



5.0 GUIDANCE FOR VOC-IMPACTED SITES: SOIL SCREENING LEVELS (March 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.

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 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 a 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., $AF_T=9$ 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 concentration. The end product is the soil cleanup screening level (CSL):

$$CSL = AF_T \times H \text{ (water quality standard)}$$

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 habitat, ecological impact, water beneficial use requirements, etc., may apply (see Section 2, "Vadose Zones Above Non-drinking Water Aquifers" below for criteria to determine a "non-drinking aquifer").

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 $\mu\text{g/L}$ (ppb) but its degradation compound could be 1,1-DCA, which has a MCL of 5 $\mu\text{g/L}$ (ppb). Soil cleanup screening levels may also be set for each individual compound based on each 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 apply VES:

- A) Complete a site assessment to define the lateral and vertical extent of soil contamination and to characterize soil physical properties. The assessment 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.
- 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.

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.

- 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

arebound@ over time. If the arebound@ upon successive tests exceeds 50 percent of the targeted screening concentration, restart the VES and repeat the cycle. If the arebound@ does not exceed 50 percent of the targeted screening concentration over a period of one year, shut down the VES. Soil matrix sampling at afine-grained horizons@ - analyzing the VOC content in soil samples rather than in vapor forms - generally will be required to confirm the cleanup.

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.
- 3) Check if there is reduction of concentrations in soil matrix samples at selected afine-grained horizons@ in the vadose zone.
- 4) Apply atransport 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.

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

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 (µg/kg)	Cleanup Level (ppb)
1	40	40
20	20	25

40

10

10