for most sites during the FS and can be based on three types of risk.

- Potential for exposure to hazardous substances during onsite remedial activities. The most significant factor determining the potential for exposure to hazardous substances is the nature of the onsite contamination. Because onsite remediation workers are equipped with the appropriate PPE and are required to use appropriate engineering controls, their risk generally should be minimal. Factors that affect the potential for exposure, however, include the likelihood of PPE failure. In general, more restrictive PPE is more likely to fail due to considerations such as worker mobility and visibility constraints, and potential for worker heat stress.

- Potential for injury due to physical hazards. Onsite remediation workers may be exposed to hazards other than exposure to hazardous substances. Hazards such as explosion, heat stress, and precarious work environments may also pose threats to workers.

- Potential for exposure during emergency response activities (assuming the need arises for onsite emergency response). Part of the design of a remedial alternative should consider the potential for worker exposure during emergency responses that may be required in the event of remedy failure. For some remedial alternatives, it is possible that emergency assistance would be handled in part by onsite workers, with offsite assistance (e.g., county HAZMAT teams) as required.

Alternatively, it is possible that an emergency response plan would require the evacuation of onsite remediation workers and use of offsite emergency responders.

2.3 CASE STUDIES

The following two case studies provide examples of the evaluations of long-term and short-term risks that are conducted during the detailed analysis. Both case studies present an evaluation of only one technology for one of several alternatives that are considered for the hypothetical site. An actual detailed analysis would include a similar evaluation for other technologies and alternatives as well. The two sites considered in the case studies are identical in all respects, except one: the XYZ Co. site considered in Case Study #1 is distant from residential or worker populations, while the ABC Co. site considered in Case Study #2 is adjacent to a residential neighborhood. A more quantitative analysis was conducted in Case Study #2 because of concern for potential short-term exposures to the neighboring community.

The sites presented in these case studies are abandoned industrial facilities that are contaminated with various volatile organic compounds (VOCs) and heavy metals. VOCs contaminate both the soil and ground water at the sites, while metals are found in the soil only. A number of leaking drums were stored above ground at the sites and were removed prior to the RI. There are also two lagoons filled with hazardous sludges. City ground-water wells are located approximately 1/4 mile from the sites. VOCs have been detected in the wells at levels high enough to force the city to use an alternate water source.

CASE STUDY #1: QUALITATIVE EVALUATION DURING DETAILED ANALYSIS

[Note: This case study presents an evaluation of only one technology for only one of several remedial alternatives; an actual detailed analysis would address other technologies and alternatives as well. All data in this case study are for illustration purposes only.]

Remedial Alternatives

Based on the results of the development and screening of alternatives, the site engineers have identified five alternatives (A through E) to be evaluated for use as remedies at the XYZ Co. site. One of the technologies included in Alternative C is ground-water pumping and air stripping for the VOCs in ground water.

Evaluation of Long-term Risks

Meeting PRGs for all contaminants in ground water is uncertain at this point due to the complex nature of the contaminated aquifer. If after remedy implementation it is determined that Alternative C does not meet PRGs for all contaminants in ground water, then the residual risk remaining after implementation will be examined to determine whether other measures need to be taken to assure protectiveness. There are no residual risks for media other than ground water for the pump-and-treat/air stripping component of Alternative C.

Evaluation of Short-term Risks

The time-frame for air stripping of VOCs from ground water at the XYZ Co. site — and therefore the time frame considered for evaluating short-term risks — is at least 20 years, and possibly as many as 50, depending on factors such as the specific aquifer characteristics.

Releases and Receiving Media. The most likely release of concern from an air stripper is the release of air contaminated with VOCs. The type of air stripper being considered for the XYZ Co. site generally achieves 99 percent or better removal of VOCs from water. The vapor phase VOCs contained in the air stripper off-gases then can be removed if necessary using air pollution control devices such as granular activated carbon columns or an afterburner, which generally achieve 90 to 99 percent destruction or removal of contaminants from the vapor phase. However, there will still be some small release of contaminants that may need to be examined further during the design stage of this remedy (if selected). Also, air pollution control devices will produce residues that in turn may need to be treated. Other releases associated with air stripping include treated water containing residual organic contaminants that will be released to surface water, and, possibly, fugitive air emissions due to leaky valves and fittings.

Fate and Transport, Exposure Points, and Exposure Routes. The release of VOCs into the air during air stripping at the XYZ Co. site could result in inhalation of volatiles transported through the air. However, the nearest target population is over one mile from the site. Long-term average concentrations may be a concern, as well as shorter-term or peak concentrations that may occur under certain conditions (e.g., temperature inversions).

Short-term Risks. The time period of exposure to air stripper off-gases (20 to 50 years) is a significant portion of a human lifetime. However, because the concentrations of VOCs in ground water are not unusually high, the releases associated with the air stripper are well-characterized, and there is no nearby target population, quantitation of these risks is not needed to select a preferred alternative.

CASE STUDY #2:
QUANTITATIVE EVALUATION DURING DETAILED ANALYSIS

[Note: This case study presents an evaluation of only one technology for only one of several remedial alternatives; an actual detailed analysis would address other technologies and alternatives as well. All data in this case study are for illustration purposes only.]

Remedial Alternatives

Based on the results of the development and screening of alternatives, the site engineers have identified five alternatives (A through E) to be evaluated for use as remedies at the ABC Co. site. One of the technologies included in Alternative C is ground-water pumping and air stripping for the VOCs in ground water. [For this case study, only benzene from the pump-and-treat component of the remedial alternative will be analyzed in detail. In an actual analysis, each contaminant of concern and each component of the remedy may need to be analyzed in a similar fashion.]

Evaluation of Long-term Risks

The RI has shown that the organic contaminants in the ground water are adsorbed to the aquifer material and are also dissolved in the ground water. The remediation goal for benzene will be readily met in the treated water, which will subsequently be discharged into the nearby surface water. Remediation of the water remaining in the aquifer, however, is much less certain. The residual concentration of benzene in this remaining water will depend on several factors, including the adsorptive characteristics of benzene with the aquifer material, the specific pumping regimen, and the length of time that this technology is implemented. If, at a later stage (e.g., during the five-year review), it is determined that the contaminants are not being extracted at the desired levels, the pumping regimen may need to be modified (or some other approach may be needed). At a minimum, the pumping of ground water is expected to be an effective barrier against further contaminant migration. Due to the uncertainty regarding the residual concentration of contaminants that may remain in ground water, the permanence of the pump-and-treat technology, in terms of future risks, is unknown at this time.

Evaluation of Short-term Risks

Short-term impacts due to air emissions from air stripping are expected to be the most significant risks from the pump-and-treat component of the remedy at ABC Co. site. [This case study does not consider fugitive emissions from sources "upstream" of the air stripper (e.g., separators, holding tanks, treatment tanks), although these sources may have been evaluated in an actual risk assessment.] In order to assess these risks during the detailed analysis stage, exposure concentrations from the ABC Co. site will be estimated by combining emissions modeling with dispersion modeling. Before proceeding with this analysis, the following steps were taken.

- An appropriate atmospheric fate and transport model, derived from the SCREEN model developed by EPA's Office of Air Quality and Planning Standards was chosen. (A more complete listing and comparison of atmospheric fate models is given in Table 3-2 of the *Superfund Exposure Assessment Manual* [EPA 1988e].)

- Required inputs for the atmospheric fate and transport model were obtained. These inputs included the emission rate of contaminants from the air stripper into the atmosphere (based on contaminant concentrations in ground water, system flow rate efficiency of the air stripping process, and efficiency of the air pollution control device); atmospheric dispersion factors for contaminants; and meteorological data (wind speed, prevalent direction, stability, mixing height, and temperature). More detailed parameters, such as surface roughness height and specific topographic features, were not required for the model that was chosen.

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CASE STUDY #2:
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(Continued)

- The population that will be affected by short-term releases was identified. This information was obtained from the baseline risk assessment, and was based on the population distribution and density of the surrounding community, and meteorological data such as the prevailing wind direction.

- The toxicity characteristics of the contaminants were obtained from the baseline risk assessment.

Exposure Assessment. Releases are expected to occur during both the construction and the implementation stages of the pump-and-treat technology. The time frame for each of these stages varies and, therefore, the release and exposure potential also will vary. The most probable release of concern from implementation of the air stripper [the focus of this case study] has been identified as the release of air contaminated with volatile organic chemicals (VOCs) from the stripping tower to the atmosphere. Benzene is one of the volatile contaminants in the ground water being treated, and is expected to be present as a residual in the stripper off-gases. The following equation (EPA, *Emission Factors for Superfund Remediation Technologies*, Draft, Office of Air Quality Planning and Standards, 1990) was used to calculate the benzene emission rate into the air stripper off-gases:

$$ER\ (g/s) = C \times Q_{in} \times (SE/100) \times K$$

where
ER = emission rate of benzene (g/s)
C = concentration of benzene in water = 2.5 mg/L
Q_{in} = influent water flow rate = 1700 L/min
SE = stripping efficiency of tower for benzene = 99.99%
K = constant to convert units = 1.67×10^{-5} (g-min/mg-s)

An SE of 99.99 percent is used in these calculations to determine the reasonable maximum emission rate of benzene into the air. Actual SEs would be between 90 and 99.99 percent, depending on several operating parameters. Solving this equation, ER = 0.071 g/s.

Because this system will use an air pollution control device (APCD) such as granular activated carbon (GAC) columns to remove contaminants from gases released to the atmosphere, ER is the rate of release of benzene from the ground water into the stripper off-gases rather than the rate of release of benzene directly to the atmosphere. The release rate of benzene to the atmosphere, therefore, can be calculated using the following equation:

$$q = ER \times (1 - DRE/100)$$

where
q = mass release rate to atmosphere (g/s)
ER = emission rate from air stripper to APCD = 0.071 g/s
DRE = destruction/removal efficiency of APCD = 95%

A DRE of 95 percent is used to obtain a reasonable maximum release rate to the atmosphere. Applications of similar APCDs achieve 95 to 98 percent destruction and removal efficiency for benzene in air. Solving for the atmospheric release rate of benzene, q = 0.0035 g/s.

Using fate and transport modeling [analysis not shown], the atmospheric release rate of benzene is converted to an exposure point concentration at a residence 250 m downwind of the site. The short-term air concentration (24-hour average) of benzene is estimated to be 6×10^{-4} mg/m^3. The average annual longer-term concentration of benzene in air at the site boundary, as determined by the same model, is estimated to be 3.4×10^{-4} mg/m^3.

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CASE STUDY #2:
QUANTITATIVE EVALUATION DURING DETAILED ANALYSIS
(Continued)

The only potential exposure pathway identified for releases from the air stripper is the air (inhalation) pathway. Because the toxicity criterion used to characterize short-term risk is a threshold concentration (see Toxicity Assessment below), a short-term intake does not need to be calculated. The longer-term intake is needed to evaluate the cancer risk associated with inhalation of benzene. This intake is calculated by first obtaining the long-term site-specific exposure duration of 30 years from the baseline risk assessment. (An exposure duration of 30 years is used because, while the time for implementation of the pump and air stripping technology may be up to 50 years, an individual is not expected to stay in the community for more than 30 years. If the maximum time for implementation were less than the exposure duration identified in the baseline risk assessment, then exposure would be computed using the maximum implementation time as the exposure duration.) Using other exposure values obtained from the baseline risk assessment (e.g., inhalation rate of 20 m^3/day), the longer-term (lifetime average) intake of benzene due to the air stripper is approximately 7.3×10^{-5} mg/kg-day.

These concentrations and intakes are based on conservative steady-state assumptions regarding atmospheric conditions. Therefore, there is uncertainty surrounding the atmospheric data (which are inputs to the model) that could lead to higher (but probably lower) concentrations. For example, variations in wind speed and direction will result in different contaminant concentrations for both maximum short-term and long-term exposure point concentrations. Some amount of published research data is available (mainly from water treatment plant studies) on the reliability of the APCDs used in air stripping. This information, combined with data from previous program experience, indicates that the uncertainty associated with the effectiveness of the APCDs is low.

Toxicity Assessment. To assess risk from exposure to the short-term benzene concentration (24-hour average), a toxicity criterion corresponding to a similar exposure duration is used. One such criterion, identified through consultation with the TSC, is EPA's acute inhalation criteria (AIC). The AIC provides a threshold level above which acute inhalation exposure to benzene could result in toxicity to the most sensitive target organ (bone marrow and the immune system). The AIC for benzene is 190 ug/m^3. [In this case study, the AIC for benzene was assumed to be readily available. In an actual risk evaluation, this may not always be the case. When toxicity information is not readily available — especially when, as in this case study, the longer-term exposure point concentration is not significantly different from the shorter-term point concentration (and the longer-term has toxicity information) — then either delaying the assessment or expending resources to obtain the shorter-term toxicity information is not recommended.]

To assess risk from exposure to the longer-term benzene concentration (annual average) for the 30-year exposure duration, the inhalation cancer slope factor for benzene of 0.029 $(mg/kg\text{-}day)^{-1}$ is identified from the baseline risk assessment.

Risk Characterization. Short-term risk to the community from benzene is determined by comparing the short-term concentration of 6×10^{-4} mg/m^3 (i.e., 0.6 ug/m^3), with the AIC of 190 ug/m^3, to result in a ratio of 0.003. Because this ratio is less than 1, short-term risk to the community solely from benzene is considered to be unlikely.

Using the longer-term intake of 7.3×10^{-5} mg/kg/day, and the slope factor of 0.029 $(mg/kg/day)^{-1}$, the upper-bound excess individual lifetime cancer risk to the community from long-term exposure to benzene in the atmospheric releases from the air stripper is approximately 2×10^{-6}, within EPA's acceptable risk range.

[Uncertainties associated with the site-specific exposure information and the toxicity information, discussed in more detail in the baseline risk assessment, also are important to consider at this stage of the analysis.]