MCL Evaluation for Trichloroethylene (TCE)

California Department of Health Services
Division of Drinking Water and Environmental Management

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INTRODUCTION

Pursuant to the Calderon/Sher Safe Drinking Water Act of 1996 (SB 1307), the California Department of Health Services (DHS) has reviewed the maximum contaminant level (MCL) for trichloroethylene (TCE) for possible revision by conducting a cost-benefit analysis.

Currently, the MCL for TCE is 5 ppb, the reporting limit is 0.5 ppb, and the public health goal (PHG) is 0.8 ppb. Four TCE levels below the current MCL (0.8, 2, 3 and 4 ppb) were evaluated in terms of health risks and the costs of treatment and monitoring.

BACKGROUND

Trichloroethylene, commonly referred to as TCE, is a volatile, chlorinated hydrocarbon widely used as a solvent, paint stripper, and degreasing agent. Patterns of TCE contamination of drinking water generally parallel use patterns, with the highest levels and highest number of contaminated wells occurring in urban areas. Over 350 drinking water sources in California have reportable levels of TCE contamination (i.e., greater than 0.5 ppb). Systems with contamination exceeding the MCL are required to provide treatment that lowers TCE concentrations to levels below 5 ppb.

Cancer is the primary health concern from TCE exposure. Depending on the particular exposure scenario, animal study, and tumor site selected in the PHG risk analysis, the range of drinking water concentrations within *the de minimis* level (10^{-6}; one excess cancer case in one million people exposed over a lifetime of 70 years) ranges from 0.1 to 64 ppb. Since the 5 ppb MCL is within that range, it meets the acceptable risk level of 10^{-4} to 10^{-6} that Federal and State regulatory agencies use for establishing drinking water MCLs to protect public health.

DHS adopted the MCL of 5 ppb in 1989, based on the OEHHA risk assessment stating that it fell within the range of *de minimis* risk levels. The US EPA adopted the same MCL as DHS in 1991. Although the updated OEHHA risk assessment has not significantly changed from the initial assessment (the PHG of 0.8 ppb falls within the *de minimis* range), since the PHG is almost an order of magnitude lower than the MCL and TCE is still detected in some drinking water supplies, DHS has conducted a comprehensive review.

At the time that DHS adopted the MCL, it designated both packed tower aeration (PTA) and granular activated carbon (GAC) as the best available technology for removal. Subsequent experience has demonstrated that although air stripping is typically more cost effective than GAC, permitting difficulties with PTA make GAC a more viable option for many systems. For this reason, additional treatment costs are limited to GAC systems for the cost-benefit analysis. It is assumed that sources currently using PTA to meet the current TCE MCL would continue to use PTA and incur no additional cost for lowering of the MCL.

TCE MCL REVIEW PROCEDURE

The TCE MCL review was based on the "Procedure for Reviewing Maximum Contaminant Levels (MCLs) for Possible Revision" (see Appendix A). The past four years of TCE data from the Division of Drinking Water and Environmental Management compliance monitoring database (WQI) were used as the basis for the cost benefit analysis at the following levels: 0.8 ppb (PHG), 2 ppb, 3 ppb, and 4 ppb. The WQI database includes only public water systems that submit monitoring data to DHS. There is no data in the data base for private wells, since they are not regulated by DHS.

IDENTIFICATION OF AFFECTED SOURCES

Occurrence Data

Sources that reported TCE detects to the WQI database during the period of January 1996 through December 1999 were identified. Population and source data for each system were taken from the Permits, Inspections, Compliance, Monitoring, and Enforcement system information database (PICME).

Data Reduction

Only active sources were included in the analysis. Sources with "inactive", "abandoned", "destroyed", "standby", "monitoring", or "agricultural" designations were eliminated from the analysis. Also, monitoring data from within the distribution system and at the treatment plant were excluded since this data did not necessarily represent the water quality from a single source. For each active source, an average TCE concentration was calculated from monitoring data indicating detectable levels of TCE. Sources were then categorized based on the level of treatment required to comply with the proposed MCL levels (see *treatment costs* section).

Table 1 summarizes the distribution of public water systems, by county, with active TCE-contaminated sources. In most counties, the total number of systems affected is less than the number of sources shown in Table 1, since a single system may have more than one contaminated source.

Table 1
Distribution of TCE contaminated sources by county

County	*Number of TCE contaminated sources*	*County*	*Number of TCE contaminated sources*
Butte	5	Sacramento	9
El Dorado	1	San Bernardino	31
Fresno	14	San Diego	1
Kern	4	San Joaquin	4
Los Angeles	252	San Mateo	1
Merced	3	Santa Clara	1
Monterey	2	Santa Cruz	4
Orange	13	Solano	1
Riverside	24	Sonoma	4

CALCULATIONS

1) Health risks

Since TCE is considered a carcinogen, health benefits are estimated by calculating the incremental reduction in theoretical excess cancer cases avoided by a change in the MCL. The basic assumption for this analsys is that there would be a reduction of 1 excess cancer over a 70-year lifetime per 1,000,000 people exposed to 0.8 ppb less TCE in their drinking water. The following equation was used:

EC = ΔTCE conc x pop. exposed x 0.00000125

where: EC = Excess cancer cases due to 70 years of exposure to TCE , [Excess cancer cases per 70-year lifetime]
ΔTCE conc = Decrease in TCE concentration (ppb) to meet new MCL, [ppb]
pop. exposed = system population/ # of sources per system, [# of people]
0.00000125 = excess cancer risk per ppb of TCE calculated from the 1/1,000,000 risk per 0.8 ppb (PHG), [1 EC/ 1,000,000 people/ 0.8 ppb]

Excess cancer cases (EC) per year were estimated by dividing the results of the excess cancer case per 70-year lifetime by 70.

2) Treatment costs

Treatment cost estimates vary according to the level of treatment a system currently has in place and whether or not a source is considered an "affected source". An affected source is defined as one whose average TCE concentration exceeds the compliance criterion for a given MCL review level. Table 2 outlines the compliance criterion for each MCL review level, based on DHS' rounding policy.

Table 2
Compliance Criteria for Possible MCLs

Potential MCL (µg/L)	4	3	2	0.8
Criterion for Exceeding (µg/L)	>4.5	≥3.5	>2.5	>0.85

Treatment cost estimates are developed by categorizing sources as follows, based on available system/source data, and estimating costs as appropriate:

	contaminant level average	***current treatment***	***costs to be estimated***		
			capital	***O&M***	***monitoring***
1	≤ existing MCL criteria	none	x	x	x
2	≤ existing MCL criteria	nonBAT (installed for other contaminant)	x	x	x
3	≤ existing MCL criteria	BAT (installed for other contaminant)	-	-	x
4	> existing MCL criteria	BAT (installed for contaminant under review)	-	-	-

The assumption is made that a source in category 4 would experience no additional capital costs, while the increase in O&M costs would be relatively insignificant and the monitoring costs would stay the same.

GAC Capital Costs

Capital costs for treatment are based on EPA cost estimates for GAC (1989). Unit costs were adjusted to reflect present day values by assuming a 4.5% increase in cost per year since 1989. EPA capital costs include the following components: Site work, manufactured equipment, concrete, steel, labor, pipes and valves, electrical components and instrumentation, and housing. EPA estimates do not include costs of real estate, contractor overhead and profit, engineering and legal fees, administration, or special site work.

Table 3
GAC unit capital costs
(EPA, 1989)

Package-plant GAC adsorbers (<1 MGD)		*Conventional steel pressure GAC vessels (1-25 MGD)*	
System Capacity (mgd)	*Unit Cost ($/KGal)*	*System Capacity (mgd)*	*Unit Cost ($/KGal)*
0.1	1.88	1	0.50
0.2	1.16	2	0.41
0.3	0.92	3	0.36
0.4	0.76	4	0.33
0.5	0.69	5	0.31
0.6	0.66	10	0.28
0.7	0.59	15	0.26
0.8	0.56	25	0.25
0.9	0.53		

The design flow was based on an average daily demand of 150 gpd/capita multiplied by a peaking factor of 1.5. For each affected source, the design flow was calculated using the following equation:

Design flow = (source population) x (maximum daily demand)

where: source population = system population/number of sources
maximum daily demand = 1.5 x (150 gpd/cap)

The uniform annual capital costs were calculated using the capital recovery discount factor for discrete compounding (Lindeburg, 1997), assuming an 8% interest rate and a 30-year life of a GAC vessel.

Uniform annual cost = (Initial capital cost * $(1 + i)^n$ / $((1 + i)^n - 1)$

where: i = interest rate
n = life of GAC vessel

GAC O&M costs

O&M costs were based on a GAC usage rate of 0.0469 lb GAC/ KGal and a GAC replacement cost of $1/lb. Disposal costs for spent GAC, potentially costing $0.65/lb GAC, were not included in the O&M cost estimate. For purposes of this estimate, the GAC is assumed to treat 70% of its design flow. For each affected source, the O&M costs were calculated using the following equation:

O&M ($/Yr) =
(design flow, KGal/Yr) x (0.7 operation factor) x (0.0469 lb GAC/KGal) x ($1/lb GAC)

Monitoring costs

Monitoring costs were based on the sampling requirements for a system with newly installed GAC treatment and reflect the post treatment monitoring required in addition to the baseline source water monitoring (California Code of Regulations, Title 22, Chapter 15, Article 5.5, Primary Standards – Organic Chemicals). Disinfection byproduct (DBP) monitoring, specifically for trihalomethanes (TTHMs) and haloacetic acids (HAA5), is included in the monitoring costs since it will be required of GAC systems using chlorination. Table 4 summarizes the monitoring costs based on system size and average TCE concentration.

Table 4
Yearly Monitoring Costs per Source Exceeding an MCL

	TCE monitoring[1]		*DBP monitoring*	
	£4 ppb	*>4 ppb*	*<10,000 persons*	*>10,000 persons*
Additional samples required per year	15	12	1 HAA5 1 TTHM	4 HAA5 4 TTHM
Cost per year($)	1500	1200	175	700

SUMMARY OF ASSUMPTIONS

The following assumptions were used to facilitate the analysis:

1. Cancer is the primary health concern of TCE exposure
2. Active sources that exceed the MCL criterion based on average detected TCE concentration between January 1996 and December 1999 would need to treat with GAC to meet the MCL.
3. The number of theoretical excess cancer cases decrease linearly based on the following relationship derived from the PHG: 1 excess cancer per 1,000,000 people per 0.8 ppb change in TCE concentration per 70-year lifetime.
4. The number of people served by a drinking water source is equal to the total number people that the system serves divided by the number of sources in the system.
5. Average daily water demand = 150 gpd/person

6. Water demand peaking factor = 1.5
7. Although GAC and PTA are BAT for TCE treatment, GAC would always be the treatment method chosen for additional removal.
8. Sources treating with PTA treatment to meet the current TCE MCL and do not exceed a possible MCL criterion are not included in this estimate of GAC costs for compliance with possible MCL changes.
9. Systems treating with PTA for contamination other than TCE that exceed a possible TCE MCL criterion would opt to treat with GAC for TCE removal and incur capital, O&M costs, and monitoring costs.
10. Systems using GAC for compliance with a different organic would not incur additional capital or O&M costs for removal of TCE to meet possible TCE MCL criteria, but are assumed to require additional monitoring for TCE and DBPs.
11. Untreated sources that exceed a possible MCL criterion would incur the capital, O&M, and monitoring costs of GAC treatment.
12. Systems are operated at 70% of design capacity.
13. There has been a 4.5% annual increase in USEPA GAC cost estimates for annual capital and O&M costs since 1989.
14. The interest rate for the capital costs is 8%.
15. A GAC vessel has a 30-year life at which time, identical additional capital costs are required for replacement.
16. Systems with an average TCE concentration ≤4 µg/L are currently on a reduced baseline monitoring schedule of 1 sample/yr, while those with a TCE concentration >4 ppb are currently on a baseline monitoring schedule of 4 samples/yr.
17. Cost per analyses are: TCE sample = $100; HAA sample = $115; THM sample = $60.
18. GAC installation would include chlorination and thereby require DBP monitoring. (The DBP rule will not affect groundwater systems for another three years, but the monitoring costs are included, assuming that by the time a new MCL were in effect and a system installed treatment, the DBP rule would be applicable.)

SUMMARY OF IMPACTS

Tables 5 through 7 summarize the estimated cost impacts for each of the possible MCLs reviewed. Table 5 details the estimated costs that would be incurred for TCE-contaminated sources. Table 6 summarizes the cost-benefit analysis for each possible MCL by providing the total number of affected sources, the estimated reduction in theoretical excess cancer cases, and the estimated cost per theoretical cancer case reduced. Table 7 shows how the progressive lowering of MCL levels would affect the number of sources impacted in each county.

Table 5
Estimated Costs for All Affected Sources

MCL (ppb)	*No. affected sources*	*Capital Costs ($M)*	*Annual Amortized Capital Costs ($M)*	*Annual O&M and Monitoring Costs ($M)*	*Average Annual Cost per Source ($)*
4	15	1.6	0.1	0.9	68,000
3	31	3.1	0.3	2.1	77,000
2	61	6.7	0.6	3.4	66,000
0.8	215	24.3	2.2	8.1	48,000

Table 6
Estimated Costs vs. Theoretical Risks

MCL (ppb)	*No. affected sources*	*Estimated reduction in population exposed*	*Estimated annual reduction in excess cancer cases*	*Cost per cancer case reduced ($M)*
4	15	219,000	0.004	271
3	31	528,800	0.01	195
2	61	857,700	0.03	148
0.8	215	1,994,400	0.06	176

Table 7
Distribution by County of Sources Affected by a Lower MCL

County	*# TCE detects*	*# sources > 0.8 ppb*	*# sources > 2 ppb*	*# sources > 3 ppb*	*# sources > 4 ppb*	*# sources > 5 ppb*
Butte	5	4	0	0	0	0
El Dorado	1	1	0	0	0	0
Fresno	14	12	6	4	4	3
Kern	4	3	2	1	1	1
Los Angeles	252	204	112	90	75	68
Merced	3	2	0	0	0	0
Monterey	2	1	0	0	0	0
Orange	13	9	2	1	1	0
Riverside	24	21	9	7	7	3
Sacramento	9	5	0	0	0	0
San Bernardino	31	19	4	4	4	3
San Diego	1	1	1	1	1	1
San Joaquin	4	3	2	1	1	0
San Mateo	1	1	0	0	0	0
Santa Clara	1	1	0	0	0	0
Santa Cruz	4	4	2	1	0	0
Solano	1	1	0	0	0	0
Sonoma	4	3	1	1	1	1
Total Wells Affected	**374**	**295**	**141**	**111**	**95**	**80**

REFERENCES

1. California Department of Health Services Water Quality Management Database (CDHS WQI), Division of Drinking Water and Environmental Management.

2. California Department of Health Services Permits, Inspection, Compliance, Monitoring and Enforcement Database (CDHS PICME), Division of Drinking Water and Environmental Management.

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5. Lindeburg, M.R. 1997 Civil Engineering Reference Manual. Professional Publications, Inc. Belmont, CA. pp. 2.1–2.5

APPENDIX A. PROCEDURE FOR REVIEWING MAXIMUM CONTAMINANT LEVELS (MCLS) FOR POSSIBLE REVISION

August 1, 1999

Objectives: Pursuant to Health and Safety Code Section 116365(g), DHS is to conduct a comprehensive review of all factors related to a possible revision of an MCL, including changes in technology or treatment techniques that permit a materially greater protection of public health or attainment of the public health goal (PHG), and any new scientific evidence that indicates that the substance may present a materially different risk to public health than was previously determined.

Criteria for selection of MCLs for comprehensive review:
Subsequent to the establishment of a PHG, the following criteria will be used to determine whether or not to select the MCL for comprehensive review.

1. Is the PHG lower than the state MCL?
2. Have there been any changes in the risk assessment since the existing MCL was promulgated, pursuant to criteria above?
3. Have there been any changes in technology making contaminant removal more feasible and/or less expensive, pursuant to criteria above?
4. If contaminant is a carcinogen, was existing MCL set at a level associated with greater than a *de minimis* (one excess case of cancer in a million people exposed for a 70-year lifetime) risk?
5. Are there any significant trends in contamination levels indicated by recent occurrence data?

Procedure for comprehensive review:
The comprehensive review includes a cost benefit analysis that, to the extent possible, reflects the incremental costs and benefits that would be accrued if the MCL were to be revised to a more stringent level between the existing MCL and down to and including the PHG. The review also includes an evaluation of the feasibility of quantification at any levels that fall below the current reporting level. The steps are as follows:

1. Obtain drinking water source and system data to use in developing benefits and costs:
   (a) All available detection data on occurrence in drinking water in California for past 4 years from WQI (Division of Drinking Water and Environmental Management [DDWEM] compliance monitoring database) and local primacy agencies (LPAs); data should be chronological by drinking water source, within system, within county, whenever possible.
   (b) For each drinking water source---type, volume of water supplied, and the population served for each of the last four years (if available); if not available, then for each system--- type and number of sources, proportion of water supplied by groundwater vs surface water, total volume of water supplied for each of past four years, and population served. (If volume of water supplied is not available, estimate using population and 150 gallons/day/person.)

2. Establish a number of possible MCL levels (review points) ranging from the PHG up to the MCL, for purposes of developing an adequate cost-benefit curve.

3. Evaluate the feasibility of quantification at any review points that fall below the current reporting level (DLR).
   (a) Discuss available methods and method detection levels with Sanitation and Radiation Laboratory (SRL); contact members of Reporting Levels Workgroup (RLW) for input on feasibility of quantification at levels below DLR.
   (b) Eliminate from further consideration any review points that SRL and RLW agree are definitely not quantifiable within $\pm$ 20%; do not eliminate those that are borderline.

4. Develop a matrix of the contaminated drinking water sources, including highest contamination data point, the number of people served, and the estimated water flow in gallons per minute; order from lowest to highest contamination data point for easy division into ranges. A range consists of any level above the lower review point up through the next highest point; e.g., if the review points were 1, 2, and 3, then the ranges would be 1.5 up through 2.5, and 2.6 up through 3.4. (in conformance with Department policy on significant figures, which requires rounding to the nearest significant figure and that, the number 5 be rounded to the nearest even number).

5. Benefit determination, i.e., <u>theoretical</u> adverse health effects avoided. Note that this determination assumes that adverse health effects occur immediately on exceeding an MCL; this would <u>never</u> actually be the case, because the MCLs are always set with a significant margin of safety to ensure against that; but for purposes of this type of analysis, the MCL is used as the cutoff for immediate risk of adverse effect.
   (a) For carcinogens, determine the number of excess theoretical cancer cases avoided as a function of theoretical cancer risk, contaminant concentration, and population exposed at concentrations just above the review point up through the current MCL.
   (b) For noncarcinogens, determine the number of people exposed to the contaminant at concentrations just above the review point up through the current MCL; this number is an estimate of the number of people that would no longer be exposed to the risk of the adverse health affect.

6. Cost determination for removal treatment and additional monitoring incurred
   (a) Determine BAT to use in review
      1) Determine whether any new technologies for removal are available that could qualify as Best Available Technology (BAT) for review points (pursuant to Section 116370, H&S Code, requires proof of effectiveness under full-scale field applications for removing the contaminant to below the MCL, i.e., the review points in this case).
      2) Determine technical feasibility of using existing BAT to remove the contaminant to the level of each of the review points.
      3) Determine most cost effective treatment for use in estimating treatment costs (existing BAT or newly qualified BAT; a combination might also be most cost effective, e.g., one more cost effective in the lower concentration range, the other in a higher range).
      4) Develop/obtain cost curves to use in treatment cost estimate
   (b) Calculate incremental treatment costs
      1) For each source with contamination above a review point but not above the existing MCL, calculate treatment costs based on estimated source flow and contamination.

2) For each review point, sum the number of sources being treated and the treatment costs to determine total incremental costs for each point; also sum incremental costs for each system and the number of systems needing treatment.

(c) Calculate incremental monitoring costs

1) If a determination was made that quantification is feasible below the current DLR to accommodate a review point below that level, to the extent possible, estimate the number of sources that would be required to do follow-up quarterly monitoring if the reporting level were lowered, and determine the cost per source/year, as well as the number of systems involved and the costs per system/year. Sum costs for all sources/systems that would be impacted for each review point.
2) For a source with contamination above a review point but not above the existing MCL, calculate the cost of an MCL compliance determination (confirmation sample(s) + 5 additional samples within 6 months). Determine the number of sources/systems that would be required to do compliance determinations for each review point and sum the costs.

Evaluation of comprehensive review

Assess benefits versus costs for each review point. Consider the ratio of benefits to costs at each of the review points.