INTERIM GUIDANCE FOR INVESTIGATING POTENTIAL 1,2,3-TRICHLOROPROPANE SOURCES IN SAN GABRIEL VALLEY AREA 3

SAN GABRIEL BASIN
LOS ANGELES COUNTY, CALIFORNIA

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Interim Guidance for Investigating Potential 1,2,3-Trichloropropane Sources in San Gabriel Valley Area 3

1. Purpose and Scope

This document has been prepared to provide guidance to the United States Environmental Protection Agency (USEPA) Region 9 and the Los Angeles Regional Water Quality Control Board (LARWQCB) in locating potentially responsible parties (PRPs) who may have used the chlorinated volatile organic compound (VOC) 1,2,3-trichloropropane (1,2,3-TCP). An additional intended use of this document is to guide LARWQCB oversight of investigations at PRP facilities in San Gabriel Valley (SGV) Area 3 of the San Gabriel Basin Superfund Site in Los Angeles County, California, to assess potential releases of 1,2,3-TCP.

The body of this document provides a summary of background information on the identification of potential sources, investigation and sampling strategies, sampling methods, analytical methods, and remediation of 1,2,3-TCP contamination. Information on chemical properties, environmental fate and transport, uses and manufacturers, regulatory levels, documented occurrences of 1,2,3-TCP environmental contamination in the United States (U.S.), and health risk information is provided in a series of appendices. This document in intended to be used as interim guidance for investigating potential 1,2,3-TCP sources in SGV Area 3 and may be updated in the future as deemed necessary.

1,2,3-TCP is a synthetic (not naturally occurring) chemical that is a clear, colorless, dense, moderately volatile, and moderately flammable liquid; it is, described as having a sweet but strong acrid odor similar to chloroform. 1,2,3-TCP was previously used as a solvent, as a soil fumigant, and as a branching agent for polysulfide polymers. Alternate chemical names, chemical properties, and environmental fate and transport characteristics are provided in Appendix A. The California Department of Health Services (DHS) notification level (NL) for 1,2,3-TCP in drinking water is 0.005 005 micrograms per liter (µg/L).

2. Identification of Potential Sources

1,2,3-TCP occurs in groundwater in the central portion of SGV Area 3 at concentrations up to 413 nanograms per liter (ng/L) (0.413 µg/L); (see[Figure 2-1]). The depth to groundwater in this portion of Area 3 ranges from approximately 275 to 300 feet below ground surface (bgs) as of January 2004. The subsurface alluvial sediments consist predominantly of sand and gravel, with minor amounts of silt and clay.

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Figure 2-1 1,2,3-Trichloropropane Contamination, San Gabriel Valley ~~in SGV~~ Area 3

The source(s) of 1,2,3-TCP contamination in SGV Area 3 ha~~ve~~s not been determined to date. Because of the significant depth to water in the central portion of the operable unit (OU), contaminant travel times between the ground surface and groundwater table~~, depending on the volume of a release (i.e., a large amount over a short duration or smaller quantities over a long duration),~~ are expected to be on the order of ~~tens of years~~decades. Therefore, sources (e.g., facilities) of potential concern include those that either have operated for many years (i.e., decades) or have used large quantities of chemicals, or both. The previous existence of a "dry well" for disposal of relatively small quantities of liquid waste containing 1,2,3-TCP is another potential mechanism to explain the 1,2,3-TCP groundwater contamination in Area 3 (see Appendix D, MacKenzie Chemical Works site), although none have been identified.

Uses and manufacturers of 1,2,3-TCP are described in Appendix B. Based on this information, the types of business operationes ~~(e.g., facilities)~~ that are considered to be potential sources of 1,2,3-TCP releases are summarized in Table 2-1.

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TABLE 2-1
Uses of 1,2,3-TCP, Products, and Types of Businesses Using Products

Uses of 1,2,3-TCP	Products	Types of Businesses/Operations	Comments and Example Site or Source[a]
Former (Historic) Uses			
Paint and varnish solvent	Paint and varnish Paint and varnish stripper Furniture finish remove	Paint manufacturer Commercial painting facility Solvent manufacturing or recycling facility Paint stripping facility Antique restoration facility	The cited uses were referenced in Johnson (1968), but are not known today. No information is currently available to indicate that these uses continue.
Degreasing agent	Degreasing agent	Metals plating shop Painting facility Electronics manufacturer	Former MCAS Tustin, CA. Use of 1,2,3-TCP is estimated to have occurred in the 1950s.[b]
Soil fumigants of which 1,2,3-TCP is a minor component	D-D Telone II	Agricultural applications Soil fumigants were used on citrus fruits, pineapple, soy beans, cotton, tomato, and potatoes~~.~~	Central Valley, CA. Used from 1946 to the present.

TABLE 2-1
Uses of 1,2,3-TCP, Products, and Types of Businesses Using Products

Uses of 1,2,3-TCP	Products	Types of Businesses/Operations	Comments and Example Site or Source[a]
"Branching" agent for polysulfide polymers	Aircraft tank sealants	Aircraft manufacturers Aircraft fuel tank manufacturers Aircraft maintenance facilities	San Fernando Valley Superfund Site (Area 1 – North Hollywood and Burbank). Polysulfides have been in used for aircraft tank sealing since the 1950s.
	Binder for rocket fuel	Rocket motor manufacturer Rocket motor test facility	Used for rocket fuel binder from 1946 to 1958.
	Construction sealants	Commercial construction	Used as construction sealants since the 1950s.
Current Uses			
Chemical intermediate for synthesis of other products	Polysulfone liquid polymers Polysulfides	Aerospace, automotive, consumer goods, electrical, electronic, health care and industrial equipment Compressor and pump valve components	
Chemical intermediate for synthesis of other products	Hexafluoropropylene (key building block to produce Teflon fluoropolymers) Polysulfides (catalyst sulfidation agents, formulation of extreme pressure lubricant additives)	Agrochemical, electronics, dyes/pigments, pharmaceutical, and specialty polymer facilities Lubrication product manufacturer	Ciba-Geigy, NJ
Byproduct of the manufacture of epichlorohydrin	Over 80 percent of the 1,2,3-TCP manufactured in the U.S. is a byproduct of the manufacture of epichlorohydrin and is incinerated onsite	Petrochemical/industrial chemical complexes	No epichlorohydrin manufacturing is known to have occurred in the San Gabriel Valley.
"Branching" agent for polysulfide polymers	Polysulfide polymer sealants Sealants for insulating glass windows Construction adhesive Boat hull sealants	Window manufacturers Boat manufacturers Adhesive manufacturer	Polysulfide polymer sealants are still used for glass sealants and construction adhesives.

TABLE 2-1
Uses of 1,2,3-TCP, Products, and Types of Businesses Using Products

Uses of 1,2,3-TCP	Products	Types of Businesses/Operations	Comments and Example Site or Source[a]
"Branching" agent for polysulfide polymers	Aircraft tank sealants	Aircraft manufacturers Aircraft fuel tank manufacturers Aircraft maintenance facilities	San Fernando Valley Superfund Site (Area 1 - North Hollywood and Burbank), California. Polysulfide polymers have been used as aircraft tank sealants from the 1950s to the present.
Soil fumigants of which 1,2,3-TCP is a minor component	Telone II	Agricultural applications Soil fumigants were used on citrus fruits, pineapple, soy beans, cotton, tomato, and potatoes.	Central Valley, CA. Telone II (introduced in 1956) is still in use for vegetables, field crops, fruit and nut trees, grapes, nursery crops and cotton.

Notes:
[a] See Appendix D. Only limited information is available for the periods of use of some of these chemical products. Therefore, the cited periods of use may not preclude use during other time periods.
[b] Associated with a former vehicle maintenance building.

Of the types of business operationes that have historically involved the use ofd 1,2,3-TCP (Table 2-1), the most likely types of businesses to have operated in SGV Area 3 in the past are paint manufacturers,; commercial painting facilities,; paint stripping facilities,; metal plating shops,; electronics manufacturers,; solvent manufacturer or recyclers,; aircraft fuel tank manufacturers,; rocket motor test facilities,; and aerospace, automotive, compressor, and lubrication manufacturers. It should be noted that further refinement of Table 2-1 to a short list of businesses most likely to have historically used 1,2,3-TCP will require significantly more effort than expended in preparation of this interim guidance document.

It is possible that prior agricultural activities could have potentially been responsible for some 1,2,3-TCP groundwater contamination. However, the relatively limited extent of contamination in SGV Area 3 is more consistent with a release originating from a point source for the contamination. Unless a release occurred at a fumigant storage or distribution facility, agricultural activities would be expected to result in more widespread 1,2,3-TCP contamination at relatively low concentrations compared to the NL, rather than the more isolated 1,2,3-TCP at concentrations in groundwater of over 0.400 ung/L (>50 times the NL) present in SGV Area 3. Also, as presented in Table 3-2, other VOCs commonly found in soil fumigants at present have not been detected in groundwater in SGV Area 3.

3. Investigation and Sampling Strategies

A summary of site investigation tasks and descriptions is provided in Table 3-1. Because of the chemical properties of 1,2,3-TCP (volatile, soluble, mobile), a combination of environmental media will need to be sampled to identify sources of 1,2,3-TCP groundwater contamination: soil, groundwater, and potentially soil gas (only if a true near-surface source area has been identified). Initiating potential sourcite investigations through using a soil gas surveyampling may not be the most effective approachproduce data of sufficient quantity

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~~and quality~~ to identifying an area of a 1,2,3-TCP release, based on past experience in the San Fernando Valley Superfund Site (Area 1 - North Hollywood and Burbank), California (Tetra Tech, 2003).

The occurrence of 1,2,3-TCP with other contaminants in soil or groundwater may, in some cases, assist in determining the source of 1,2,3-TCP in soil or groundwater, as summarized in Table 3-2.

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TABLE 3-1
Summary of Investigation Tasks and Descriptions

Investigation Task	Description
Determine Study Area	Focus study ~~areas~~ on areas of regional 1,2,3-TCP groundwater contamination, and on areas that are up-gradient of existing regional contamination.
	Migration of 1,2,3-TCP contamination may not initially be governed by the regional groundwater flow direction, but may at first follow any preferential pathways in subsurface strata in the vadose zone. In some cases, the preferential flow direction of soil vapor in the vadose zone may be significantly different from the preferential flow direction of groundwater in the saturated zone.
Perform PRP Searches and File Reviews	Focus PRP searches and file reviews on the types of operations/businesses listed in Table 2-1.
	The business/operation may potentially be evaluated by looking for contaminants that occur with 1,2,3-TCP in soil and groundwater, as summarized in Table 3-2.
	Review regulatory files at the Regional Water Quality Control Board (RWQCB), the California Environmental Protection Agency (Cal-EPA) - Department of Toxic Substances Control (DTSC), and the City Fire Department Hazardous Materials Management Unit for any evidence of 1,2,3-TCP use or release. Specific documents to be reviewed include material safety data sheets (MSDS), hazardous materials business plans, and chemical inventory information.
	Review site investigation reports (including Phase I environmental assessments, preliminary site investigations, subsurface investigations, hydrogeologic assessments, groundwater monitoring reports, soils investigations, underground storage tank (UST) and above-ground storage tank (AST) leak detection, investigation and closure reports, excavation reports, soil gas survey investigations, and soil and groundwater samples) that included 1,2,3-TCP as an analyte.
Review of Groundwater Monitoring Data	Groundwater samples from wells may need to be re-analyzed for 1,2,3-TCP (see Appendix C for additional details on this topic), because 1,2,3-TCP was generally not analyzed with low-level reporting limits until approximately 1999, when a DHS Action Level (now referred to as the notification level [NL]) was established. The detection limit for 1,2,3-TCP in groundwater prior to 1999 may be as high as 10 µg/L, which is well above the current DHS NL of 0.005 µg/L. 1,2,3-TCP may be detected as a tentatively identified compound (TIC) in historic monitoring data at concentrations exceeding approximately 90 µg/L
Soil Gas Sampling	Soil gas surveys are currently anticipated to be of limited success as an approach for investigating potential 1,2,3-TCP releases. Therefore, soil gas surveys should be based on an evaluation of prior facility operations and should subsequently be focused in areas where 1,2,3-TCP releases are likely to have occurred. The need for focused soil gas surveys is based on prior experience at the San Fernando Valley Superfund Site (Area 1 - North Hollywood and Burbank).

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TABLE 3-1
Summary of Investigation Tasks and Descriptions

Investigation Task	Description
Subsurface Soil Sampling	Soil samples should be collected and analyzed every 5 to 10 feet over the entire depth of a boring, because the detection of 1,2,3-TCP may be limited to small stratigraphic lenses over short intervals, as observed in San Fernando Valley Superfund Site (Area 1 - North Hollywood and Burbank) (Tetra Tech, 2003). Alternatively, selected soil samples may be analyzed according to observed elevated head space readings, as measured with an organic vapor analyzer (OVA) or flame ionization detector (FID).
	The traditional approach for collecting and analyzing subsurface soil samples by direct-push methods, a California modified soil sampler, or equivalent is recommended.
Groundwater Sampling	Collect groundwater samples for 1,2,3-TCP analysis from existing monitoring and production wells, and install new monitoring wells at key locations to help further refine the interpreted extent of 1,2,3-TCP in groundwater.

The California Department of Pesticide Regulation advised that where 1,2,3-TCP is a contaminant of concern, the groundwater should also be analyzed for 1,2-dichloropropane, which commonly occurs in much higher concentrations than 1,2,3-TCP, and 1,2,2-trichloropropane (1,2,2-TCP), which is a byproduct of the manufacture of 1,3-dichloropropene (Howe et al., 1999). Ethylene dibromide (EDB) and 1,2-dibromo-3-chloropropane [DBCP] are other common soil fumigants that may be present in groundwater.

TABLE 3-2
Comparison of Contaminants to Potential Businesses/Operations

Contaminants Detected in Groundwater	Potential Business/Operation (see Appendix B)
1,2,3-TCP only	Painting or paint stripping, aviation/fuel tank sealing, boat construction facilities, compressor and pump maintenance/manufacturing
1,2,3-TCP with trichloroethene (TCE), tetrachloroethene (PCE)	Metal or plastics plating facility, paint stripping facility, painting facility, aviation/fuel tank sealing, automotive manufacturing, mechanical maintenance shop
1,2,3-TCP and perchlorate	Aerospace/rocket motor production, testing, and disposal
1,2,3-TCP with 1,2-dichloropropane, 1,2,2-trichloropropaneTCP, and potentially ethylene dibromide [EDB] and 1,2-dibromo-3-chloropropane [DBCP].	Agricultural application (especially citrus) of soil fumigant; storage or distribution center off agricultural chemicals

4. Sampling Methods

Recommendations for sampling methods for of collecting ion of soil, groundwater, and soil gas samples for 1,2,3-TCP analyses are provided in this section. All sampling methods are listed and briefly described in Table 4-1. Following this table, Sections 4.1, 4.2, and 4.3

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provide additional details on specific issues pertaining to sampling of each media. Analytical methods are provided in Section 5.

TABLE 4-1
1,2,3-TCP Sampling Methods

Media	Sampling Method	Sample Container
Groundwater		
Groundwater – in situ samples	HydroPunch™ sampler, (collect groundwater sample with small-diameter bailer inside HydroPunch™ assembly, decant to VOA vial).	40-millilter (ml) volatile organic analysis (VOA) vial, HCl to pH <2, no headspace, cooled to 4 degrees Celsius (°C).
	BAT™ system groundwater sampler (evacuated 120-ml glass vial) is filled when septa is punctured in the subsurface.	Cool glass vial to 4°C immediately upon retrieval;, submit to laboratory for analysis.
	SimulProbe™ (able to collect simultaneous soil and groundwater samples).	Immediately transfer liquid sample to 40-ml VOA vial, HCl to pH <2, no headspace, cool to 4°C.
	NOTE: Use of in situ, depth-specific samples permits characterization of the vertical extent of 1,2,3-TCP contamination.	**NOTE:** Given the depth to groundwater in SGV Area 3 (275 to 300 feet bgs), the cost to collect in situ groundwater samples below the water table may be cost prohibitive. Depending on the depth of sample collection, these in situ methods may need to be used in combination with subsurface drilling methods.
Groundwater – production wells	Fill sample container directly from wellhead tap, taking care to minimize sample aeration.	40-ml VOA vial, HCl to pH <2, no headspace, cool to 4°C.
Groundwater - monitoring well	Dedicated pump (low-flow method preferred).	Directly fill 40-ml VOA vial, HCl to pH <2, no headspace, cool to 4°C.
	Diffusion bag sampler(s) (allow to equilibrate per instructions).	Carefully decant sample(s) into 40-ml VOA vial(s), HCl to pH <2, no headspace, cool to 4°C.
	NOTE: With the aide of multiple sampler collection devices, a vertical concentration profile may be obtained.	**NOTE:** Vroblesh and Campbell (2001) report that when using polyethylene-based passive diffusion samplers for VOCs, the concentrations of 1,2,3-TCP measured with the diffusion bag sampler was were within 10-percent of the concentration in ambient water.
Multiple-port groundwater monitoring well	Use Westbay sampling equipment to collect groundwater sample.	Fill 40-ml VOA vial directly from Westbay sample container, HCl to pH <2, no headspace, cool to 4°C.
Soil		
Soil - surface	Sample directly with Encore sampler.	Encore sampler, cooled to 4°C.
	Sample collection in a glass jar may be acceptable if soil conditions (e.g., the presence of gravel) prevents the use of an Encore sampler. This will require approval on a case-by-case basis. If approved, collect the grab sample with stainless steel spade, packing soil tightly into jar.	4-ounce glass jar (no headspace), cooled to 4°C.

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TABLE 4-1
1,2,3-TCP Sampling Methods

Media	Sampling Method	Sample Container
Soil ~~–~~ subsurface	Direct push sampler Piston sampler California modified soil sampler SimulProbe™ (able to collect simultaneous soil and groundwater or soil and soil gas samples)	Brass or stainless steel (SS) sample sleeve; seal end with Teflon tape, foil, and plastic end caps; cooled to 4°C.
Soil Gas		
Soil Gas	Install temporary or permanent soil gas sampling probe, purge, and sample per LARWQCB/DTSC guidance (2003).	Syringes, glass bulbs wrapped in Aluminum foil, SUMMA™ canisters.

4.1 Groundwater

Groundwater samples may be collected from production wells, conventional groundwater monitoring wells, multiple port monitoring wells, and with diffusion bag samplers. In~~-~~ situ (depth-specific) groundwater samples may be collected to characterize the vertical extent of 1,2,3-TCP groundwater contamination.

Monitoring Wells

Sample collection from conventional and multiple~~-~~-port monitoring wells is the most common and direct method for detecting and monitoring 1,2,3-TCP in groundwater. A low-flow ~~method~~ sampling method is recommended to minimize 1,2,3-TCP losses due to volatilization from turbulence within the well and during filling of sample containers. Samples collected in this manner will yield laboratory analytical results that are considered to be more representative of actual in situ groundwater concentrations.

Diffusion Bag Samplers

Vroblesh and Campbell (2001) reported that when using polyethylene~~-~~-based passive diffusion samplers for VOCs, concentrations of 1,2,3-TCP measured in samples collected with the diffusion bag sampler were within 10 percent of the concentrations in ambient water. This close agreement indicates that diffusion bag samplers are a viable alternative for collection of groundwater samples for analysis of 1,2,3-TCP. If a series of bags ~~are~~ is suspended at different depths in a well, a vertical profile of 1,2,3-TCP concentrations may be obtained, assuming that the well is not acting as a conduit for vertical groundwater flow (which would result in non~~-~~representative samples). This method is best suited for detailed profiling in wells with relatively short (i.e., 50 feet or less) monitoring well screen intervals. Procedures for use of diffusion bag samplers are provided in Interstate Technology and Regulatory Council guidance (ITRC, ~~(~~ 2004).

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In Situ Groundwater Sampling

In situ (depth-specific) sampling during drilling of monitoring wells can be performed using a HydroPunch-™, SimulProbe™, or BAT-™ sampler in order to assess the vertical extent of 1,2,3-TCP groundwater contamination. However, given the depth to groundwater in the central portion of SGV Area 3 (275 to 300 feet bgs), the cost to use this approach as a screening technique would be prohibitively expensive and time consuming.

4.2 Soil

Soil samples for analysis should be collected in Encore samplers to reduce 1,2,3-TCP losses from volatilization. Direct-push samples collected in stainless-steel or brass sleeves should be sealed with Teflon tape, foil, and plastic end caps. For samples of loose soil with gravel, or coarse, loose sand or gravel that cannot be sampled with an Encore sampler, pack the soil tightly into a 4-ounce glass jar and close the cap tightly. It should be noted that given the moderate volatility of 1,2,3-TCP, surface soil samples are unlikely to contain detectable concentrations of 1,2,3-TCP. Consequently, an alternative approach to characterizing concentrations of 1,2,3-TCP in soil, for example during screening-level investigation of a site, would be to use heated soil head space field analyses. All samples should be placed on ice immediately and maintained at 4°C prior to analysis.

The selection of subsurface samples for submittal to a laboratory for 1,2,3-TCP analysis can be targeted based on headspace concentrations, visible staining, or odor. Concentrations of 1,2,3-TCP are expected to be higher in fine-grained materials (e.g., silt), than coarse-grained materials (e.g., gravel), where it would be more easily volatilized in the vadose zone or be more rapidly flushed away by groundwater flow in the saturated zone (i.e., below the groundwater table).

4.3 Soil Gas

Little information is available on the effectiveness of soil gas surveys in assessing sources and releases of 1,2,3-TCP and the extent of 1,2,3-TCP soil contamination. A soil gas survey was completed during 2003 at the Aeroquip Corporation in the San Fernando Valley Superfund Site (Area 1 - North Hollywood and Burbank), California (Tetra Tech, 2003). However, 1,2,3-TCP was essentially not detected in any soil gas samples above the detection limit of 1 µg/L (Appendix D). For this reason, until additional soil gas investigations in the U.S. showing effective quantification of 1,2,3-TCP in soil gas at a range of concentrations have been documentedsampling results are produced, soil gas surveys are not expected anticipated to be particularly effective for identifying 1,2,3-TCP sources. A combination of subsurface soil samples, groundwater sampling, and potentially soil gas sampling near suspected releases is expected to be the most effective approach to identifying 1,2,3-TCP sources.

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LARWQCB-lead investigations at facilities in the SGV where suspected releases of VOCs (e.g., TCE or PCE) have occurred typically begin with a soil gas survey, which has been shown to be an cost-effective strategy. However, because 1,2,3-TCP is less volatile than PCE or TCE (see Appendix A) and more difficult to detect, these limitations need to be considered when designing a soil gas survey to help locate potential 1,2,3-TCP releases. It is recommended that evaluation of operations at the facility or business be performed first, so that collection of soil gas samples can be focused on those areas where elevated subsurface

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concentrations associated with a release are likely to occur. This approach may be more effective than using a sampling grid approach for screening a facility for potential 1,2,3-TCP releases.

5. Analytical Methods

A summary of recommended analytical methods for the analysis of 1,2,3-TCP in soil, soil gas, and groundwater, is provided in this section.

5.1 Groundwater

Because accepted ~~collection~~ methods (see Section 4) generally result in collection of samples with low levels of turbidity (e.g., less than 5 nephelometric turbidity units [NTUs]) from monitoring or production wells ~~with low levels of turbidity (e.g., less than 5 nephelometric turbidity units [NTUs])~~, most groundwater samples can be analyzed using methods developed for (unfiltered) drinking water. To allow laboratories to meet the DHS detection limit for reporting (DLR) purposes ~~(DLR)~~ of 0.005 µg/L for 1,2,3-TCP (consistent with the NL of 0.005 µg/L), DHS developed two analytical methods ~~which~~ that are DHS-approved for analysis of water (including groundwater) samples for public (drinking) water systems: ~~m~~Methods DHS PT-GC/MS and DHS LLE-GC/MS. In addition, two other alternative methods are DHS approved if the laboratory can demonstrate that it can meet the DLR without method modification: EPA 504.1~~,~~ and EPA 551.1. These four methods are summarized in Table 5-1. EPA ~~m~~Methods 504.1 and 55~~-~~1.1 are the older analytical methods that DHS continues to approve. It should be noted that when using these older methods, 1,2,3-TCP detection in a sample that has a high total dissolved solids (TDS) or VOC content, or otherwise precludes unambiguous confirmation, should be confirmed with one of the DHS gas chromatography/mass spectroscopy (GC/MS) methods above. The DHS methods are recommended for definitive identification and quantification, especially for concentrations close to the NL.

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TABLE 5-1

DHS-Approved Analytical Methods for 1,2,3-TCP in Water

Method	Detection Limit (µg/L)	Sample Container	Holding Time	Approximate Cost per Sample
DHS PT-GC/MS[a]	0.005	40-m~~L~~l vial, HCl to pH <2; cooled to 4°C	14 days	$150
DHS LLE-GC/MS	0.005	1-L amber bottle; cooled to 4°C	14 days before extraction; 24 hours for extract analysis	$225
EPA 504.1	Varies by laboratory; typical detection limits in the past have been 0.02 µg/L	40-m~~L~~l vial with sodium thiosulfate; cooled to 4°C	14 days before extraction; 24 hours for extract analysis	$85
EPA 551.1	Varies by laboratory; one laboratory reported a 0.008 µg/L detection limit	60-m~~L~~l vial with ammonium chloride; cooled to 4°C	14 days before extraction; 14 days for extract analysis	NA

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[a]Used by USEPA Region 9 for groundwater monitoring samples.

Based on results in the EPA ~~'s~~ San Gabriel Basin database, samples from essentially all of the active production wells in SGV Area 3, most of which are used to supply (unfiltered) drinking water, have been analyzed using one of the DHS methods (see ~~'Appendix~~ C, unregulated contaminant for which monitoring is required ~~'~~ [UCMR~~l~~]).

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For all of these methods, the laboratory should be provided with a statement of work (SOW) that defines the needed quality control (QC) for the analyses to provide for reproducible, comparable, defensible data. The ~~quality control~~QC specifications should include requirements for initial and continuing calibration, instrument tuning, internal standards, laboratory control standard, matrix spikes, duplicates, method detection limits, and documentation. The project-specific SOW should identify the specific ~~quality control~~QC procedures, level of effort (the frequency of the runs), acceptable ~~quality control~~QC limits, and corrective action requirements.

DHS Analytical Methods

The DHS Sanitation and Radiation Laboratories (SRL) ha~~s~~ve developed two ~~gas chromatography/mass spectroscopy (~~GC/MS~~)~~ methods (Purge and Trap GC/MS and Liquid-Liquid Extraction GC/MS) that are capable of 1,2,3-TCP quantification at the DLR. In February 2002, ~~CA~~ DHS published the two new analytical methods, listed below.

- *Determination of 1,2,3-Trichloropropane in Drinking Water by Purge and Trap Gas Chromatography/Mass Spectrometry* (DHS PT-GC/MS). http://dhs.ca.gov/ps/ddwem/chemicals/unregulated/TCPbyPT-GCMS.pdf.
- *Determination of 1,2,3-Trichloropropane in Drinking Water by Continuous Liquid-Liquid Extraction and Gas Chromatography/Mass Spectrometry* (DHS LLE-GC/MS). http://dhs.ca.gov/ps/ddwem/chemicals/unregulated/TCPbyLLE-GCMS.pdf.

Both methods use GC/MS in the selective ion monitoring (SIM) mode and isotope dilution to meet the low DLR. Quantitation is performed using isotope dilution with TCP-D5. VOCs ~~which~~ that co-elute or overlap with TCP or TCP-D5, and ~~which~~ that yield the same fragment ions as TCP or TCP-D5, can be a major source of error in both these methods. Due to the extreme sensitivity of these methods, even low abundances of these ions can result in severe interference when the interfering compound is present at sufficiently high concentrations. The following compounds have the potential to interfere: trans-1,4-dichloro-2-butene (m/z 75 ion), isopropylbenzene (m/z 75 ion), o-xylene (m/z 79 ion). QC data for the individual sample batches should be reviewed to evaluate the impact of these interferences on analytical data.

The list of laboratories that are certified by DHS under the Environmental Laboratory Accreditation Program (ELAP) to perform 1,2,3-TCP analysis in drinking water is available at http://www.dhs.ca.gov/ps/ls/elap/html/lablist.htm.

Oth~~l~~der Analytical Methods

1,2,3-TCP is listed as an analyte in water for EPA Methods 502.2, 524.2, and 8260. These methods were used commonly in the past for the analysis of 1,2,3-TCP in water, and are also currently used in some applications where 1,2,3-TCP is not the primary target analyte and where other chlorinated solvents are of primary concern (e.g. TCE, PCE, etc.). However,

due to the fact that the 1,2,3-TCP detection limits are much higher than the NL for 1,2,3-TCP (0.005 µg/L), EPA methods 502.2, 524.2, and 8260 are not DHS-approved for analysis of 1,2,3-TCP in drinking water (Table 5.2). ~~Due to the extremely low DHS DLR required to meet the NL for 1,2,3-TCP (0.005 µg/L or 5 ng/L), EPA mMethods 502.2, and 524.2 are not appropriate for measuring this compound in drinking water, even though 1,2,3-TCP is listed as an analyte in the method descriptions. However, these methods have been used in the past for the analysis of 1,2,3-TCP in water or are currently in use for samples in which 1,2,3-TCP is not the primary target analyte~~. Nonetheless, EPA Methods 524.2 and 8260 using SIM mode have been used successfully for the analysis of 1,2,3-TCP in water by some laboratories to achieve a detection limit of 0.002 µg/L and 0.005 µg/L, respectively. The price of the EPA Method 524.2 or 8260 analyses is approximately doubled when using the SIM mode (up to $500 per sample).~~The detection limits of these methods are considerably higher than the DHS DLR of 0.005 µg/L.~~

It should be noted that for facility investigations to support an EPA site investigation or for a drinking water source, the DHS-approved analytical methods listed in Table 5-1 are recommended, not the alternative methods listed in Table 5-2.

TABLE 5-2
Other Analytical Methods for 1,2,3-TCP in Water

Method	Detection Limit	Sample Container	Holding Time	Approximate Cost per Sample
EPA 524.2 [b]	0.03 µg/L	40-m~~L~~l vial with ascorbic acid[a]; HCl to pH <2; cooled to 4°C	14 days	$225 to $275
502.2	0.4 µg/L	40-m~~L~~l vial with ascorbic acid[a]; HCl to pH <2; cooled to 4°C	14 days	$110 to $275

[a] Use of ascorbic acid is recommended in samples collected from some public drinking water systems to remove any chlorine that may be in the water. Ascorbic acid is a very weak acid that is not be suitable for lowering the pH of the sample (HCl is instead used for that purpose).

[b] EPA 524.2 has recently been used in the SIM mode for the analysis of 1,2,3-TCP with a the detection limit of 0.002 µg/L.

5.2 Soil

Recommended analytical methods for the analysis of 1,2,3-TCP in soil samples are provided in Table 5-3. California has not proposed reporting limits for 1,2,3-TCP in soils. However, it is common to use USEPA preliminary remediation goals (PRGs) in soils as potential levels of concern that would set the upper boundary of acceptable target reporting limits. The EPA Region 9 PRGs for 1,2,3-TCP are 0.034 milligrams per kilogram (mg/kg) for residential soil ~~[~~(10^{-6} cancer risk~~]~~) and 0.076 mg/kg for industrial soil ~~[~~(10^{-6} cancer risk~~]~~) (see Appendix C). As shown in Table 5-3, detection limits for EPA Methods 8021B and 8260B can meet these target reporting limits. The detection limit for 1,2,3-TCP using EPA Method 8270C (Table 5-3) is the expected reporting limit based on analysis of similar compounds. To quantify 1,2,3-TCP below the EPA PRGs, Method 8270C would have to be run in SIM to meet these target reporting limits.

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TABLE 5-3
Analytical Methods for 1,2,3-TCP in Soil

Method	Detection Limit (µg/kg)	Sample Container	Holding Time	Approximate Cost per Sample
EPA 8021B	Approximately 10 micrograms per kilogram (µg/kg)	Encore sampler, brass or stainless-steel~~SS~~ sleeve[a], cooled to 4°C	14 days; otherwise analysis must be completed within 48 hours if samples are not frozen prior to the expiration of the 48-hour period. Sample should not be frozen below ~~–~~-20°C due to potential problems with seals and the loss of constituents upon sample thawing.	$150
EPA 8260B	Approximately 5 µg/kg [b]	Encore sampler, brass or stainless-steel ~~SS~~ sleeve[a], cooled to 4°C	14 days; otherwise analysis must be completed within 48 hours if samples are not frozen prior to the expiration of the 48-hour period. Sample should not be frozen below ~-20°C due to potential problems with seals and the loss of constituents upon sample thawing.	$225 to $350
EPA 8270C	Approximately 330 to 660 µg/kg	Encore sampler, brass or stainless-steel~~SS~~ sleeve, cooled to 4°C	14 days; otherwise analysis must be completed within 48 hours if samples are not frozen prior to the expiration of the 48-hour period. Sample should not be frozen below ~-20°C due to potential problems with seals and the loss of constituents upon sample thawing.	$195

[a] To minimize analyte loss, EPA recommends collecting a soil sample in an Encore sampler, or extruding the sample into an empty sealed vial, cooling to 4 ± 2°C for no more than 48 hours, then freezing to -7°C upon laboratory receipt.

[b] By using selective ion monitoring, the 8260 detection limits can be reduced by orders of magnitude.

No specific interferences have been identified for the ~~columns used for the~~ methods presented in Table 5-3. However, matrix-specific interferences ~~may~~ potentially may be present.

5.3 Soil Gas

Soil gas surveys have been used to investigate suspected 1,2,3-TCP sources in groundwater basins like the SGV to a very limited extent. A contractor performed a soil gas investigation at an aircraft industry facility in the San Fernando Valley Superfund Site (Area 1 - North Hollywood and Burbank), California. Soil vapor samples were analyzed using an unpublished procedure and with a GC with an MS detector (GC/MS) in both "~~"~~open scan" ~~"~~ and SIM modes (Pavlick, 2005). Soil gas samples were collected as either whole samples in SUMMA canisters or Tedlar bags, or on charcoal/tenax tubes. Soil gas samples were analyzed either directly or using a tenax trap to collect 1,2,3-TCP prior to desorption into the GC/MS. The sensitivity of this unpublished GC/MS SIM method was approximately 0.1 to 0.2 part per billion by volume (ppbv~~V~~).

~~In this case,~~Subsurface collection probes for the soil gas samples were placed at depths 20 to 30 feet above the groundwater table near a monitoring well in which 1,2,3-TCP had been previously detected ~~of~~ up to 200 µg/L (Tetra Tech, 2003). Soil gas samples collected from

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these probes contained either very low, or non-detectable, concentrations of 1,2,3-TCP. The contractor performing the analysis noted that the analytical method was reliable, but suggested that the soil gas survey did not appear to be a reliable method for locating sources of 1,2,3-TCP contamination~~not robust enough to be used as a stand-alone procedure~~, because groundwater and soil analytical results did not correlate well to the soil gas analytical results. Ultimately, the contractor concluded that, until further soil gas analysis research was performed, soil gas analysis for 1,2,3-TCP should be combined with 1,2,3-TCP analysis of samples of soil and groundwater from the facility, to have sufficient understanding of the presence/absence of 1,2,3-TCP.

Methods for soil gas analysis should be a function of the sampling method chosen (i.e., passive or active) and the intended use of the data collected. Field analysis using portable instrumentation, such as GC and/or MS, may be performed, usually by a mobile laboratory, or samples may be shipped to an off-site laboratory. Off-site laboratory analysis is generally more expensive, but reliable, because more rigorous ~~quality control~~QC procedures are in place.

Currently, there are limited information and data regarding the sampling and analysis of 1,2,3-TCP in soil vapor/ambient air. National Institute for Occupational Safety and Health (NIOSH) M~~m~~ethod 1003 is currently used for monitoring worker exposure in ambient air. The NIOSH method for off-site laboratory analysis involves extraction of the sample on a solid sorbent with carbon disulfide, and analysis by GC with an ~~flame ionization detector (~~FID~~)~~. The method requires the use of a charcoal tube for sample collection and analysis by a GC/FID, with a reporting limit of roughly 1 part per million by volume (ppm~~V~~v). This NIOSH method lacks the sensitivity and selectivity required for most facility source investigations. Table 5-4 ~~below~~ summarizes the methods that are available for 1,2,3-TCP analysis of soil gas. Method modifications to meet the project- or site-specific detection limits may need to be evaluated and considered.

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TABLE 5-4
Analytical Methods for 1,2,3-TCP in Soil Gas

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Method	Detection Limit	Sample Container	Holding Time	Approximate Cost per Sample
EPA 8260B	1 µg/L - vapor	Amber gas-tight glass bulb or SUMMA canister	4 hours for amber gas-tight glass bulb; 72 hours for SUMMA canister[a]	NA
NIOSH 1003	0.01 mg/ sample	Solid sorbent	None published, but analysis should be done as soon as possible to minimize analyte loss	NA
EPA TO-15	0.050 micrograms per cubic meter (µg/m^3)	SUMMA canister	30 days	$125

[a]LARWQCB requirement.

6. Remediation and Treatment

6.1 Remediation

Only limited information is available on remediation of 1,2,3-TCP contamination. Potential remediation approaches are summarized ~~below~~ in Table 6-1.

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TABLE 6-1
Remediation Approaches for 1,2,3-TCP Contamination

Approach	Media	Description
Pump and Treat	Groundwater	Effective for containment or source control. Not expected to be cost effective for source remediation. See Table 6-2 for groundwater treatment approaches.
In Situ Vacuum Extraction and In Situ Oxidation.	Soil, Soil Gas (vapor), and Groundwater	Full-scale remediation of soils, bedrock, and groundwater is underway at the Tyson Superfund Site near Philadelphia, Pennsylvania, using in situ vacuum extraction of silty clay soils, dual extraction of water and vapor from underlying fractured sandstone, and collection and treatment of seep water. Vapor treatment uses activated carbon adsorption (Pezullo et al., 2005). Oxidants have been injected into the subsurface in areas of DNAPL containing 1,2,3-TCP to oxidize contaminants in the subsurface. The more volatile byproducts from the oxidation reactions are captured by the vacuum extraction system that is designed to recover these byproducts. It should be noted that because the Henry's Law constant for 1,2,3-TCP (3 x 10^{-4}) atm-m^3/mol; see Appendix A) is below the 10^{-3} threshold commonly used to assess application of soil vapor extraction (SVE) as a stand-alone remedial alternative, vacuum extraction may not be the most effective remedial approach (see Appendix D, MacKenzie Chemical Works site). This technique is applicable to soil gas concentrations from tens to thousands of µg/.m^3 and total soil VOC concentrations of up to hundreds of thousands of mg/kg (i.e., percentage levels).
Dechlorination by Hydrogen Releasing Compounds	Groundwater	Use of Hydrogen Release Compound (HRC®) for in situ treatment of 1,2,3-TCP resulted in 99.9% reduction over 1,000 days at confidential site in California (Reilly, 2005). HRC has also been used at the John Taylor Fertilizers Company in Yuba City, CA (CRWQCB, 2004) and Western Farm Service, Inc. (CRWQCB, 2002). HRC is a product designed for in situ treatment of chlorinated solvents or any anaerobically degradable substance. HRC slowly hydrolyzes releasing lactic acid, which is utilized by microbes to produce hydrogen, thereby inducing reductive dechlorination. This technique is applicable to concentrations ranging from less than 1 µg/L to 1 mg/L.
Permeable Reactive Barrier (PRB)	Groundwater	1,2,3-TCP has been shown to be reduced by zero-valent iron. Therefore, the application of permeable reaction barrier (PRB) technology may be a viable approach to remediation of a shallow 1,2,3-TCP plume (Focht and Gillham, 1995; Vidic and Pohland, 1996). Others have described the feasibility of using a PRB for remediation of 1,2,3-TCP in groundwater (USEPA, 1998). EnviroMetal Technologies, Inc. (ETI) has performed bench column testing to treat 1,2,3-TCP in groundwater. Treatability testing involved water from a site in California and use of a 100 percent commercially available granular iron supply. The influent concentration of 437 µg/L 1,2,3-TCP declined to non-detectable

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TABLE 6-1
Remediation Approaches for 1,2,3-TCP Contamination

Approach	Media	Description
		concentrations during a 12-hour residence time at room temperature (ETI, 2005). Based on this testing, ETI is recommending the application of a granular iron PRB to treat 1,2,3-TCP groundwater contamination. Given the depth to groundwater in SGV Area 3 (275 to 300 feet bgs), a PRB could not be installed via a trench, but would likely need to be installed by injecting the materials into the subsurface via closely spaced wells.
In Situ Biodegradation	Groundwater	1,2,3-TCP was not readily biodegradable in aerobic biodegradation tests and is only slowly transformed by bacteria under aerobic and anaerobic conditions (World Health Organization [WHO], 2003). Bosma (2002) has genetically engineered a strain of bacteria that can utilize 1,2,3-TCP as a food source. However, the microbial activity is insufficient to sustain bacterial growth. Peijnenburg, et al. (1998) observed the reductive dehalogenation of 1,2,3-TCP in anaerobic sediments. See Appendix A for additional discussion of 1,2,3-TCP biodegradation.
SERDP Initiatives	Groundwater	The U.S. Department of Defense~~'s~~ Strategic Environmental Response and Development Program (SERDP) sponsors initiatives for innovative remediation approaches. The SERDP currently (April 2005) has a project (CU-1457) listed on their website (http://www.serdp.org/research/Cleanup.html) ~~which~~ that involves investigating prospects for remediation of 1,2,3-TCP by natural and engineered abiotic degradation reactions.

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It should be noted that the effectiveness of the remediation approaches presented in Table 6-1 at the low (about 0.400 un~~n~~g/L or less) 1,2,3-TCP concentrations observed in SGV Area 3 has not been assessed at the present time. Such an assessment will require significantly more effort than expended in preparation of this interim guidance document.

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6.2 Treatment

Although treatment of 1,2,3-TCP in groundwater is underway at some contaminated sites in the U.S., only limited information regarding the technologies is available at this time. The initial screening of groundwater treatment technologies presented below was prepared based on experience at the San Fernando Valley Superfund Site (Area 1 - North Hollywood and Burbank), California.

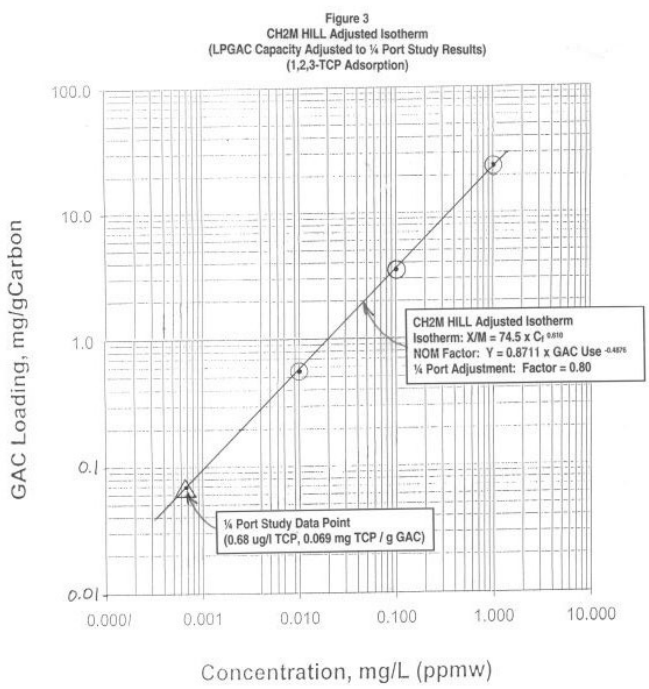
TABLE 6-2
Ex-Situ Groundwater Treatment Technology Screening for Removal of 1,2,3-TCP

Treatment Technology	Application Performance Opinion
Air Stripping	Poor
Liquid-Phase Granular Activated Carbon Adsorption	Very Good
Advanced Oxidation	Poor
Biological Reduction	Poor
Ion Exchange	NA
Reverse Osmosis	Fair
Zero Valent Iron Dechlorination	Fair

NA – Not applicable

Key Treatment Technology Discussion:

Ex-situ treatment using liquid-phase granular carbon adsorption (LGAC) is the technology that is in use for treatment of 1,2,3-TCP in groundwater at the San Fernando Valley Superfund Site (Area 1 - North Hollywood and Burbank), California. The isotherm figure to the right presents an isotherm developed for 1,2,3-TCP using site-specific rapid small small-scale column test data provided by Calgon Corporation and full-scale site data from the San Fernando Valley Superfund Site (Area 1 – North Hollywood and Burbank), California.



Typical LGAC vessel design flux (5 to 8 gallons per minute (gpm)/square foot) and empty bed contact time (10 minutes) assumptions are used. Treatment of 1,2,3-TCP using LGAC appears to have an unusually long mass transfer zone, which is defined as the bed (i.e., carbon inside the vessel) depth required to reduce a specific VOC from inlet concentrations to a target concentration. For most VOCs (e.g., TCE and PCE), the mass transfer zone needed to remove 99 percent of the inlet VOC mass may be about 1 to 2 feet of carbon bed depth. However, for 1,2,3-TCP it appears that the

mass transfer zone may be much longer, for example up to 5 feet of carbon bed depth. This, in turn, results in earlier breakthrough (and higher carbon use) compared to most other common VOCs.
~~Typical LGAC vessel design flux (5 to 8 gallons per minute ([gpm])/square foot) and empty bed contact time (10 minutes) assumptions are used. Treatment of 1,2,3-TCP using LGAC appears to have an unusually long mass transfer zone, which results in earlier breakthrough than most common VOCs (e.g., TCE and PCE)~~.

Advanced Oxidation

The HiperOxidation™ (HiPOx™) process has been in use for treatment of primarily m~~M~~ethyl ~~T~~tert-iary ~~B~~butyl ~~E~~ether (MTBE), with minor concentrations of 1,2,3-TCP, at the former Marine Corps Air Station (MCAS) Tustin ~~underground storage tank (~~UST~~)~~ Site 222 (Naval Facilities Engineering Command [NAVFAC], 2003). As of 2003, nearly 2,910 -pounds of MTBE and 1 pound of 1,2,3-TCP had been removed from groundwater at the former MCAS Tustin site. Based on experience at ~~the~~ former MCAS Tustin, the cost of operating the HiPOx™ treatment system is nearly three times the cost of operating an LGAC system for treatment of the 1,2,3-TCP groundwater contamination. Addition details on the operation of the HiPOx™ system for 1,2,3-TCP and other chlorinated solvents in groundwater is provided by Dombeck (2005).

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Appendices

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Appendix A
Chemical Properties/Environmental Fate and Transport

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Chemical Properties

1,2,3-Trichloropropane (1,2,3-TCP), which can be referred to using a variety of chemical names and identifiers (Table A-1), is a non-polar chlorinated alkane that is soluble in alcohol, ether, and chloroform and is slightly soluble in water. It dissolves oils, waxes, fats, chlorinated rubber and numerous resins. It is sensitive to prolonged exposure to light and heat. It is reactive with chemically active metals, strong caustics, and oxidizers. When heated to decomposition, it yields highly toxic fumes of carbon monoxide, carbon dioxide, hydrogen chloride, phosgene, and other chlorinated compounds. Table A-2 lists chemical properties of 1,2,3-TCP and how these properties relate to the behavior of 1,2,3-TCP in the environment.

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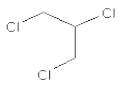

Chemical Structure:

TABLE A-1
Chemical Names and Identifiers

Item	Description	Comments
Synonyms	allyl trichloride	These may turn up during investigation into potential 1,2,3-TCP uses at Area 3 facilities/businesses
	glycerin trichlorohydrin	
	glycerol trichlorohydrin	
	glyceryl trichlorohydrin	
	trichlorohydrin	
	trichloropropane	
	1,2,3-TCP	
	TCP	

Identifiers	United Nations No.: 2810 Chemical Abstract System (CAS) Registry No.: 96-18-4 Chemical Hazard Response Information System (CHRIS): TCN Storet No.: 7743	These may turn up during investigation into potential 1,2,3-TCP uses at Area 3 facilities/businesses

TABLE A-2
Chemical Properties of 1,2,3-TCP

Property	Value	Reference	Environmental Efficacy
Molecular Weight	147.44 g	Verschueren, 1996	
Density at 20°C (Water = 1)	1.42 g/cm^3	Verschueren, 1996	More dense than groundwater, can act as DNAPL.
Boiling Point	156 °C	WHO, 2003	Liquid at room temperature
Melting Point	-14.7 °C	WHO, 2003	
Vapor Pressure at 25°C	3.1 mm Hg	ATSDR, 1992	Evaporates quickly at ambient temperatures; can be removed from surface water by evaporation.
Air Saturation at 20°C	16 g/m^3	Verschueren, 1996	
Relative Vapor Density (Air=1)	5.1	WHO, 2003	Vapor is more dense than air, can accumulate above the water table.
Henry's Law Constant at 25°C	2.8 to 4.4 mol/kg*bar	NIST database	Volatile, but does not volatilize as readily as PCE, TCE; moderate volatilization from either dry or moist soil to the atmosphere.
	22.83 Pa-m^3/mol	WHO, 2003	
	3.17 x 10^{-4} atm-m^3/mol	ATSDR, 1992	
Solubility at 25°C	1.75 g/L	WHO, 2003	Relatively insoluble, but up to 1,750 mg/L (1,750,000 μg/L) may be present in water.
Octanol/Water Partition Coefficient (log K_{ow})	2.54 (calculated) 2.27 (measured) 1.98	WHO, 2003 WHO, 2003 ATSDR, 1992	The low K_{ow} value indicates that 1,2,3-TCP is mobile in the environment.
Organic Carbon Partition Coefficient (log K_{oc})	68 98 (calc. from solubility)	NYSDEC (2005) Lyman, et al. (1982)	Is expected to display high mobility in soil, and therefore has the potential to leach into groundwater primarily as 1,2,3-TCP.

Table A-3 lists selected properties of 1,2,3-TCP relative to the properties of PCE, TCE, and 1,4-dioxane. Because PCE and TCE are the most prevalent VOCs in groundwater in SGV Area 3, comparison of the properties of 1,2,3-TCP to these VOCs can provide useful information in assessing the fate, transport, and treatment of 1,2,3-TCP in SGV Area 3.

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TABLE A-3
Chemical Properties of 1,2,3-TCP, PCE, TCE, and 1,4-Dioxane

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Based on the organic carbon partition coefficients, K_{oc}, shown in Table A-3, 1,2,3-TCP is more mobile in groundwater than PCE and TCE. The higher the K_{oc} value, the greater extent to which the chemical is adsorbed to organic material in the subsurface. Because 1,2,3-TCP has a lower K_{oc} value, it will adsorb to subsurface materials less than PCE or TCE and will travel closer to the same rate as the average groundwater velocity compared to PCE and TCE. In this manner, releases of these chemicals to groundwater should result in 1,2,3-TCP migrating further downgradient of a source compared to PCE and TCE. In addition the solubility of 1,2,3-TCP is higher than that for PCE and TCE, therefore higher initial concentrations in groundwater are possible. Vapor pressure and Henry's Law Constant values indicate that 1,2,3-TCP is more difficult to detect in soil gas than PCE and TCE and would be much more difficult to treat by air stripping. If present in vadose zone soil, 1,2,3-TCP will preferentially reside in pore moisture based on it's chemical properties. Once in the environment, 1,2,3-TCP is likely to be as resistant to aerobic degradation as PCE and/or TCE.

Environmental Fate and Transport

Abiotic Transformations

A calculated half life of 27.2 to 30.5 days for 1,2,3-TCP in the atmosphere has been reported. Therefore, 1,2,3-TCP released in the atmosphere might undergo very slow degradation in the presence of a sufficient concentration of photochemically produced hydroxyl radicals. Hydrolysis of 1,2,3-TCP in air appears to be of minor importance, with calculated half lives of 44 and 74 years (WHO, 2003).

Biotransformation and Degradation

In aerobic biodegradation tests, 1,2,3-TCP was not readily biodegradable. In a preliminary study, the co-oxidative transformation of 1,2,3-TCP by the ammonia oxidizing bacterium Nitrosomonas europaea was shown (Vanelli et al., 1990). More recent studies employing the methanotroph Methylosinus trichosporium demonstrated that 1,2,3-TCP is co-metabolized to a range of different chemicals, such as chlorinated propanols (Bosma and Janssen, 1998). However, attempts to isolate bacterial cultures that~~o~~ utilize 1,2,3-TCP as a sole source of carbon and energy have failed (WHO, 2003). Peijnenburg et al (1998) observed the reductive transformation of 1,2,3-TCP in anaerobic sediments, and determined that reductive dehalogenation was the sole reaction taking place. Anderson et al. (1991) reported a lack of biodegradation of 1,2,3-TCP in clay loam.

For soil fumigants containing 1,3-dichloropropene and chloropropanes, biodegradation appears to be much more significant for 1,3-dichloropropene than either 1,2-dichloropropane or 1,2,3-TCP. 1,3-Dichloropropene in the vapor-phase, will react with air, as well as volatilize, biodegrade, and hydrolyze in soils and surface waters. Once 1,2-dichloropropane and 1,2,3-TCP have entered the groundwater, further breakdown products are unlikely to be generated, because both compounds are resistant to hydrolysis and biodegradation.

1,2,3-TCP is not readily biodegraded and is only slowly transformed by bacteria under aerobic and anaerobic conditions. And, 1,2,3-TCP has not been shown to bioaccumulate.

Appendix B
Uses and Manufacturers

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Uses

1,2,3-TCP has been used as a solvent for hydrophobic compounds and resins, as a paint and varnish remover, and a degreasing agent up to approximately the 1950s and perhaps the 1960s. Another documented use of 1,2,3-TCP was as a "branching agent" in polysulfide polymers, which were used as sealants for aircraft fuel tanks and as a binder for rocket fuel (Kirk Othmer Encyclopedia of Chemical Technology, 2004). 1,2,3-TCP has also been used in a mixture with 1,3-dichloropropene and 1,2-dichloropropane as soil fumigants to control nematodes affecting agriculture. 1,2,3-TCP is currently used primarily as a chemical intermediate in the production of polysulfone liquid polymers and dichloropropene, synthesis of hexafluoropropylene, and as a cross-linking agent in the synthesis of polysulfides. It is also produced in significant quantities as a by-product of the production of other chlorinated compounds, including epichlorohydrin.

Solvent

1,2,3-TCP had been used in the past primarily as a solvent for paint and varnish removal, as a cleaning and degreasing agent, and as a cleaning and maintenance solvent. No current information is available to indicate that it continues to be used for these purposes (National Toxicity Program, 2005).

Soil Fumigants

Pre-1980's, agricultural use of chloropropane-containing soil fumigants for use as pesticides and nematicides was prevalent in the U.S. Some soil fumigants, which contained a mixture of primarily 1,3-dichloropropene and 1,2-dichloropropane, and in which 1,2,3-TCP was a minor component (e.g., trade name of D-D), were marketed for the cultivation of a variety of crops including: citrus fruits, pineapple, soy beans, cotton, tomatoes, and potatoes. D-D was first marketed in 1943, but is no longer available in the U.S., and has been replaced with Telone II, which was first available in 1956. Telone II reportedly contains as much as 99 percent 1,3-dichloropropane and up to 0.17 percent by weight of 1,2,3-TCP (Zebarth, et al. 1998). Before 1978, approximately 55 million pounds/year of 1,3-dichloropropene were produced annually in the U.S., and approximately 20 million pounds/year of 1,2-dichloropropane and 1,2,3-TCP were produced as by-products in the production of 1,3-dichloropropene. Over two million pounds of pesticides containing 1,3-dichloropropene were used in California alone in 1978. Telone II is still used for vegetables, field crops, fruit and nut trees, grapes, nursery crops and cotton.

Aircraft Fuel Tank Sealers

Another documented use of 1,2,3-TCP was as a "branching" or curing agent in polysulfide polymers (Kirk Othmer Chemical Encyclopedia, 2001). Polysulfide polymers have been used as the "standard sealant for virtually all aircraft fuel tanks and bodies" since the 1950s. Also, "one of the first large-scale applications of the liquid polysulfides was as a binder for rocket fuel," from 1946 until 1958. Kirk Othmer's (2001) tables list properties of a number of Morton Thiokol LP series of polysulfide polymer-based sealers, with concentrations of the branching agent (1,2,3-TCP) ranging from 0.5 to 2.0 percent. Liquid polysulfide polymers are used mainly as sealants, including for double paned windows, boat hulls and decks, printing rolls, integral aircraft fuel tanks, and aircraft bodies.

Chemical Intermediates

By the early 1980's, approximately 95% of chloropropanes were being used as chemical intermediates. Chemical intermediates are industrial chemicals that are used as the starting point to produce other chemicals. 1,2,3-TCP is currently used as an intermediate in the production of polysulfone liquid polymers, the synthesis of hexafluoropropylene, and as a cross-linking agent in the synthesis of polysulfides.

Polysulfone liquid polymers are used in the following industries: aerospace, automotive, consumer goods, electrical and electronic, health care, and in industrial equipment, such as compressor and pump valve components. Hexafluoropropylene is a fluorointermediate that is a key building block required to produce Teflon fluoropolymers and has applications in the agrochemical, electronics, dyes/pigments, pharmaceutical, and specialty polymer markets. Polysulfides are used as catalyst sulfidation agents and in the formulation of lubricant additives created for use in high~~extreme~~ pressure environments or applications~~functionality~~.

Manufacturers

1,2,3-TCP is manufactured as a stand-alone product in the U.S. It is also produced in significant quantities as an unwanted byproduct of the production of other chlorinated compounds such as epichlorohydrin, and is used internally by manufacturers as an intermediate in the production of other chemicals such as polysulfone and epoxy resins (see Table B-1 below).

TABLE B-1
1,2,3-TCP Manufacturing Information

Item	Description	Comments
Current U.S. Manufacturers	Dow Chemical Company, Freeport, Texas Shell Chemical Company, Deer Park, Texas	Primary source of 1,2,3-TCP in the U.S. and potential supplier for facilities or businesses in Area 3
Bulk Uses/Origins	External sale Unwanted byproduct of the production of other chlorinated compounds, including dichloropropene, propylene chlorohydrin, dichlorohydrin, glycerol, and especially epichlorohydrin Chemical intermediate	The majority (>80%) of the 1,2,3-TCP produced in the U.S. is a byproduct of epichlorohydrin production and is incinerated onsite (WHO, 2003). There are 20 to 30 epichlorohydrin facilities in North America, Europe, and Asia.
Production	U.S. annual production of 1,2,3-TCP in 2000 estimated to be 9,000 to 14,000 tons 50,000 tons of 1,2,3-TCP is produced globally as a byproduct of other chlorinated compounds (WHO, 2003)	
History	Production of chloropropanes (e.g., 1,2,3-TCP, 1,2-dichloropropane, etc.) for external sale starting to be curtailed by the early 1980's Chloropropanes were no longer sold for consumer use (as solvents) and, production of 1,2-dichloropropane (and 1,2,3-TCP) for agricultural use by DOW Chemical Co. was discontinued by 1983.	

Appendix C
Regulatory Levels

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A summary of regulatory levels for 1,2,3-TCP is provided below, followed by more detailed text descriptions.

TABLE C-1
Regulatory and Water Quality Levels

Regulatory Level	Agency	Concentration
Federal MCL	USEPA, Region 9	NA
California MCL	DHS	NA
California Notification Level	DHS	0.005 µg/L
Detection Limit for Purposes of Reporting (DLR)	DHS	0.005 µg/L
Preliminary Remediation Goals (PRGs)		
PRG – tap water (10^{-6} cancer risk)	USEPA, Region 9	0.0056 µg/L
PRG – tap water (noncancer risk)		30 µg/L
PRG – residential soil (10^{-6} cancer risk)		0.034 mg/kg
PRG – residential soil (noncancer risk)		71 mg/kg
PRG – industrial soil (10^{-6} cancer risk)		0.076 mg/kg
PRG – industrial soil (noncancer risk)		270 mg/kg
USEPA Risk Information (IRIS) Reference Dose as a Drinking Water Level	USEPA	42 µg/L
Drinking Water Health Advisory or Suggested No-Adverse Response Level (SNARL) for toxicity other than cancer risk	USEPA	40 µg/L

Notes:

NA – not applicable (standard does not exist)

California Notification Level

In May 1999, the California Department of Health Services (DHS) Division of Drinking Water and Office of Health Hazard Assessment announced an action level (now referred to a notification level [NL]) of 0.005 µg/L for 1,2,3-TCP. The NL is based on the categorization of 1,2,3-TCP as a probable human carcinogen, on the discovery of 1,2,3-TCP in groundwater at the San Fernando Valley Superfund Site (Area 1 - North Hollywood and Burbank), California, and over a concern that the chemical might find its way into public drinking water supplies.

UCMR Monitoring

In 2001, to obtain information about the presence of 1,2,3-TCP in drinking water sources, DHS adopted a regulation that included 1,2,3-TCP as an unregulated contaminant for which monitoring is required (UCMR). For this monitoring, DHS developed protocols for analytical methods for 1,2,3-TCP at levels comparable to the NL of 0.005 µg/L. Monitoring under the UCMR regulation was to have been completed by the end of 2003.

The adoption of these regulations occurred before the availability of a method capable of achieving 1,2,3-TCP's detection limit reporting (DLR) of 0.005 µg/L. Some utilities proceeded with monitoring, using laboratory analyses with higher DLRs. Unfortunately, findings of non-detect (ND) with a DLR higher than 0.005 µg/L do not provide DHS with adequate information needed for possible standard setting. DHS' Sanitation and Radiation Laboratory developed an adequate analytical method and some commercial laboratories are able to achieve the 0.005-µg/L DLR with either EPA method 504.1 or 551.1. Therefore, any utility with 1,2,3-TCP findings of ND with reporting levels of 0.010 µg/L or higher should perform follow-up sampling of representative sources for analysis using a method with a 0.005-µg/L DLR.

Notification of Exceedance of NL

A new law, effective January 1, 2005, requires that public water systems notify local governing bodies (i.e., city councils and county boards of supervisors) when NLs or MCLs for contaminants in drinking water supplies are exceeded. Even if notification occurred prior to that date under previous and different requirements, water systems should familiarize themselves with the new requirements for information to be provided in such a notice and determine whether a new notice should be provided to the governing bodies.

EPA Region 9 PRGs

EPA Region 9 publishes Preliminary Remediation Goals (PRGs) for guidance in performing site remediation, feasibility studies, and risk assessments. PRGs for 1,2,3-TCP are provided with cancer and non-cancer assumptions in Table C-1 (EPA Region 9, October 2004).

Appendix D
Occurrences of 1,2,3-TCP Environmental Contamination in the U.S.

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1,2,3-TCP may have been released to the environment as a result of its manufacture, formulation, and use as a solvent and extractive agent, paint and varnish remover, cleaning and degreasing agent, cleaning and maintenance agent, and chemical intermediate. Releases may occur as a result of disposal of products that contain the chemical or through agricultural land use applications of certain soil fumigants that are known to contain 1,2-dichloropropane and 1,2,3-TCP. In these instances, the fumigant was injected into the root zone, after which the soil was compacted to enhance retention of the vapor. Releases may have also occurred through the disposal of 1,2,3-TCP-containing sewage sludge from municipal sewage treatment plants.

1,2,3-TCP groundwater contamination has been detected at sites where the manufacture or use of 1,2,3-TCP containing chemicals occurred and at locations that used 1,2-dichloropropane as a soil fumigant (in which 1,2,3-TCP was an impurity). Information on the occurrence of 1,2,3-TCP at these sites may be of use in identifying and investigating potential sources in SGV Area 3 and is presented below.

Application of Soil Fumigants

Contamination of groundwater by 1,2,3-TCP as a result of soil fumigants has been observed in California, Hawaii, and British Columbia.

Central Valley, California

1,2,3-TCP groundwater contamination associated with the use of 1,2-dichloropropane as a soil fumigant was observed in the Central Valley of California (City of Shafter, 2000). In 1999, 1,2,3-TCP was detected in five of six active water supply wells at concentrations ranging from 0.02 to 0.11 µg/L (Howe, 1999). 1,2,3-TCP was found in groundwater from all wells where 1,2-dichloropropane was detected. Although 1,3-dichloropropene had been applied heavily (thousands of pounds per section), little to none showed up in groundwater from the Merced and Visalia DHS Districts. This was postulated to be due to fact that 1,3-dichloropropene, an unsaturated alk~~e~~ene, would be more easily biodegraded than 1,2-dichloropropane and 1,2,3-TCP, both of which are saturated hydrocarbons. In summary the presence of 1,2,3-TCP was positively correlated with 1,2-dichloropropane, but not with 1,3-dichloropropene.

The California Department of Pesticide Regulation advised that 1,2,2-TCP should also be analyzed where 1,2-dichloropropane and 1,2,3-TCP were detected in groundwater, as it is a byproduct of the manufacture of 1,3-dichloropropene.

Occurrence at Industrial Sites

San Gabriel Valley Superfund Sites, California

Specific sources of 1,2,3-TCP contamination in groundwater in the SGV have not been identified. However, based on results in EPA's San Gabriel Basin database, 1,2,3-TCP concentrations in groundwater at the Wynn Oil facility in the Baldwin Park OU have been as high as 46~~,000~~ u~~n~~g/L and 1,2,3-TCP has been detected in groundwater downgradient of the Wynn Oil facility at 10~~,000~~ u~~n~~g/L (beneath the Aerojet Electrosystems facility). 1,2,3-TCP was also detected in groundwater at the Spectrol Electronics facility in the Puente Valley OU at a concentration of 54~~,000~~ u~~n~~g/L. Because groundwater samples at these facilities were analyzed before mid-1995, confirmation sampling using more recent analytical methods (see Section 5) may be warranted. 1,2,3-TCP has also been detected in groundwater downgradient of the TRW Benchmark facility in the Puente Valley OU at up to 0.044 u~~n~~g/L (in October 2003).

Burbank Operable Unit Superfund Site, California

The use of 1,2,3-TCP for aircraft fuel tank sealers is suspected to be one of the sources of 1,2,3-TCP groundwater contamination in the Burbank OU at the San Fernando Valley Superfund Site (Area 1 - North Hollywood and Burbank), California. 1,2,3-TCP was detected in groundwater from 9 of the 39 monitoring wells in the Burbank OU, with concentrations ranging from 0.19 µg/L to 170 µg/L (Tetra Tech, 2003). The highest concentrations of 1,2,3-TCP occurred in samples collected from near the groundwater table. An area of 1,2,3-TCP groundwater contamination exceeding 0.1 µg/L, appearing to originate near the Burbank-Glendale-Pasadena Airport and extends approximately 5,000 downgradient, was generally defined. Lockheed Martin Corporation maintained operations numerous locations adjacent to the airport and had at least two tanks (3,000 and 12,000 gallons) containing aircraft fuel tank sealant at a facility (Plant B-5) south of the airport. At Lockheed Martin's B-6 plant, east of the airport, a small portion of the subsurface soil samples were analyzed for 1,2,3-TCP, and only one sample contained detectable 1,2,3-TCP (1,500 µg/kg at a depth of 50 feet bgs). The sample was collected close to a building previously used for testing of aircraft fuel system components at the B-6 plant.

Tetra Tech (2003) identified the Crane Company – Hydro-Aire Division, where aviation, aeronautical, and missile control systems were manufactured, as another potential source of 1,2,3-TCP in groundwater, presumably on the basis of 200 µg/L of 1,2,3-TCP being measured in a monitoring well at the facility. A soil gas survey was completed during 2003 at the Aeroquip Corporation facility, where assembly and distribution of industrial hoses occurred, in the Burbank OU (Tetra Tech, 2003). Groundwater from the Crane Company – Hydro-Aire Division monitoring well downgradient of this facility contained 200 µg/L 1,2,3-TCP, so the Aeroquip Corporation facility was thought to be a potential source of 1,2,3-TCP observed in groundwater. Fifty-four soil gas samples were analyzed for 1,2,3-TCP, however 1,2,3-TCP was essentially not detected in any soil gas samples above the detection limit of 1 µg/L. A trace concentration close to the method detection limit of 0.2 µg/L was observed in only one sample (Pavlick, 2005). Both the Crane Company – Hydro-Aire Division and Aeroquip Corporation facilities are located downgradient of Lockheed Martin's B-6 plant.

MacKenzie Chemical Works, New York

At the former MacKenzie Chemical Works Site in Central Islip, Suffolk County, New York, concentrations of 1,2,3-TCP up to 3,900 µg/L in lagoon water and up to 8,900 µg/L in offsite groundwater (600 feet downgradient) were observed, along with lower concentrations of TCE, PCE, and benzene, toluene, ethylbenzene, and xylene (BTEX) compounds (ATSDR, 2004). MacKenzie used the property from 1948 to 1987 for the manufacture of various chemical products, including fuel additives and metal acetylacetonates. MacKenzie stored 1,2,3-TCP in three 10,000-gallon tanks on the property. Other historical waste sources include aboveground storage tanks, leaking drums, waste lagoons, cesspools, and storm water drywells. The lagoons, cesspools, and drywells were sampled and found to contain contaminants attributable to facility operations, including 1,2,3-TCP at concentrations up to 20,400 µg/kg. Soil vapor concentrations of 1,2,3-TCP up to 60-2,200 µg/m^3 were detected onsite. EPA's selected a remedy for the site called for thermally-enhanced in situ soil vapor extraction (SVE) for soils contaminated with VOCs, limited excavation and offsite disposal for soils contaminated with semi-volatile organic compounds, demolition of a former laboratory building, and treatment of the groundwater using in situ air sparging with ozone injection.

Marine Corps Air Station (MCAS) Tustin, California

This former Marine Corps Air Station (MCAS) in Orange County, California was closed under Base Realignment and Closure (BRAC) and remaining contamination is being remediated prior to base reuse. The proposed plan for OU-1A (the area of TCE and 1,2,3-TCP groundwater contamination at the former MCAS Tustin) describes hydraulic containment with soil hot spot removal as the final remedy. The Department of the Navy is currently treating MTBE, the primary contaminant in groundwater, and 1,2,3-TCP, using in situ chemical oxidation. Pumped groundwater is being treated using the HiPOx treatment system. Both MTBE and 1,2,3-TCP are destroyed using ozone and hydrogen peroxide to create highly reactive hydroxyl radicals, which oxidize organic chemicals (See Section 6 for a discussion of the ongoing remediation). 1,2,3-TCP groundwater contamination at the former MCAS Tustin is associated with a former vehicle maintenance building, and degreasing or cleaning solvents used there may have contained 1,2,3-TCP (Werkmeister, 2005).

Tyson's Dump, Pennsylvania

The Tyson's Dump site, located in Montgomery County, Pennsylvania, is a four-acre abandoned sandstone quarry that was used to dispose of septic and chemical waste from 1962 to 1970. Waste disposal occurred in a series of unlined lagoons. In the 1970s, sludges and liquid wastes, primarily chlorinated and other organic solvents, were dumped into the lagoons (USEPA, May 2004).

Full-scale remediation of soils, bedrock, and groundwater is underway at the Tyson's Dump site. The cleanup involves in situ vacuum extraction in the silty clay soils of the former lagoons and surrounding area, which contains upwards of 250,000 mg/kg total VOCs and semivolatiles. The major contaminants of concern are 1,2,3-TCP, toluene, xylenes and dichlorobenzene, although there are also approximately 20 other compounds identified (See Section 6 for a discussion of the ongoing remediation).

Ciba-Geigy Superfund Site, New Jersey

Historic operations at the Ciba-Geigy Superfund Site in Toms River, New Jersey previously included the manufacture of dyes, pigments, resins, and epoxy additives. Sludges and process wastes were stored at a few locations around the former operations, resulting in groundwater contamination by many VOCs, including 1,2,3-TCP. Mean concentrations of the "north plume" at the site were 47 µg/L. The groundwater ROD prescribed a slurry wall, groundwater plume capture wells, a groundwater treatment plant, treated groundwater injection wells, a slurry wall, drum removal, and removal of contaminated soil (USEPA, September 29, 2000). The selected remedial alternative for the source areas at the site is on-site ex-situ bioremediation with off-site treatment/disposal of drummed material (USEPA, June 15, 2000).

The Ciba-Geigy site-specific pilot study performed from October 1999 to April 2000, revealed that ex-situ biological treatment reduced Chemicals of Concern (COCs) concentrations by greater than 90% and reduced the leaching of COCs by more than 99 percent. However, some COCs, such as PCE and 1,2,3 –TCP, did not respond to the aerobic biodegradation process.

RCRA Reported Releases

Known reported releases of 1,2,3-TCP into the environment during 2002 are summarized below (Scorecard website, 2005). Note that the great majority of these releases are to air. The only documented release to water was by Dow Chemical Company (4,225 pounds; not shown in Table D-1).

TABLE D-1
Reported RCRA Releases in the United States During 2002

Rank	Facility	Total Release in 2002 (Pounds)
1.	Deer Park Refining L.P., Deer Park, TX	84,859
2.	Dow Chemical Co., Freeport Facility, Freeport, TX	6,520
3.	Resolution Performance Products, Deer Park Plant, Deer Park, TX	5,330
4.	Resolution Performance Products L.L.C., Norco, LA	1,129
5.	Oxy Vinyls L.P. Deer Park, VCM Plant, Deer Park, TX	108
6.	Dow Chemical Co., Louisiana Div., Plaquemine, LA	57

Appendix E
Health Risk Information

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Human exposure to 1,2,3-TCP can occur from inhalation, ingestion of contaminated water, dermal contact with contaminated soil or water, and working in a facility where 1,2,3-TCP is used. 1,2,3-TCP can be measured in blood, urine, and breath. However, it breaks down quickly and leaves the body in breath, urine, and feces.

1,2,3-TCP causes cancer in laboratory animals (US EPA, 1997), which is the basis for the California DHS NL. It is reasonably anticipated to be a human carcinogen (NTP, 2005). In 1999, 1,2,3-TCP was added to the list of chemicals known to the state of California to cause cancer [Title 22, California Code of Regulations, Section 12000].

Health Effects

The main health effect from exposure to 1,2,3-TCP in both animals and people is damage to the respiratory system. Exposure to high levels (100 ppm) of 1,2,3-TCP for a short time can cause central nervous system damage, liver damage and eye, skin and throat irritation. Rats and mice died after breathing air containing 1,2,3-TCP. When swallowed at high levels, rats died from liver and kidney damage. At moderate non-lethal doses, rats had minor liver and kidney damage, blood disorders and stomach irritation. Animals that swallowed low doses for most of their lives developed tumors in several organs. When applied to the skin of rabbits, 1,2,3-TCP caused severe irritation, followed by injury to internal organs.

In the Eighth Report on Carcinogens (1998), 1,2,3-TCP is listed, for the first time, as a substance reasonably anticipated to be a human carcinogen. It is also listed in the Toxic Release Inventory (TRI) as an Occupational Health and Safety Administration (OSHA) carcinogen. However, the Department of Health and Human Services, USEPA, and the International Agency for Research on Cancer have not classified 1,2,3-TCP for carcinogenicity.