United States Environmental Protection Agency
Solid Waste and Emergency Response (OS-220)
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EPA

A Guide On Remedial Actions For Contaminated Ground Water

GOAL

The goal of Superfund ground-water remediation is to protect human health and the environment by restoring ground water to its beneficial uses within a time frame that is reasonable, given the particular site circumstances. This fact sheet summarizes the key issues in the development, evaluation, and selection of ground-water remedial actions at Superfund sites. For more detailed information, consult Regional Ground-Water Forum members or the Interim Final "Guidance on Remedial Actions for Contaminated Ground Water at Superfund Sites," (Ground-Water Guidance) December 1988, OSWER Directive No. 9283.1-2.

REQUIREMENTS OF CERCLA

The approach outlined in this fact sheet is designed to ensure that ground-water remeial actions will meet the following requirements of CERCLA:

- Protect human health and the environment (121(b))
- Comply with applicable or relevant and appropriate requirements (ARARs) of Fedral and State laws (121(d)(2)(A)) or warrant a waiver under CERCLA Section 121(d)(4)
- Be cost-effective (121(a))
- Utilize permanent solutions and alternative treatment technologies or resource recovery technologies to the maximum extent practicable (121(b))
- Satisfy the preference for remedies that employ treatment that permanently and significantly reduces the mobility, toxicity, or volume of hazardous substances as a principal element **or** provide an explanation in the ROD for why the preference was not satisfied (121(b)). In addition, the following provisions of CERCLA may or may not be pertinent to groundwater remediation, depending on site-specific circumstances:
- Alternate concentration limits (ACLs) from otherwise applicable or relevant and appropriate requirements can only be used for determining offsite cleanup levels under special circumstances (121(d)(2)(B)(ii)).
- Remedial actions that restore ground water are to be federally funded until cleanup levels are achieved or up to 10 years, whichever comes first. However, if the purpose of the ground-water remedial action is to provide an alternate water supply, for example, but not to restore ground water, then the Federal government will pay capital and startup costs only (104(c)(6)).
- A review must be conducted at least every 5 years if wastes are left onsite (121(c)) above health- or environment based levels to verify that the remedy continues to provide adequate protection of human health and the environment.

SCOPING GROUND-WATER REMEDIAL ACTIVITIES

Before collecting any data, it is useful to conduct two planning activities:

- ***Site management planning (See right),*** which involves identifying the types of analyses and actions that are appropriate to address site problems and their optimal sequence.
- ***Project planning (See next page),*** which includes such activities as scoping data collection efforts, initiating identification of ARARs, and work plan preparation.

SITE MANAGEMENT PLANNING

Site management planning identifies the response approaches that will be taken to address the site problems. Two response approaches can be taken to remediate ground water at Superfund sites:

- Removal actions
- Remedial actions, which can be final, or interim actions

Removal actions are authorized for any release that presents a threat to public health, welfare, or the environment. CERCLA limits Superfund-financed removal actions to $2 million and 12 months unless the criteria for granting an exemption to the statutory limits are satisfied. Remedial actions are sometimes addressed as operable units.

An operable unit is a portion of an overall response action that, by itself, eliminates or mitigates a release, a threat of a release, or an exposure pathway; it may reflect the final remediation of a defined portion of a site. At many sites, it is appropriate to implement an operable unit as an interim action. Interim actions may be implemented to prevent exposure to contaminants or prevent further degradation of ground water (by remediating hot spots, for example) while the overall remedial investigation (RI) and feasibility study (FS) are being conducted. Interim actions involving pumping can also provide critical information for evaluating the final remedy.

Characterization of the Hydrogeology

Describe, the geology using geophysical methods and sediment samples collected during drilling of soil borings and monitoring wells. Present the information using geologic cross sections and fence diagrams.

Assess the ground-water movement by using water level measurements from wells screened at various depths. Present a contour map of each aquifer to determine recharge and discharge and identify the direction of ground-water flow.

Evaluate data over time to detect seasonal or tidal fluctuations.

Aquifer tests may be used to determine the hydraulic properties of the aquifers and aquitards, and to evaluate the performance and effectiveness of the extraction system. Aquifer tests can be used in conjunction with modeling.

Characterization of Contamination

Consider selecting one or more chemicals for monitoring to reduce analytical costs and simplify modeling. These chemicals may be selected on the basis of toxicity, exposure, mobility, persistence, treatability, or volume of contaminants. If appropriate, however, nontoxic constituents or chemical classes, such as total volatile organic compounds, could also be monitored.

Determine the horizontal and vertical extent of the contaminant plume through monitoring at various locations and depths. Understand the relationship of the source to the ground water. Contaminant levels should be monitored over time to identify migration and degradation patterns. Note the density of contaminants to aid in assessing their behavior in the ground water.

Assess contaminant/soil interactions to aid in assessing the effectiveness of a ground-water extraction system. Laboratory analysis of contaminant partitioning behavior in the saturated soil may be critical to the development of the remedy and the determination of whether ground-water extraction is practicable.

PROJECT PLANNING Recommended Data Collection Activities

Evaluation of Plume Movement and Response

Consider modeling the ground water as a tool to guide the placement of monitoring wells, predict concentrations of contaminants at exposure points, estimate the effect of source control actions, and evaluate the expected performance of the ground-water remedial action.

Consideration of Technical Uncertainty

Identify sources of uncertainty, e.g., predicting the nature, extent, and movement of contamination; determining contaminant movement through the vadose zone; estimating the rate and direction of the ground-waterflow; and estimating the cost of remedial alternatives. Assess the magnitude of uncertainty from each of these sources, and weigh the costs and benefits of reducing uncertainty by collecting additional information.

Assessment of Design Parameters for Potential Treatment Technologies

Identify several likely remedial technologies during scoping to focus data collection activities. Consider data needs for screening out inappropriate technologies and for designing workable systems to provide a sound basis for selecting a remedy and reducing implementation time. Consider the costs and benefits of conducting a treatability study.

REMEDIAL ACTION OBJECTIVES

Remedial action objectives include *cleanup levels*, the *area of attainment*, and the *restoration time frame*.

Cleanup Levels

Cleanup levels will generally be set at health-based levels, reflecting current and potential use and exposure. For ground water that is a current or potential source of drinking water, maximum contaminant levels (MCLs) under the safe drinking water Act or more stringent State standards devised to protect drinking water generally are ARARs. If an MCL or State standard does not exist for a contaminant, then other potential ARARs and criterai that are not ARARs but are to-be-considered (TBC) should be identified. The most common ARARs and TBCs are summarized in Table 1. This is consistent with the Ground Water Protection Strategy which differentiates ground water on the basis of use, value, and vulnerability.

Table 1

Potential ARARs

- Maximum contaminant levels (MCLs)
- Promulgated State standards

Other Potential ARARs and TBCs

- Proposed MCLs
- Risk-specific doses
- Reference doses
- Lifetime Health advisories
- Maximum contaminant level goals
- Water quality criteria

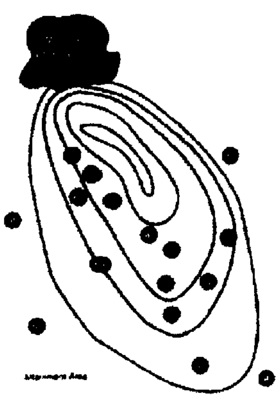
For systemic (noncarcinogenic) toxicants,cleanup levels should be set at levels to which humans could be exposed on a daily basis without experiencing appreciable adverse effects during their lifetimes. To determine aggregate effects from systemic toxicants, the hazard index is used.

For carcinogens, cleanup levels should reflect an individual excess lifetime cancer risk of 10^{-4} to 10^{-7}; that is, aggregate cancer risk levels should fall within the 10^{-4} to 10^{-7} risk range. The 10^{-4} aggregate excess lifetime cancer risk level is considered the starting point for analysis, but other risk levels between 10^{-4} to 10^{-7} may be supported on the basis of factors related to exposure, technical limitations, and uncertainties.

Alternate concentration limits (ACLs) may be established in some situations where remediation of the ground water is not practicable. CERCLA Section 121(d)(2)(B)(ii) places restrications on the use of ACLs. The ground water must discharge to nearby surface water and cause no statistically significant increase of contaminants in the surface water. In addition, provisions for enforceable institutional controls that prevent access to the contaminant plume must be made.

Area of Attainment

The area of attainment is the area outside the boundary of any waste remaining in place and up to the boundary of the contaminant plume. Generally, the boundary of the waste is defined by the source control remedy. If the source is removed, the entire plume is within the area of attainment. But, if waste is managed onsite, the ground water directly beneath the waste management area is not within the area of attainment.



Restoration Time Frame

The restoration time frame is defined as the period of time required to acheive cleanup levels in the ground water at all locations within the area of attainment. For drinkable ground water, at least one alternative should reach cleanup levels in the minimum time frame technically achievable. Technical limits to extracting contaminants that will tend to increase the restoration time frame include contaminant/soil interactions, the presence of dense nonaqueous phase liquids, continued migration form sources, widely spread plumes, and poorly transmissive aquifers. Because these conditions are not generally addressed in plume migration models, aquifer testing or saturated soil core analysis may be warranted.

Once technical limits to achieving cleanup levels have been assessed, restoration time frames for remedies can be evaluted relative to this limit on the basis of the following considerations:

- Feasibility of providing an alternate water supply – including schedule, cost, quality, reliability, and yield. Also, whether the alternate water supply is itself irreplaceable should be considered. Readily available alternate water supplies will increase the flexibility to select longer restoration time frames.

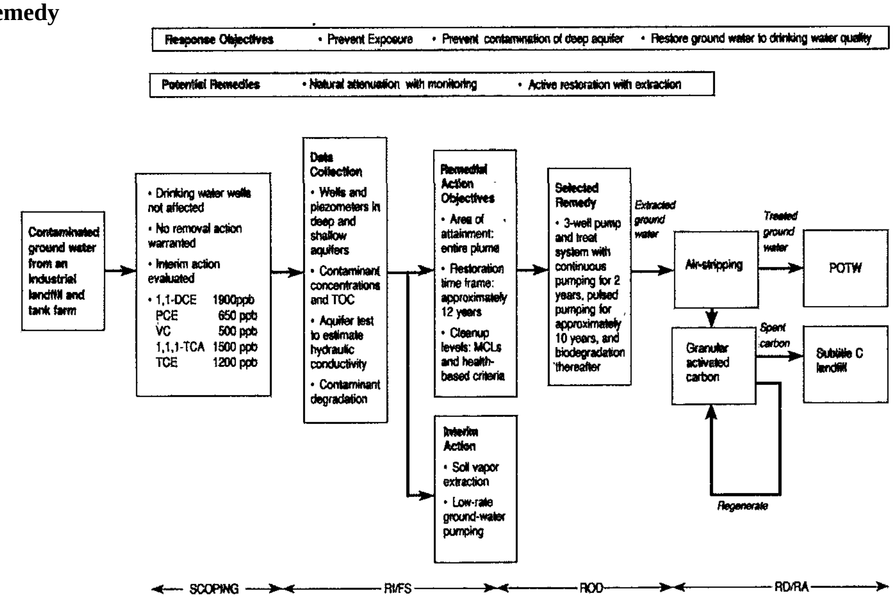
- Potential use and value of the ground water – including the timing of anticipated demand, the magnitude of the demand, the need (drinking, irrigation), and the availability of other water sources. If there is a high demand for the ground water, shorter time frames are warranted.

- Effectiveness and reliability of institutional controls – effective controls restricting use or access to contaminated ground water may increase the flexibility to select a remedy with a longer restoration time frame. Examples of institutional controls include licensing of well drillers, well construction permits, well quality certification, and regulations of new development and property transactions.

- Ability to monitor and control contaminant movement – complex flow patterns, for example in fractured bedrock or karst areas, and unusual distributions of contaminants may increase the benefits of shorter restoration time frames.

Figure 1

Sample Remediation Process-- Ground-Water Remedy



GENERAL RESPONSE ACTIONS

After developing remedial action objectives, general response actions are identified. General response actions for contaminated ground water include *active restoration*, *plume containment* through hydraulic control, and *limited or no active response*, combined, if appropriate, with institutional controls to protect human health. These are discussed below.

Active restoration is useful when there are mobile contaminants, moderate to high hydraulic conductivities in the contaminated aquifer, and effective treatment technologies available for the contaminants in the ground water. Innovative technologies for active restoration may include biorestoration, soil flushing, in situ stream stripping, soil vapor extraction, in situ vitrification, and others.

Plume containment seeks to minimize the spread of a plume through hydraulic gradient control, which can be either active or passive. Containment is appropriate where active restoraton is not practicable or where the beneficial uses of the ground water do not warrant it. In addition, plume containment may be combined with active restoration or natural attenuation to achieve cleanup levels.

Limited or no active response includes two remedial scenarios: (1) a natural attenuation alternative that eventually achieves cleanup levels throughout the area of attainment and includes monitoring and institutional controls; and (2) wellhead treatment or provision of an alternate water supply with institutional controls, when complete restoration to cleanup levels is not practicable.

Factors that may cause active restoration to be impracticable or not cost-effective include:

- Widespread plumes such as at industrial areas, mining sites, and pesticide sites
- Hydrogeological constraints such as with fractured bedrock, or where the transmissivity is less than 50 square feet per day
- Contaminant-related factors such as the presence of dense nonaqueous phase liquids
- Physical/chemical factors such as partitioning to soil or organic matter.

FORMULATING REMEDIAL ALTERNATIVES

A range of remedial technologies can be combined under a particular general response action. Process options for extraction include: extraction wells, extraction/injection systems, and interceptor drains and trenches. Treatment options include biological, chemical, physical, thermal, or in situ methods. Treated ground water can be discharged to surface water or a publicly-owned treatment works, reinjected to the aquifer, or used as a drinking water supply. Finally, there are various options for containment, monitoring effectiveness, and institutional controls. Alternatives are developed by combining these various process options into a comprehensive response approach.

DETAILED ANALYSIS OF ALTERNATIVES AND SELECTION OF REMEDY

CRITERIA AND BALANCING

The analysis of remedial actions for ground water is made on the basis of the following evaluation criteria. Considerations that are unique to ground water are noted.

Threshold criteria

- *Overall protection of human health and the environment*: Will the remedy achieve and maintain clean-up levels? Are all exposure pathways controlled; e.g., discharge points, points of use?
- *Compliance with ARARs*: Will the remedy attain MCLs or state standards in potentially drinkable ground water or justify a technical impracticability waiver? Are ARARs met for the treated ground water and any treatment residuals that are generated?

Balancing criteria

- *Long term effectiveness and permanence*: Remedies that achieve the cleanup levels will be comparable with respect to this criteria. For remedies that will not restore ground water, how reliable are the engineering or institutional controls used to prevent exposure?
- *Reduction of mobility, toxicity, and volume*: What reductions are achieved through treatment in any phase of the remediation process? This includes initial treatment of ground water and subsequent treatment of resulting residuals. Special note should be given to remedies that transfer contaminants from ground water to air without treatment of the air releases, especially if risk through the air pathway exceeds 10^{-6}.
- *Short-term effectiveness*: What is the restoration time frame? What cross-media impacts occur as a result of ground-water treatment or construction of a containment facility? How much farther will the plume spread before the remedy is completed?
- *Implementability*: What permitting requirements must be met for discharge of treated ground water? Are there access problems with installation of the remedy--e.g., extraction wells and slurry walls--in terms of resources required? Are there capacity limitations on POTWs receiving discharge waters? What uncertainties exist with the treatment process considered?
- *Cost*

Modifying criteria:

- *State Acceptance*
- *Community Acceptance*

If the alternatives will achieve the same long term goals, the primary balancing criteria will be implementability, cost and short term effectiveness.

DOCUMENTATION

In addition to the standard documentation, a ROD for a ground-water action should include the following components:

- Remedial action objectives defined in the FS for each alternative: i.e., the cleanup levels, the area of attainment, and the restoration time frame.
- A description of the technical aspects of the selected remedy that will form the basis of design for the system, such as the following:

(***Detailed Analysis-- Continued from previous page)***
– Number of extraction wells
– Treatment process
– Control of cross-media impacts
– Expected pumping and flow rates
– Management of residuals
– Gradient control system
– Type of institutional controls and the implementing authority

Since performance of remedies for restoring contaminated ground water can often be eval-uated only after the remedy has been implemented and monitored for a period of time, remedial action objectives should be presented as ranges to accommodate reasonable degrees of change during design and implementation. An option is to include two possible scenarios in the remedy, e.g., ground-water extraction until cleanup levels are attained, or groundwater extraction until an equilibriumis reached and contaminant mass is no longer being removed at significant rates, at which time portions of the plume that remain above cleanup levels should be monitored and institutional controls established to prevent access to contaminated ground water.

EVALUATING PERFORMANCE AND MODIFYING REMEDIAL ACTIONS

Performance evaluations of the full-scale remedial action are conducted periodically to compare actual performance to expected performance. Conducting performance evaluations and modifying remedial actions is part of a flexible approach to attaining remedial action objectives.

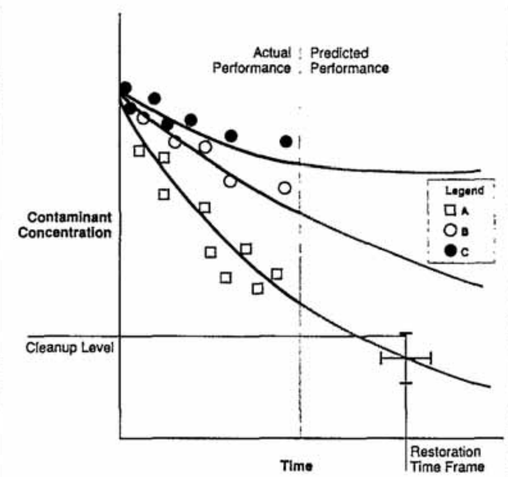
Figure 2 represents a decrease in contaminant concentration over time for three ground-water remedial actions of varying effectiveness. Line A represents a remedial action that is meeting design expectations, and the desired cleanup levels are predicted to be reached within the anticipated time. Line B represents a remedial action that is predicted to achieve the cleanup levels, but the action will have to be operated longer than anticipated. Line C represents a remedial action that will not achieve the desired cleanup levels for a long time, if ever, without modifying the remedial action.

After evaluating whether cleanup levels have or will be achieved in the desired time frame, the following options should be considered:

- Discontinue operation
- Upgrade or replace the remedial action to achieve the original remedial action objectives or modified remedial action objectives
- Modify the remedial action objectives and continue remediation, if appropriate.

Performance monitoring should ensure that residual contamination has been removed. This will generally require monitoring ground-water concentrations after active measures have been completed to allow contaminant concentrations in the soil and ground water to re-equilibrate.

FIGURE 2
Predicting Remedial Action Performance



MULTIPLE SOURCES STRATEGY

At sites where there are multiple sources of ground-water contamination, some of which are Superfund sites, it may be appropriate to implement a multiple-source strategy. The Superfund program should work cooperatively with other responsible entities to achieve comprehensive remedies, and may accept primary responsibility for coordinating all involved parties during the source identification phase of work.

The Superfund program should coordinate an initial scoping plan for source identification that would include limited sampling. Locations of possible sources may be determined through two surveys: (1) a survey of contributors to and users of the affected ground water (termed a “contributor/user assessment”) that will help identify the other parties that must be involved in the formulation of an effective remedy; and (2) a survey of potential sources such as solvent storage facilities located at or upgradient of the area of contamination.

Superfund will implement appropriate remedial actions related to National Priorities List sites once an RI/FS is initiated. At this point, the Regional Administrator, in consultation with the Assistant Administrator of OSWER, should evaluate the appropriateness of the Superfund program retaining primary responsibility for coordinating the ground-water response action for all sources. This decision may be determined by factors such as the contribution of Superfund sources relative to other sources, as well as the availability and willingness of other involved parties to initiate action.

Response actions generally fall into three categories: provision of alternate water supply, source control measures, and ground-water remedies. Superfund resources may be used to provide an alternate water supply if an NPL site is a significant contributor to the plume and if the need to alleviate the public health threat does not allow for identification and involvement of other parties at that time. Actions to prevent or minimize spread of contaminants from the source are often implemented at multiple source groundwater sites before completing plume characterization, which can be lengthy and complicated at these sites.

The amount of Superfund resources used to address ground-water contamination will derive primarily from the extent to which the overall contamination can be attributed to the Superfund site. It will also depend on the willingness and capability of the other involved parties to take actions to address the contamination for which they are responsible.