

REMEDICATION GUIDANCE
FOR
PETROLEUM AND VOC IMPACTED
SITES

SECTION II

CHAPTER 4.0

Guidance for Petroleum-Impacted Sites: Soil Screening Levels - May 1996

Summary

This chapter explains an interim approach, or "guidance," using numerical soil screening levels, to evaluate the need for remediation of soils contaminated by petroleum hydrocarbons. Use this approach to find out when a site requires remedial action or what level of remediation you must reach to conclude the environmental study and cleanup, thus reaching "site closure."

This approach defines the differences in requirements between types of certain chemicals, or "constituents," in petroleum hydrocarbons and between drinking and non-drinking water aquifers – underground water-saturated formations from which water flows into wells and springs. You can still use "risk analysis" (determining the long-term effect of residual contaminants on groundwater and their potential hazard for people) for particular sites and/or "fate and transport models" (the mathematical models that show what happens to chemicals as they move through soil or water) that consider groundwater protection, to propose alternate soil cleanup levels. This guidance also includes "Closure Criteria for Low Risk Fuel Contamination Sites".

The approach in this guidance does *not* replace any site assessment requirements of the Regional Board. This "interim guidance," or amendments to it, will be in effect until the State Water Resources Control Board finishes a new field guide – the "Leaking Underground Fuel Tanks" (LUFT) manual

– for cleaning up contamination from leaking underground tanks. Then the Board will review the "interim guidance" for further use.

Background

The Regional Board created the Water Quality Advisory Task Force to identify and recommend ways to reduce the cost of meeting existing clean water laws without compromising water quality and public health. The Task Force focused its deliberations on certain problem areas, one of which was site cleanup. In reviewing this area, the Task Force found that "there is no clear definition of what is clean," and that cleanup expectations were not consistent across all Regional Board programs.

The Task Force also recommended forming a Technical Review Committee (TRC), composed of representatives from the private and public sectors, to discuss existing and proposed programs, and to devise cleanup standards in concert with Regional Board staff. The Task Force stated:

"Establishing a set of clear and consistent standards for site cleanup should be the first task undertaken by the Regional Board staff and its Technical Review Committee. The Regional Board should establish standards for identifying when a threat or probable threat to groundwater has occurred and when a site has been adequately remedied. ... the Regional Board should make every effort to ensure that the standards are consistent

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across all programs under its jurisdiction, and, whenever possible, consistent with those of other agencies in the Region. The standards should allow the community to use more cost-effective methods, such as risk-assessment approaches, and fate and transport models where appropriate, as means to determine if soil contamination poses a risk to ground water".

Objective

The following guidelines aim to simplify the remediation process by making it easy to choose levels of screening for contaminants at a certain site ("site-specific soil screening levels"). This works for most petroleum-impacted sites in a way that both protects water resources and is still cost effective. Through this approach, the Board seeks to encourage prompt cleanups that restore sites to their intended uses.

The approach relates only to the evaluation of petroleum-impacted soils and does not address groundwater directly. Before using the approach, however, you must complete a thorough site characterization and assessment. This should be a highly detailed review and sampling, providing information about the types of contaminants and how far they spread into the soil.

The Regional Board intends to close investigations of petroleum-impacted sites based on this "guidance." The closure is subject to land-use changes or gaining new information about the site. However, the Board may require groundwater monitoring if it confirms that soil contamination has

impacted groundwater.

The attached Table 4-1 provides the basis for the "guidance" procedures. Table 4-1 defines the soil screening levels above drinking water aquifers; below it are footnotes which explain the concentration screening levels of chemical components and clarify the procedures, as well as the screening levels to be used for sites above non-drinking water aquifers.

Since there is no adequate measure of risk or toxicity for total petroleum hydrocarbons (TPHs) per se, the screening levels for TPHs in Table 4-1 are based on the carbon range numbers of the TPHs. These ranges reflect the mobility of the material; the shorter carbon-chain TPHs (C4-C12) move more easily in soil than the longer carbon-chain TPHs (C23-C32). The table is organized into a matrix of screening "levels", based on distance of constituents above groundwater and carbon chain ranges.

At most petroleum-impacted sites, the main constituents which cause concern are benzene, toluene, ethylbenzene, and xylenes (BTEX). In addition, methyl tertiary butyl ether (MTBE) is also required for analysis. Analyze lead, other fuel additives and polycyclic aromatic hydrocarbons (PAHs) where needed, based on the product (gasoline, diesel, fuel oil, etc.) that was discharged into soil.

The screening levels for BTEX in Table 4-1 are generated based on the attenuation factor method developed by this Regional Board for volatile organic compounds (VOCs) (see Appendix A). Because of BTEX mobility and toxicity, the screening levels are determined based on distance from groundwater and soil

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material type within the distance. The table values for BTEX can be interpolated between distance and proportional to fraction of each lithological thickness (see Appendix A for detail).

The screening level values in Table 4-1 are geared to protect groundwater. They also are intended to protect people from exposure when they come in contact with the chemicals, through such means as direct contact with soil, dust particles or gaseous compounds in the air. These "direct human health exposure pathways" are defined by the USEPA methodology (referenced in the ASTM Standard Guide for Risk-Based Corrective Action Applied at Petroleum Release Sites (E1739-95)). The screening levels also fall below the preliminary remediation goals (PRGs) published by the USEPA, Region IX.

As a responsible party, you can use the attached "Closure Criteria for Low Risk Fuel Contamination Sites" to obtain a site closure. And you can also propose alternative soil screening cleanup levels which are supported by "risk assessment approaches" and/or "fate and transport modeling" if they also address groundwater protection (i.e., groundwater in this case is considered a receptor rather than as a pathway). Discuss use of alternative approaches with the Regional Board staff. Any cleanup values derived under this guidance or alternative approaches are generally recommended to be below the health risk-based screening threshold values, such as PRGs.

Procedures

To use Table 4-1, you will need to do the following:

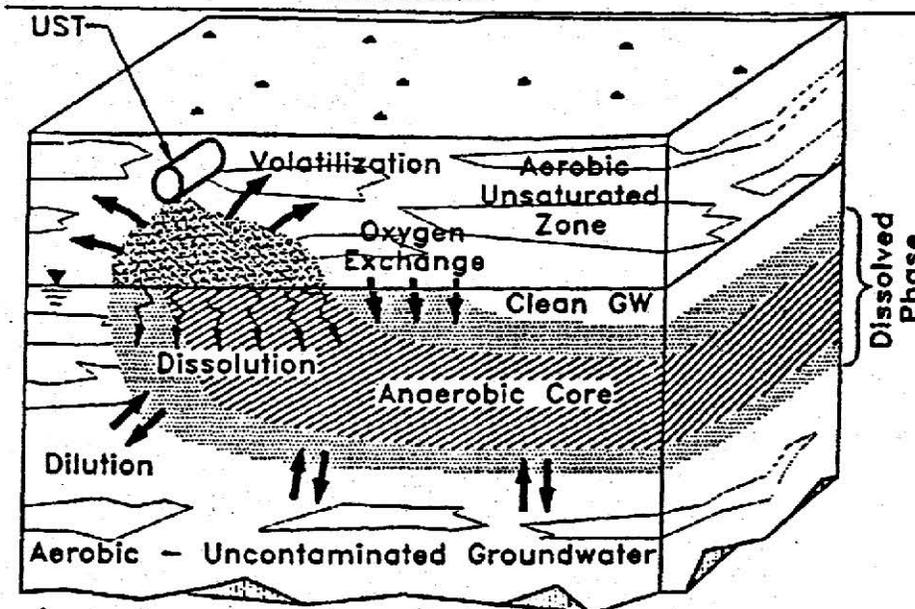
- 1) A thorough site characterization/assessment that shows the type of contaminants of concern, the lateral and vertical extent of the contamination, and the existence of a "clean zone" above groundwater. The clean zone generally consists of at least a 20-foot interval in which multiple consecutive samples (including soil matrix and/or soil gas) cannot be traced above a required detection limit (see Appendices B and C for required detection limits);
- 2) An analysis of beneficial uses for groundwater underlying the site. All Los Angeles Region's groundwaters are considered drinking water, unless they are excluded under the criteria specified in State Water Resources Control Board (SWRCB) Resolution 88-63 (i.e., TDS > 3,000 mg/l, deliverability of < 200 gal/day, or existing contamination that cannot be reasonably treated). However, Regional Board staff shall determine the water use for a specific site based on Regional Board's Water Quality Control Plan (Basin Plan) objectives; and
- 3) Use of appropriate analytical methods. Use EPA Method 8020 for BTEX and MTBE components and confirm positive results above the screening level with EPA Method 8260 to prevent possible false identification by EPA Method 8020. Measure TPH levels using EPA Methods 418.1 and 8015 (DHS Modified). Method 418.1 measures the total TPHs, therefore, Method 8015 (or Method 8260) is needed to identify carbon ranges. If

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the total TPH from either test are below the applicable screening level for the C4-C12 range, no other TPH screening is necessary. TPH levels greater than the C4-C12 screening level should be differentiated using Gas Chromatograph/Mass Spectrometry (GC/MS) carbon range methods for hydrocarbon screening or speciation or EPA Method 8015 (DHS Modified). EPA Method 8310 shall be used for PAH analysis to achieve a detection limit of 0.2 ppb for individual constituent of PAHs.

Discuss the site assessment results, proposed screening levels, and confirmation testing results with Regional Board staff. If the findings are below applicable Table 4-1 values, cleanup of the soil is not required. If findings are above the required values, soil cleanup should take place to levels which are at or below the screening values, or certain values derived by any alternative method which is acceptable to Regional Board staff. Consideration should be given to historically high water levels at sites of concern.

A Typical Hydrocarbon Plume Undergoing Natural Bioremediation;
Cross-section



Legend:

- | | |
|---|--|
|  Aerobic Margins |  Residual Phase |
|  Anaerobic Core |  Water Table |

Cross Section

Source: U.S. EPA

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Examples

Example 1:

An underground storage tank was removed at a gasoline station. Gasoline contamination in soil has been confirmed and the lateral and vertical extent of the contamination has been adequately defined. Site lithology consists of 60% sand and 40% silt. Depth to groundwater is 40 feet from the surface. Soil samples obtained at 10, 15, and 20 feet below ground surface showed the following results (Table E1). TPH as gasoline (C4-C12) was identified by EPA Method 8015 (Modified).

From Table 4-1, the soil screening level for TPH (C4-C12) is 500 mg/kg at 20 to 30 feet above the groundwater table. By interpolating the table values, soil screening levels for a lithology of 60% sand and 40% silt are calculated as follows. The screening level for benzene in sandy soil, 30 feet above groundwater, is $[(30-20)/(80-20)] \times (0.033-0.011) + 0.011 = 0.015$. In the same way, the screening level for silty soil is 0.02. Given the site lithological composition of 60% sand and 40% silt, the final screening level for benzene at 30 feet above groundwater is $(0.015 \times 0.6) + (0.02 \times 0.4) = 0.017$. Results for other constituent and depth are in Table E2.

Table E1:

Sample Depth (ft)	Distance Above Groundwater (ft)	TPH (C4-C12)	mg/kg (ppm)			
			B	T	E	X
10	30	1500	1.6	9.1	ND	63
15	25	210	0.01	0.4	ND	ND
20	20	100	0.005	ND	ND	ND

ND=non-detected. Detection limit=0.005 mg/kg for BTEX.

Table E2:

Distance Above Groundwater	Sand	Silt	60% sand / 40% silt
30	B=0.015	B=0.02	0.017
	T=0.58	T=1	0.75
25	B=0.013	B=0.016	0.014
	T=0.44	T=0.75	0.56

The analytical results at 10 feet (30 feet above groundwater) definitely call for soil cleanup action since all concentrations are above the screening levels as defined above for TPH, benzene, toluene, and xylene. All other results are below the screening levels; therefore, cleanup does not need to extend beyond 15 feet below surface.

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EXAMPLE 2:

A property located in L.A. central basin earmarked for redevelopment was found to be impacted by petroleum product. The source had been determined and removed. Several soil borings were drilled around the source area and soil samples were obtained at different depths. Laboratory analyses of the soil samples revealed that the concentrations C4-C12 = 1000 mg/kg, C13-C22 = 7000 mg/kg, and C23-C32 = 25000 mg/kg extended to a depth of 18 feet below ground surface. A shallow "perched" groundwater was first encountered at 35 feet below grade, and found to be not impacted yet. However, information obtained from the RWQCB Basin Plan shows that the regional drinking water aquifer is at about 170 feet below ground surface.

In this example, if the perched groundwater is determined to be non-drinking water, TPH screening level for ">150 feet" category in Table 4-1 applies. Since all soil concentrations are less than the table values, no soil cleanup is required. The same would apply to the regional groundwater aquifer, that is, no soil cleanup is required and case could be closed.

Table 4-1: Maximum Soil Screening Levels (mg/kg) for TPH and BTEX above Drinking Water Aquifers

T P H	Distance Above Groundwater	Carbon Range		
		C4-C12	C13-C22	C23-C32
	>150 feet	1,000	10,000	50,000
	20-150 feet	500	1,000	10,000
<20 feet	100	100	1,000	

B T E X	Distance Above Groundwater	Lithology			
		Gravel	Sand	Silt	Clay
	150 feet	B=0.044 T=2 E=8 X=23	B=0.077 T=4 E=17 X=48	B=0.165 T=9 E=34 X=93	B=0.8 T=43 E=170 X=465
	80 feet	B=0.022 T=1 E=4 X=11	B=0.033 T=2 E=7 X=20	B=0.066 T=4 E=15 X=40	B=0.34 T=18 E=73 X=200
20 feet	B=0.011 T=0.15 E=0.7 X=1.75	B=0.011 T=0.3 E=0.7 X=1.75	B=0.011 T=0.45 E=2 X=5.3	B=0.044 T=2.3 E=9 X=24.5	

- TPH = Total petroleum hydrocarbons.
- BTEX = benzene, toluene, ethylbenzene, and xylenes, respectively. MCLs (ppm): B=0.001, T=0.15, E=0.7, X=1.75.
- MTBE (methyl tertiary butyl ether) must be included in BTEX analyses.
- BTEX screening concentrations determined per the attenuation factor method as described in RWQCB Guidance for VOC Impacted Sites (March 1996), with a natural degradation factor of 11 for benzene. Table values for BTEX can be linearly interpolated between distance above groundwater and are proportional to fraction of each lithological thickness.
- Values in Table 4-1 are for soils above drinking water aquifers. All groundwaters are considered as drinking water resources unless exempted by one of the criteria as defined under SWRCB Resolution 88-63 (TDS>3000 mg/L, or deliverability <200 gal/day, or existing contamination that cannot be reasonably treated). Regional Board staff will make a determination of potential water use at a particular site considering water quality objectives and beneficial uses. For non-drinking water aquifers, regardless of depth, TPH for ">150 feet" category in the table should be used; BTEX screening levels are set at 100 times respective MCLs as preliminary levels determined to be protective of human health and the environment.
- Distance above groundwater must be measured from the highest anticipated water level. Lithology is based on the USCS scale.
- For BTEX, each component is not to exceed the specified screening level.
- For TPH, the total allowable for each carbon range is not to be exceeded. In areas of naturally-occurring hydrocarbons, Regional Board staff will make allowance for TPH levels.
- BTEX to be analyzed by EPA Method 8020 or EPA Method 8260 (usually for confirmation).
- TPH to be analyzed by EPA Methods 418.1 plus 8015 (Modified). Ranges of TPH to be analyzed by GC/MS carbon range methods (EPA Method 8260) or EPA Method 8015 (Modified).

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CLOSURE CRITERIA FOR LOW RISK FUEL CONTAMINATION SITES - April 1996 Fact Sheet

The following fact sheet and Table 4-1 (closure criteria) have been prepared in response to recent studies reevaluating the management of fuel contamination cases related to leaking underground tanks in California. These closure criteria apply to fuel contamination sites only, and are intended for use by the regulated community, other regulators, and consultants. If a site has non-fuel related contamination, it is not a candidate for closure under these criteria.

BACKGROUND

In October 1995, The Lawrence Livermore National Laboratory presented "Recommendations to Improve the Cleanup Process for California's Leaking Underground Fuel Tanks" to the State Water Board. That report, endorsed in part by the Executive Director of the State Water Board, recommended that natural biological processes (passive bioremediation) and monitoring be used at the majority of low risk fuel contamination sites in California. The use of passive bioremediation instead of active cleanup would dramatically increase the number of fuel contamination sites eligible for closure in California.

In order to apply the recommendations of the State Water Board, it is critical that low risk sites be defined. The definition of low risk sites and a soil screening table (criteria) were developed by this Regional Board's staff and Groundwater Technical Review Committee to identify fuel contamination sites that do not

pose a significant threat to groundwater and would therefore qualify for closure as low risk fuel contamination cases. The criteria are consistent with similar information issued by other Regional Boards and with this Regional Board's "Interim Site Assessment and Cleanup Guidebook" (1996).

These criteria are issued for the purpose of expediting the closure of low risk fuel contamination cases. If a site meets the closure criteria, including the soil screening levels in the attached table, and does not require groundwater monitoring, that site will be closed without further requirements. Many sites that do not meet all of the criteria may also be considered low risk, and may be eligible for closure after additional data are submitted. Soil screening levels in Table 4-1 are reasonable, yet protective of water quality, and should ensure that there will be minimal impacts to groundwater from contaminated soil.

USE OF PASSIVE BIOREMEDIATION AT LOW RISK SITES

Passive bioremediation is a complex natural process that reduces the petroleum hydrocarbon mass in the soil and groundwater. Petroleum hydrocarbons are generally biodegradable as long as naturally-occurring bacteria are present, have an adequate supply of oxygen and nutrients, and have a favorable environment.

While passive bioremediation is an appropriate cleanup method for many fuel contamination sites, and is frequently approved by this Regional Board, it is not appropriate at all

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sites. It is also important to note that as the rate of passive bioremediation is typically very slow, fuel concentrations may not reach closure levels for many years. Regional Board staff evaluate proposed cleanup methods on a case-by-case basis and determine when passive bioremediation and monitoring, instead of an active cleanup, are appropriate. When groundwater has been contaminated, monitoring will usually be required to demonstrate that the contamination plume is stable and that the contaminant concentrations are decreasing.

A checklist, developed by the U.S. EPA, should be used to evaluate whether passive bioremediation in groundwater is appropriate at a specific site. The checklist is included, and the supporting documentation can be obtained by calling Sandra Kelley, of Regional Board staff, at (213) 266-7521, or by downloading it from our electronic bulletin board at (213) 266-7663. The checklist will assist in: 1) determining if passive bioremediation in groundwater is appropriate for a site, 2) identifying where additional information may be required, and 3) evaluating the completeness of a corrective action plan, if required.

HOW TO APPLY LOW RISK CRITERIA TO A FUEL CONTAMINATION SITE

A site is eligible for closure as a low risk fuel contamination site if it meets the following definitions, and soil contaminant concentrations (for each constituent) are lower than the screening levels in Table 4-1.

DEFINITIONS

A. LOW RISK SOIL CONTAMINATION - sites are ready for closure when:

- 1. The leak has been stopped and ongoing sources, including fuel-saturated soil and soil which contains mobile fuel components, have been removed or remediated.** "Sources" include tanks and associated piping, gasoline-saturated soil, and soil with mobile gasoline components (e.g., leachate or vapor) that can degrade groundwater quality or pose a significant threat to human health or the environment. "Significant threat" is a long-term adverse effect on groundwater quality, including causing the non-localized exceedance(s) of maximum contaminant levels (MCLs) in the groundwater and/or posing a potential hazard to human health.
- 2. The site has been adequately characterized and the soil contamination appears stable.** The vertical and horizontal extent of the soil contamination has been defined, and data demonstrate that it is stable. It is recognized that subsurface conditions are highly variable and that there is always some uncertainty associated with evaluating data at a site.
- 3. Detectable levels of contaminants in the soil are lower than the soil screening levels in the attached Table 4-1.**

B. LOW RISK GROUNDWATER CONTAMINATION - sites are ready for closure when:

- 1. The leak has been stopped and ongoing sources, including free product, have been removed or remediated.** "Sources" include tanks and associated piping, free-floating gasoline, gasoline-saturated soil, and soil which contains mobile gasoline components (e.g., leachate or vapor) that can degrade groundwater quality or pose a significant threat to human health or the environment.

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"Significant threat" is a long-term adverse effect on groundwater quality, including causing the non-localized exceedance of maximum contaminant levels (MCLs) in the groundwater and/or posing a potential hazard to human health.

2. **The site has been adequately characterized, and the groundwater contamination plume is stable.** The vertical and horizontal extent of the groundwater contamination plume has been defined and data demonstrate that the plume is stable. Potential horizontal and vertical conduits, which could act as preferential pathways for the dissolved plume, must also be evaluated.

A stable groundwater plume is characterized by decreasing or stable concentrations of hydrocarbons in groundwater, and no MTBE is detected. Evidence of biodegradation can be demonstrated by a comparison of background and hydrocarbon plume concentrations of site-specific indicators (e.g., oxygen, nitrate, redox potential, and bacteria concentrations). These data may be necessary to supplement other site-specific information when utilizing passive bioremediation as a cleanup method. Groundwater monitoring may be required.

3. **No drinking water wells or aquifers, or surface waters have been or are likely to be affected.**
4. **Groundwater has been impacted, but contaminant levels are below MCLs, or**

Groundwater has been impacted and contaminant levels exceed MCLs; however, treatment performance criteria demonstrate that a significant reduction of the contaminant levels cannot be achieved. The groundwater plume must be stable, and continued groundwater monitoring may be required.

Low risk groundwater contamination sites that require additional monitoring will be issued pre-closure letters stating that the case may be eligible for closure when groundwater monitoring is completed.

Many fuel contamination sites with both soil and groundwater contamination may be eligible for separate soil closure while the groundwater cleanup/monitoring is ongoing.

WHAT CAN A RESPONSIBLE PARTY DO TO EXPEDITE REVIEW OF A LOW RISK CASE?

If a responsible party believes that a site meets the low risk criteria, we recommend that the responsible party provides the oversight agency with a summary of the Site Investigation and Cleanup History (form attached) to expedite staff review of the closure request.

The Regional Board believes that these closure criteria will expedite low risk case closures while maintaining a high degree of water quality protection.

All responsible parties, regulators, and consultants are encouraged to use the criteria to evaluate their sites and determine if they are considered to be low risk and ready for closure. If you have any questions concerning this fact sheet, or if you believe that your site can be considered a low risk site that does not meet the criteria, please contact Elijah Hill at (213) 266-7558, Harry Patel at (213) 266-7575, or Jack Price at (213) 266-7622.



CHAPTER 5.0

GUIDANCE FOR VOC-IMPACTED SITES: SOIL SCREENING LEVELS - May 1996

Summary

This interim approach, or "guidance," is designed to protect groundwater quality. The methodology contained in this guidance calculates soil cleanup screening levels for volatile organic compounds (VOCs) when they are found in the subsurface zone that extends from the ground surface to the top of the water table. This area, known as the "vadose zone," is not saturated by groundwater, but can have a high moisture content and local areas of saturation.

This guidance also spells out performance standards for "vapor extraction system," which is a method of drawing air containing gaseous contaminants out of the vadose zone by a vacuum system. "Vapor extraction" has not only become a popular but also an effective cleanup process for VOCs.

The soil cleanup screening levels for vadose zones are calculated from "attenuation factors" (AFs), which refer to a potential ratio of the contaminants found in soil versus the contaminants in the groundwater. The AF Method (defined in Appendix A) derives from equations based on chemical and physical parameters, using data obtained by Regional Board staff.

After a complete site assessment, a responsible party may use these soil cleanup screening levels as: 1) screening criteria below which no remediation is required, 2) proposed soil cleanup targets, and/or 3) performance criteria to evaluate the effectiveness of remedial

actions. If desired, you may also propose site-specific soil cleanup criteria using health-based risk assessment and/or fate and transport models which contain measures for groundwater protection.

This approach provides a set of soil cleanup screening levels for VOC-impacted sites to encourage prompt soil remediations to a level of concentration that both protects ground water quality and is cost effective. However, this approach does not exempt any site assessment required by the Regional Board, and should not be used to define the extent of soil contamination, or substituted for any sophisticated site-specific fate and transport study and/or risk assessment. Any cleanup values derived under this guidance or other alternative approaches shall be below the health risk-based screening threshold values, such as the Preliminary Remediation Goals (PRGs).

Background

When the Regional Board created a Water Quality Advisory Task Force in December 1992, the Task Force's mission was to evaluate and provide recommendations to regulatory agencies on how to reduce costs to businesses while still meeting clean water laws and without compromising water quality and public health. One of the Task Force's recommendations was to establish cleanup standards for all programs of the Regional Board.

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There have been many attempts in the past to provide cleanup standards, and, currently, there are many documents published under various titles and from several sources providing cleanup guidance which are primarily health based. The California Department of Toxic Substances Control (DTSC), through its Office of Scientific Affairs, issued a draft Technical Directive in January 1994 concerning Health-Based Soil Screening Levels. These tabulated levels are not to be used for contaminants that move between soil and water. They are also not intended to protect groundwater. When the document is finished, it will replace the USEPA Region IX's Preliminary Remediation Goals (PRGs) for screening sites where chemicals have been released. USEPA's PRGs are based on available toxicity values (but not Cal/EPA toxicity values for carcinogens) and are not considered by the DTSC to protect health in all situations. You can use PRG tables for general risk screening purposes but they do not take into account impact on groundwater or address ecological concerns.

You can use these health risk-based cleanup values for soil remediations where surface or groundwater is not affected. These values are not to be used for vadose zones affecting municipal or domestic use groundwater and will not be discussed further in this document.

VOC Cleanup Process

1. Vadose Zones Above Drinking Water Aquifers

Under the State Board Resolution 68-16 (the Anti-degradation Policy), no degradation of

water quality of this State is permitted. The level of soil cleanup required to protect health and water quality depends on many site-specific factors, such as the type and distribution of soil contaminants, land use, ground cover, distance to the water body, use of the water body (drinking, industrial use, serving as a barrier to protect clean water from ocean water, etc.), hydrogeology of the area, site lithology, cleanup procedures, etc.

The subsurface investigation, as conducted at this region, involves tracing a discharge of VOCs from the vadose zone to groundwater and to define the lateral and vertical extent of contamination in both the vadose and saturated zones. This investigation can at a minimum: (1) evaluate the potential threat of soil contamination to groundwater quality, and (2) determine the need for soil cleanup.

Use of the following process requires the RP to conduct a thorough site assessment and characterization to determine the type of VOCs, its concentration and the vertical and lateral extent of contamination, depth to ground water, and the type of soils encountered from ground surface to groundwater.

To find out the vertical extent of contamination, a minimum "clean zone" should be established. The clean zone is the area in which contaminants in multiple consecutive samples (including soil matrix and/or soil gas) cannot be detected above a required detection limit. The depth of the clean zone depends upon site-specific factors such as type of VOCs, depth to groundwater, or vadose zone materials. Analytical methods used to detect the concentration of contaminants are EPA

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Methods 8010, 8020, 8260 and/or soil gas analytical protocols specified in the Regional Board's "Requirements for Active Soil Gas Investigation (March 96)".

State Board Resolution 92-49 (as amended in 1994) requires follow-up groundwater monitoring at soil cleanup sites where contaminants are left in place at higher concentration values than computed from either the following guidance or an acceptable "fate and transport" study, or at which VOCs in soil has been confirmed to cause ground water contamination.

VOC Cleanup Screening Level

You can estimate target VOC soil cleanup screening levels as a function of physical and chemical properties of the impacted site and the contaminant. The model for creating a site-specific attenuation factor (AF) is based on an equation describing VOCs existing in "multi-phase equilibrium" in the vadose zone. Multi-phase refers to the various forms of VOC contaminants; they can be gaseous, liquid, or adsorbed onto solid particles. The AF is a measure of the concentration of contaminants that can be retained in the soils above the water table as a function of both distance above the water and the composition of soils and sediment, or "lithology," encountered between the point of discharge and the water.

The equations developed were used to calculate AF values based on soil physical property data collected in this region and chemical property data for 29 common VOCs, and modified by the factors of distance above

groundwater and the vadose zone lithology. The detailed calculation procedures are described in Appendix A of this document.

Soil cleanup screening levels determined through the AF method allow the RP to meet less stringent soil cleanup goals in situations where groundwater is deep and/or the vadose zone consists of fine grained materials such as silt or clay.

To simplify AF application and calculation processes, Table 5-1 offers total average attenuation factors, AF_T , in terms of distance above groundwater and the vadose zone lithology. AF_T can be applied directly from the table (e.g., $AF=11$ given groundwater at 80 feet and sandy soil condition); or can be interpolated between table values for distances above groundwater less than 150 feet (e.g., $AF=9$ given distance above ground water 70 feet and sandy soil condition). For a site of combined lithological composition, AF_T values should be proportional to the fraction of each lithological thickness in total distance of the vadose zone between the contaminant and groundwater. The caption of Table 5-1 provides an example.

To use Table 5-1 directly, minimum data required include contaminant concentrations at various depths, depth to groundwater, and vadose zone lithology between the point of VOC detection and water. Use the 150-foot values for AF_T for distances greater than 150 feet above groundwater. Use the table values of AF_T to determine total VOC concentrations for soil cleanup.

As a final step, multiply the selected table value AF_T by the water quality standard

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concentration. The end product is the soil cleanup screening level (CSL):

$$\text{CSL} = \text{AF}_T \times (\text{water quality standard})$$

Use the water quality standard in the formula in three situations:

(1) If the aquifer to be protected is a drinking water aquifer, the water quality standard shall be the MCLs if set, or applicable federal or state water quality standards if the MCLs are not set (e.g., tap water criteria of USEPA PRGs).

(2) If the aquifer is designated as a drinking water aquifer but now contaminated, the water quality standard shall consider criteria and requirements for water treatment and water usage after remediation, such as well-head treatment, pump and treat, re-injection, etc., which may require less stringent standards than MCLs.

(3) If the aquifer is used for non-drinking water, other criteria, such as aquatic life

respective MCL. In this case, the most stringent screening level is applied as the target level for cleanup.

As addressed in Appendix A, the AF method has limitations, such as: (1) Non-aqueous Phase Liquids (NAPLs) are not considered; (2) VOC gaseous phase is assumed as lost mass. If VOC gaseous phase transport in the vadose zone is considered to be a major threat to groundwater, more vapor phase studies are needed; (3) the method is not a form of vadose zone transport model; and (4) the method is not a substitute for human health risk assessment.

Vapor Extraction of Volatile Organic Compounds

Since it is effective and is one of the least costly processes for removing VOCs, "vapor extraction system" (VES) - system of using piping underground to create a vacuum to draw out gaseous material - is being used increasingly for remediation of VOC-impacted sites. The following steps must be taken to

When MCL is to be used in a situation of multiple VOC contamination, use the lowest MCL among the VOCs and their degradation products where they are detected. For example, MCL for 1,1,1-TCA is 200 µg/L (ppb) but its degradation compound could be 1,1-DCA, which has a MCL of 5 µg/L (ppb). Soil cleanup screening levels may also be set for each individual compound based on each

should include at least one deep soil boring to find out the vadose zone lithology at the site, with samples collected from fine-grained soil layers for VOC analysis.

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- B) Conduct a feasibility study to determine if VES is applicable to the site.
- C) Measure soil physical properties to determine operating parameters of VES.
- D) Collect soil gas samples at various locations and depths to provide a baseline data of soil vapor concentrations.
- E) Conduct a pilot test to determine the zone of influence and the best locations of extraction wells and associated soil vapor monitoring probes.
- F) Remove VOCs by using the VES specifically designed for the site. Once installed and operating, VES must continue until there is no further drop in VOC concentration over time at the extraction wells and in strategically placed vapor monitoring wells.
- G) Measure the "rebound concentrations." This begins at the point when no decrease in vapor concentration is observed. The VOC is then monitored after specified periods of time, with no extraction, to measure the concentrations as they "rebound" over time. If the "rebound" upon successive tests exceeds 50 percent of the targeted screening concentration, restart the VES and repeat the cycle. If the "rebound" does not exceed 50 percent of the targeted screening concentration over a period of one year, shut down the VES. Soil matrix sampling at "fine-grained horizons" - analyzing the VOC content in soil samples rather than in vapor forms - generally will be required to confirm the cleanup.

Initially, elevated detection limits may be used to monitor the VOC concentrations. However, as extraction progresses the analytical detection limit must be lowered to below the soil cleanup screening level. This is to assure that the concentration attained is not a function of elevated detection limits. For example, 1 ppm may be the initial detection limit. Unless the detection limit is lowered as extraction proceeds, it would appear that the VOC concentration has reached its minimum level at 1 ppm.

If the targeted cleanup levels cannot be attained, the Regional Board staff will use one or more of the following performance criteria or additional requirements to clear the site from further vadose zone remediation by VES:

- 1) Reduce overall VOC concentrations at all extraction and monitoring points as compared to the baseline level.
- 2) Verify that concentration reached an "asymptotic level" - in which concentration gradually decreases to a constant level - by monitoring concentration rebounds after extraction shut downs.

Guidance for VOC-Impacted Sites

- 3) Check if there is reduction of concentrations in soil matrix samples at selected "fine-grained horizons" in the vadose zone.
- 4) Apply "transport modeling" to show that any residual contaminants will not pose further threat to groundwater quality.
- 5) Implement groundwater monitoring if contaminants exceeding target screening levels are to be left in the vadose zone.

In case of coarse materials in the vadose zone, where most VES is applied, you can compare soil gas concentration in $\mu\text{g/L}$ with soil cleanup screening levels calculated in this guidance process to determine the effectiveness of the remediation and when to terminate it. See Appendix A for further explanation.

2. Vadose Zones above Non-Drinking Water Aquifers

Non-drinking water aquifers are not usable for municipal or domestic supply, as defined in State Water Resources Control Board (SWRCB) Resolution 88-63 (i.e., TDS > 3000 mg/L, deliverability < 200 gal/day, or existing contamination that cannot be reasonably treated). Regional Board staff shall make site-specific water use determinations based on the Basin Plan objectives.

VOCs are usually toxic; some of them even carcinogenic. They cannot be rapidly broken down in the natural subsurface environment

and are very mobile in the vadose zone, thus posing a threat to groundwater quality. Although not supplied for municipal or domestic use, non-drinking waters shall not be contaminated any more than their "background" levels. They also shall not adversely impact an underlying usable drinking water aquifer by discharging VOCs into the drinking water.

When soil cleanup standards above non-drinking water aquifers are to be determined, criteria other than drinking water standards, such as aquatic life habitat, ecological impact, economic importance of the aquifer, water beneficial use requirements, availability of reuse in other water bodies, etc., will be considered. However, the cleanup standards should normally not be as stringent as required for usable drinking water bodies.

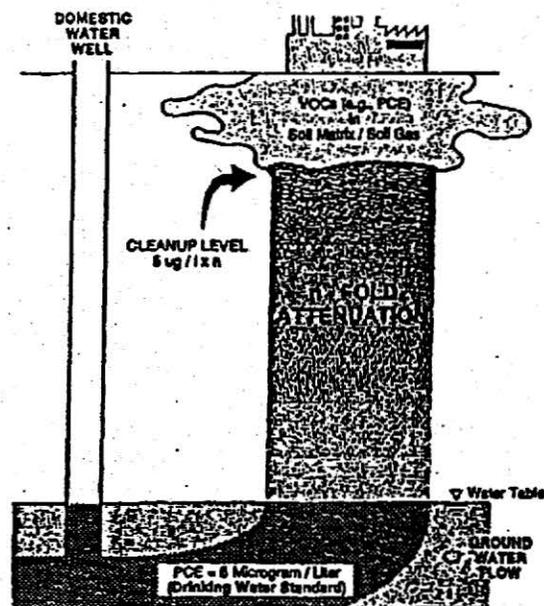


Illustration of Attenuation Effect

Table 5-1: AVERAGE ATTENUATION FACTOR FOR DIFFERENT DISTANCE ABOVE GROUND WATER AND LITHOLOGY*

DISTANCE ABOVE G.W.	LITHOLOGY			
	GRAVEL	SAND	SILT	CLAY
150	13	26	51	255
120	10	19	39	193
100	8	15	30	151
80	5	11	22	109
60	3	7	13	67
40	1	3	5	26
20	1	1	3	13
10	1	1	1	7

Distance (ft) Between Ground Water (G.W.) and the Measured Point;
Lithology (USCS Standard) Between Ground Water and the Measured Point.

*= See Section 5 of Appendix A

EXAMPLE:

A manufacturing factory used PCE in its degreasing process. Soil data are shown in table below. Ground water at the site is about 80 feet below ground surface. Lithology is about 50 percent gravel and 50 percent sand. Use Table 5-1 to determine the attenuation factor (AF) for different depths as follows:

At surface level (i.e., 80 feet above ground water): $AF_{80} = 5 \times 50\% + 11 \times 50\% = 8$

At 20 feet level (i.e., 60 feet above ground water): $AF_{60} = 3 \times 50\% + 7 \times 50\% = 5$

At 40 feet level (i.e., 40 feet above ground water): $AF_{40} = 1 \times 50\% + 3 \times 50\% = 2$

Calculate the soil cleanup screening levels at respective depths by multiplying AF by MCL for PCE (5 ppb), and compare the results with the soil data at the site as shown below. Because soil concentrations are equal to or smaller than the cleanup screening levels, no soil cleanup is required.

Depth (ft)	Soil Data ($\mu\text{g}/\text{kg}$)	Cleanup Level (ppb)
1	40	40
20	20	25
40	10	10