American Water Works Association

The Authoritative Resource on Safe Water SM

A REVIEW OF COST ESTIMATES

OF MTBE CONTAMINATION

OF PUBLIC WELLS

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Executive Summary

This report reflects an assessment of existing estimates of how much it will cost in the U.S. to address MTBE-contaminated water supplies for Public Water Systems (PWS). The intent is to ascertain whether existing estimates may be reasonably reliable. Our focus is the 2001 study by Komex H_2O Science, Inc. (a consulting firm; hereafter referred to as Komex).

Komex (2001) developed rough estimates of the cost imposed by MTBE contamination of groundwater. The Komex effort considered three cost-generating components: (1) LUST remediation, (2) treating contaminated drinking water at private wells, and (3) treating contaminated drinking water at wells serving Public Water Systems. Our review has focused solely on the latter component – the impact on PWS wells.

Our review reveals that Komex probably underestimated the costs of MTBE contamination at PWS wells. There are more PWS wells than Komex estimated, and the cost to treat an MTBE-contaminated well is probably much closer to the high-end value used by Komex than its low-end value (and the cost for treating many PWS wells may be far greater than the upper-end cost Komex applied).

Our assessment suggests that the cost of MTBE contamination of PWS wells is likely to be in the range of $4 billion to $85 billion. A "reasonable best estimate" of cost, given the limited data at hand, is on the order of $25 billion.

If the odor threshold for MTBE in water is less than the 5 ppb assumed in the Komex study, then the number of PWS wells impacted will increase significantly. At an odor threshold at 2 ppb or lower (as supported by scientific investigations), our reasonable best estimate increases to $50 billion or more and at 1 ppb or lower the cost could be as high as $85 billion.

S.1 Three Main Cost Elements Have Been Estimated

The Komex 2001 study developed cost estimates for three components of MTBE-related groundwater impacts:

1. The cost to treat PWS wells with MTBE above a taste and odor threshold

2. The cost to treat private wells with MTBE above the threshold

3. The cost to remediate groundwater related to leaking underground storage tanks (LUSTs).

Figure S.1 provides a summary of the Komex (2001) findings for each of the three cost components examined, with the total combined cost across all three elements of $31 billion to $141 billion (presumably in year 2000 dollars).

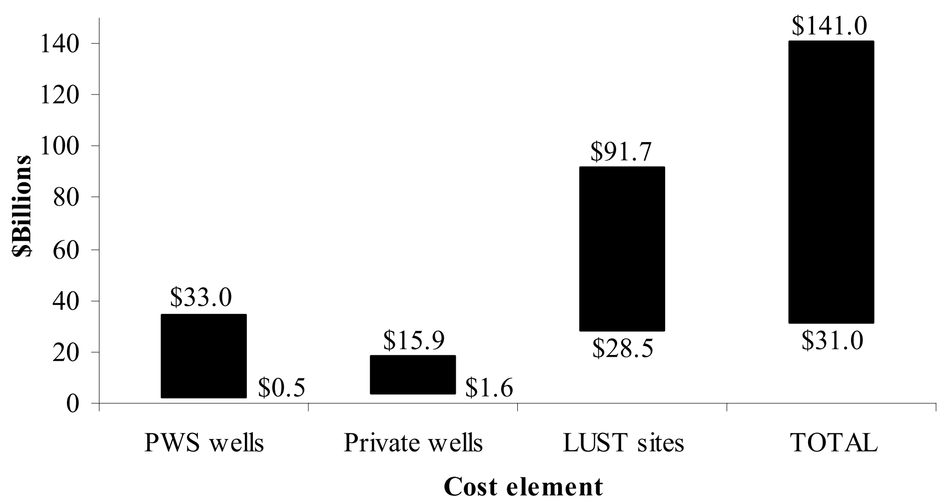

Figure S.1. Komex (2001) cost estimates for MTBE impacts on groundwater.

Note that the low end of the LUST-related costs – $28.5 billion – is probably the basis for the cost figure that has often been mentioned in connection with the potential size of MTBE-related impacts on groundwater. However, it is important to observe that this is simply the Komex low-end estimate for one of the three estimated cost components; the LUST-related costs do NOT include the cost associated with MTBE contamination of drinking water supply wells.

S.2 Focusing on the Cost to Treat Contaminated Public Water Supply Wells

In this report, we focus on one of the three cost components – the cost to treat MTBE-tainted drinking water at contaminated wells at PWS. The Komex estimate for this component ranged broadly, from $0.5 billion to $33 billion, and is derived from a very simple analysis for which only limited documentation is available for review.

The Komex analysis of PWS cost impacts is derived from three main elements:

1. The number of PWS wells. Here, Komex seems to have *underestimated* the number of wells in PWS, by at least 17%, and perhaps by quite a bit more.

2. The percent of PWS wells that will have MTBE at greater than or equal to 5 parts per billion (ppb). The empirical evidence on this issue is not definitive, but the range used by Komex appears to be a reasonable approximation. Available data on the percent of PWS wells currently documented with MTBE above 5 ppb is consistent with the lower half of the range used by Komex. However, a much higher percentage of PWS wells have detected MTBE. While many of these wells with detected MTBE currently have concentration levels below 5 ppb, in time the percent of wells with concentrations that reach or exceed 5 ppb could increase to the upper end of the range, or beyond. In addition, scientific evidence suggests that the detectable odor threshold for MTBE in water is considerably less than 5 ppb, implying that water suppliers may need to take action when their wells have concentrations as low as 2 ppb, or even less. This lower threshold for action will mean that MTBE removal costs will be incurred at a higher percentage of PWS wells than estimated for 5 ppb.

3. The cost to treat each PWS well. Here, it looks as if Komex may have *underestimated* the cost per well. The lower-end Komex estimate seems too low (e.g., based on what may be an atypically small well), whereas the upper-end cost per well used by Komex seems more reasonable. For some PWS wells, costs could be higher than the upper-end cost per well used by Komex, perhaps by a considerable margin. Also, there are costs typically associated with PWS well contamination in addition to the cost of treatment (e.g., the cost of testing, and the cost of obtaining replacement water until treatment is operable), and these costs are omitted from the Komex estimates.

On net, it appears as if Komex is likely to have underestimated the costs to treat MTBE-tainted PWS wells. Table S.1 provides a summary of the values used at the low and high ends of each step by Komex, as well as their final cost estimate. Also in Table S.1 is our updated reinterpretation of the Komex study, and our assessment of what may be a "reasonable best estimate" if the threshold for undertaking MTBE removal is 5 ppb.

On the whole, the Komex upper-end estimate of the costs of remediating PWS wells ($33 billion) probably is a much better number than its lower-end estimate and may be an underestimate. We believe the range is more likely to be on the order of $4 billion to $85 billion (see Figure S.2), with a "reasonable best estimate" of $25 billion (in year 2000 dollars) based on currently available information.

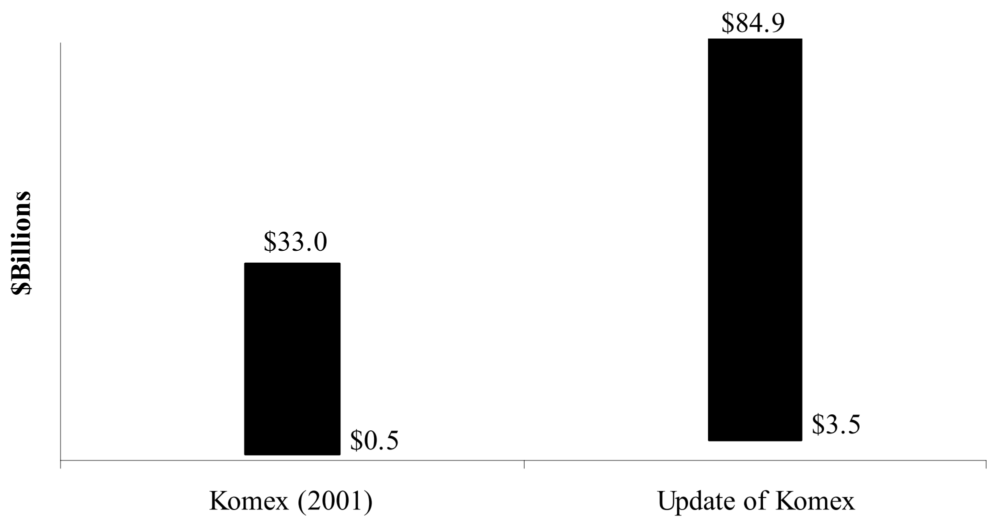

Figure S.2. Estimates of MTBE costs for treating PWS wells (5 ppb odor threshold, year 2000 dollars).

S.3 Sensitivity Analysis

A key factor in this cost assessment is the concentration at which MTBE in drinking water wells becomes a cause for mitigating action by the impacted PWS. In the discussion above, we have assumed that an MTBE concentration of 5 ppb would act as a threshold for PWS action because that is the threshold concentration applied by Komex, and because 5 ppb is the current odor-based Secondary Maximum Contaminant Level (SMCL) for MTBE in the State of California. However, as noted in the body of this report, scientific evidence suggests that a reasonably high proportion of tested consumers can correctly detect the odor of MTBE in water at concentrations far lower than 5 ppb. This will have a significant impact on the cost of MTBE contamination for PWS wells, because it will greatly increase the percentage of PWS wells at which treatment or other mitigating actions will need to be taken.

Available occurrence data suggest that the proportion of MTBE-impacted PWS wells requiring treatment would at least double (relative to the number at 5 ppb) if the MTBE odor threshold for many consumers is 2 ppb. The number of impacted wells requiring treatment probably would more than triple if the odor threshold is at or below the 1 ppb level. This would increase our reasonable best estimate of MTBE-related costs on PWS wells to at least $50 billion at an odor threshold of 2 ppb and perhaps as high as $85 billion for odor thresholds at 1 ppb or lower.

S.4 Other Factors to Consider

The estimates in Table S.1 and Figure S.2 above reflect only a portion of the potential impact of MTBE on groundwater, because we focus only on the cost to treat MTBE-tainted PWS wells (and we do not re-evaluate the cost impacts for LUST remediation or impacts on private wells).

In addition, there are many other potential costs – above and beyond drinking water treatment at tainted wells – that are imposed on the public from MTBE contamination of PWS source waters in the United States. These omitted costs include impacts on surface waters, and the cost of replacing tainted well waters until effective treatment is installed and operable. These and other cost elements omitted here may add appreciably to the total cost that MTBE will impose on American communities, as customers and owners of the nation's public water supply systems.

Table S.1. Derivation of MTBE cost estimates: Impacts on PWS wells only (5 ppb odor threshold)

Cost component step, per Komex approach	Komex study (2001)		Update/ reinterpretation		Reasonable best estimate
	Low	High	Low	High	
a. Step 1: Number of PWS wells	110,762[a]	137,695[a]	145,144[h]	193,042[h]	193,000
b. Step 2: % of PWS wells with MTBE ∃5 ppb	0.4%[b]	2.2%[c]	0.4%[i]	2.2%[i]	1.0%
c. *Number of PWS wells w/ MTBE ∃5 ppb* (c = a H b) i.e., # wells = Step 1 H Step 2	443.0[d]	3,029.3[d]	580.6	4,246.9	1,930.0
d. Step 3: Cost per PWS well to treat MTBE (in *millions* of year 2000 dollars)	$1.0[e]	$12.0[f]	$6.0[j]	$20.0[k]	$13.0
e. Result: Cost to remove MTBE at PWS wells (e = d H c) in *billions* of 2000 year dollars	$0.4[g]	$36.4[g]	$3.5	$84.9	$25.1

a. As reported in Komex (2001), for 50 states, based on USGS study that used SDWIS and personal communication with some state primacy agents.
b. As reported in Komex (2001), based on CA DHS 2001 study of 7,835 groundwater sources.
c. As reported in Komex (2001), based on USGS 2000 study of 1,190 CWS in 10 states.
d. Derived by simple multiplication, does not match Komex (2001) spreadsheet (range of 496.9 to 2,733.0), due to rounding and aggregation across states by Komex.
e. As reported by Komex (2001), based on aspects of a UC Davis study – not well documented and appears to be for fairly small well size (100 gpm).
f. As reported by Komex (2001), based on California MTBE Research Partnership study (2000), well documented work by Malcolm Pirnie Inc.
g. Derived by simple multiplication, does not match Komex (2001) spreadsheet (range of $0.5 to $32.8 billion), probably due to rounding # of wells, as per note d.
h. Low end is based on SDWIS (2005 draw of 2003 data) for number of groundwater PWS; high end is 33% greater to reflect multiple wells in some PWS, plus reflects the fact that mixed surface and groundwater-using PWS are not included in groundwater classification in SDWIS.
i. Limited available occurrence data, but these tend to fall within range used by Komex (2001). Results tend toward lower end of Komex range, but in some states the probability is higher than Komex upper end. Therefore, Komex range adopted here as reasonable, given lack of other data.
j. Low-end cost per well based on a mix of air stripping technologies (without any vapor phase controls) and granular activated carbon, for moderately sized wells (~350 gpm), allowing for some additional control costs.
k. High-end cost is higher than Komex (2001) estimate, to conservatively reflect PWS wells larger than 600 gpm (i.e., based on Granular Activated Carbon treatment for a 1,000 gpm well), and to help account for Komex omission of several cost-impacting factors beyond the cost of well treatment.

A REVIEW OF COST ESTIMATES OF MTBE CONTAMINATION OF PUBLIC WELLS

1. Introduction and Background

This report reflects an assessment of existing estimates of how much it will cost in the U.S. to address MTBE-contaminated water supplies for Public Water Systems (PWS). The intent is to ascertain whether existing estimates may be reasonably reliable or in need of revision and further investigation.

1.1 Objectives

The key objectives of this effort are to:

1. Review existing estimates of the costs of MTBE contamination of PWS wells, specifically, the estimate derived by Komex H_2O Science, Inc. (Komex) in 2001, to ascertain how accurate or flawed the results might be, and why.

2. Examine the data sources, methods, and assumptions used in the prior Komex study, and review readily available newer and/or better data and assumptions, to determine (in rough terms) how much and in what direction the existing cost estimates may be inaccurate. The intent is to gauge whether, in what direction, and (to the degree feasible in a preliminary review) how much each component of the Komex cost estimate may be in error. Ultimately, we try to assess whether, and by how much, the combined errors imply

the total cost estimates may be in error, and whether the true costs are likely to be higher or lower than the existing estimates.

1.2 An Overview of the Komex Study

In 2001, a consulting firm, Komex, developed analyses of the costs associated with MTBE contamination of groundwaters. Komex developed cost estimates for three groundwater cost components:

1. The cost of cleaning up Leaking Underground Storage Tank (LUST) sites.
2. The cost of treating water at MTBE-contaminated private wells.
3. The cost of treating water at MTBE-contaminated wells at PWS systems.

For each component, Komex developed spreadsheet models to derive cost estimates on a state-by-state basis, and then summed across states to obtain national cost estimates. The Komex results were as follows:

1. For cleaning up LUST sites: $28.5 to $91.7 billion
2. For private wells: $1.6 to $15.9 billion
3. For PWS wells: $0.5 to $33.0 billion.

The combined total thus ranges from *$31 billion to $141 billion*. These results presumably reflect estimated totals over a 30-year timeframe, and reflect year 2000 price levels. However, it is difficult to ascertain many key details because there was no report or other form of systematic documentation provided by Komex. Instead, Komex appears to have only produced the simple spreadsheets it used, supplemented by very abbreviated talking point notes. Some PowerPoint presentations by Komex staff also are available. Overall, the available Komex materials shed limited light on the basis for the estimates used or derived.

Even though the Komex cost estimates are based on very simple models and assumptions and are not fully documented, they have become the focal point for the national debate over the costs associated with MTBE contamination. A $29-billion figure is often cited with regard to MTBE-imposed groundwater costs, probably reflecting only the low-end estimate for LUST-related cleanup costs.

1.3 The Komex Study Component on the Cost of PWS Well Impacts

In this report, we focus solely on the PWS-related MTBE contamination cost estimate as derived by Komex. The Komex estimate ranges from $500 million to $33 billion, and is derived in three simple steps:

1. How many PWS wells there are in each state, and thus in the nation as a whole (Komex reports 110,762 to 137,695 across the 50 states)

2. The probability that a PWS well will be impacted by MTBE at a concentration of 5 µg/L[1] or higher (Komex uses available occurrence data to deduce that this probability ranges from 0.4% to 2.2%)

3. The treatment cost per well to remedy MTBE contamination (Komex believes the cost to range from $1 million to $12 million per well).

The results of the first two steps are multiplied to derive an estimate of the number of PWS impacted with MTBE at 5 µg/L or more. This estimate of MTBE-impacted wells (which Komex estimates to be in the range of 497 to 2,733) is then multiplied by the cost per impacted well, as derived in the third step. Based on this simple logic, Komex derives its final cost estimates. For example, for the low-end cost estimate, Komex multiplies 497 wells times $1 million per well to derive its estimate of $497 million).

The three sections that follow provide a discussion of each of these three steps in sequence. Section 5 then provides additional context by identifying other cost-impacting factors that need to be considered to estimate the full cost of MTBE impacts on PWS.

1. µg/L = micrograms per liter, and is often used interchangeably with parts per billion (ppb). A 5 µg/L odor threshold level was used by Komex, and is retained here for our review of the Komex findings. However, a lower odor threshold may apply (see Chapter 3), which could have a large impact on raising the cost estimates.

2. The Number of PWS Wells

The first step in the Komex estimate focuses on the number of wells used by PWS in each state. This section reviews the data Komex used and the results obtained. We then compare the Komex numbers to those derived from a more recent look at the most relevant data source. We conclude that, in general, Komex underestimated the number of wells serving PWS in the U.S.

2.1 Review of Komex Data, Assumptions, and Results

Komex cites data from what appears to be an unpublished U.S. Geological Survey (USGS) study (Komex cites a personal communication from Marilee Horn, presumably a USGS employee, in 2001). We do not have the unpublished USGS study that Komex uses, but Komex notes that the USGS findings are based on the U.S. Environmental Protection Agency (EPA) Safe Drinking Water Information System (SDWIS) database.

SDWIS is the official database of PWS compiled by EPA, with input from state primacy agencies. It is the most complete and definitive source of up-to-date information on PWS, as it is used for regulatory permitting and compliance tracking under the Safe Drinking Water Act.

The Komex data reports a number of PWS wells per state. Then, Komex sums the state-level estimates to derive a reported national total of 110,762 to 137,695 wells serving PWS, in the 50 states.

2.2 Evaluation of Komex Inputs and Results

We queried the SDWIS database (the latest accessible version reflects data as of 2003) to see if the Komex results match what is available from the best data source available (and supposedly the same database that served as the basis for the USGS findings that Komex cites). We found that the number of wells was not explicitly available from a SDWIS query (this may reflect a security-related change instituted after 9-11-2001).

However, SDWIS does provide the number of groundwater-based PWS (U.S. EPA, 2005a), meaning that we can derive a count of how many PWS have at least one well. The results are approximately 145,000 PWS, which is 17% higher than the Komex estimate.

It is important to note that the SDWIS-based results of the number of groundwater-based PWS understates the number of PWS wells, for two key reasons. First, many PWS have more than one well (in some instances, a PWS may have dozens of wells). Second, the SDWIS classification of "groundwater" systems excludes those PWS that use some mix of both surface water and groundwater (i.e., these "mixed systems" are reported only under the surface water category). Thus, our findings, even though they exceed Komex's estimate by 17%, under-count PWS wells because Komex omits groundwater-using mixed systems, and because many groundwater-using PWS have more than one well.

2.3 Conclusions about Potential Accuracy of Komex Findings

The SDWIS data suggest that Komex underestimated the number of PWS wells in the U.S., perhaps to a significant degree. SDWIS data show that the *number of PWS using groundwater exclusively* exceeds the Komex estimate of *number of PWS wells.* A summary of our findings, compared to the Komex study results, are shown in Table 1.[2]

Table 1. Comparison of Komex well counts and SDWIS groundwater PWS counts

	KOMEX	SDWIS (2003 #s)	Difference (Komex-SDWIS)
Alabama	1,056	417	639
Alaska	1,717	1,337	380
Arizona	2,274	1,442	832
Arkansas	896	705	191
California	13,186	6,488	6,698
Colorado	1,955	1,569	386
Connecticut	1,377	2,924	(1,547)
Delaware	610	501	109
District of Columbia	0	–	–
Florida	3,532	6,328	(2,796)
Georgia	2,878	2,268	610
Hawaii	410	113	297
Idaho	1,228	1,969	(741)
Illinois	3,543	4,860	(1,318)

2. For some states, the Komex well number estimate exceeds the SDWIS PWS count. These values appear to occur for states where Komex contacted state or local officials rather than rely on the USGS data. The Komex results for these states may reflect the impact of the multiple wells per PWS, and/or mixed systems, in these states.

Table 1. Comparison of Komex well counts and SDWIS groundwater PWS counts (cont.)

	KOMEX	SDWIS (2003 #s)	Difference (Komex-SDWIS)
Indiana	3,091	4,364	(1,273)
Iowa	2,102	1,814	288
Kansas	814	745	69
Kentucky	295	260	35
Louisiana	2,893	1,556	1,337
Maine	566	1,900	(1,334)
Maryland	1,227	3,661	(2,434)
Massachusetts	1,627	1,504	123
Michigan	2,904	11,815	(8,911)
Minnesota	2,431	7,675	(5,244)
Mississippi	2,652	1,374	1,278
Missouri	2,451	2,475	(24)
Montana	1,135	1,803	(668)
Nebraska	1,737	1,302	435
Nevada	566	590	(24)
New Hampshire	1,187	2,127	(940)
New Jersey	2,476	4,019	(1,543)
New Mexico	2,168	1,242	926
New York	5,140	8,983	(3,843)
North Carolina	4,281	6,830	(2,549)
North Dakota	665	444	221
Ohio	2,989	5,148	(2,159)
Oklahoma	2,157	912	1,245
Oregon	1,541	2,365	(824)
Pennsylvania	5,010	9,433	(4,423)
Rhode Island	152	454	(302)
South Carolina	1,845	1,202	643
South Dakota	1,090	560	530
Tennessee	389	602	(213)

Table 1. Comparison of Komex well counts and SDWIS groundwater PWS counts (cont.)

	KOMEX	SDWIS (2003 #s)	Difference (Komex-SDWIS)
Texas	12,347	5,379	6,968
Utah	1,202	828	374
Vermont	841	1,223	(382)
Virginia	2,139	2,846	(707)
Washington	11,808	3,884	7,924
West Virginia	554	897	(343)
Wisconsin	2,608	11,373	(8,765)
Wyoming	490	634	(144)
Totals	**124,229**	**145,144**	**(20,915)**

The results shown in Table 1 understate the number of PWS wells. This is because there are PWS with more than one well, and because those PWS that use both surface and groundwater sources are not included in the SDWIS results shown in Table 1. Therefore, to develop a preliminary "more likely" estimate, we multiply the understated SDWIS results by 33% and consider this a high-end estimate. We use the SDWIS-based number of PWS that exclusively use groundwater as a low-end estimate, even though we know it reflects an underestimate of PWS wells.

2.4 Potential Next Steps to Bolster the Analysis

More refined and accurate estimates of the number of PWS wells may be derived from additional investigation of the SDWIS database and, perhaps, a review of data from primacy agents in key states (e.g., California, New Hampshire). This could confirm or refine the number of PWS using groundwater, either exclusively or in combination with surface supplies. This might also reveal more information of PWS well configurations – namely the number of wells in use at PWS, and the size of those wells (as noted later in this report, the production size of a well will have a potentially large impact on the cost of treatment).

A review of various regulatory analyses may also be useful to address the issues of the number of PWS that do have wells, and the number and size of those wells. For example, the AWWA and National Drinking Water Advisory Council review of the cost analysis developed by EPA for the arsenic MCL was one place where it was brought to light that "mixed systems" (i.e., those

PWS using some combination of both surface and ground waters) were not reflected in the SDWIS count of groundwater systems. There may have been follow-up analyses related to the arsenic rulemaking that would help us assess how many mixed systems really exist (and perhaps discuss the number of wells in such systems). Also, the Community Water System Surveys (CWSS) conducted periodically by EPA have sometimes provided data on numbers of wells per system, and these data have been examined in the context of estimating the costs of the radon and arsenic rulemakings under the Safe Drinking Water Act.

Therefore, a review of information noted above may shed valuable light on the number of PWS wells and, possibly, the sizing of these wells.

3. The Probability that a PWS Well has MTBE at 5 ppb or Higher

The second step in the Komex approach is to assign a range of probabilities that a PWS well will be impacted by MTBE at a concentration of 5 µg/L or higher.[3] This section considers Komex's data source and results, and then compares them with results from other available data sources. We conclude that the upper end of the range used by Komex may overestimate the current probability that wells are contaminated at elevated (> 5 ppb) levels, while the lower end of the range appears consistent with current findings. However, it is hard to evaluate and compare the data because some available information refers to *water systems* [PWS or community water systems (CWS)] with elevated MTBE contamination, rather than *wells* at PWS. In addition, groundwater contamination is a dynamic process, and estimates based on limited past sampling may understate the true future magnitude of the problem.

It is important to note here that our primary analysis is based on the Komex use of 5 µg/L as the MTBE concentration at which water suppliers would need to take action at contaminated drinking water wells. However, if the odor-based threshold concentration for PWS action at MTBE-contaminated wells is less than 5 µg/L, then this will impact the probability that a PWS well will require treatment. We provide a sensitivity analysis at the end of this chapter to address the possibility that action may be required at wells with MTBE concentrations below 5 µg/L, based on scientific evidence that the odor threshold for consumers may be 2 µg/L or less.

3.1 Review of Komex Data, Assumptions, and Results

Komex cites two sources to develop a range of probabilities. The low estimate is from an ongoing survey of California groundwater sources conducted by the State of California Department of Health Services (DHS), with Komex using the data compiled as of 2001. The survey included 7,835 sources of PWS waters and reported that 0.4% of the sample had concentrations of at least 5 µg/L. Komex obtained the high estimate from a USGS survey of 1,190 CWS in 10 states. This study found that 2.2% of the CWS wells in this survey had MTBE concentrations of at least 5 µg/L.

3. The concentration of 5 µg/L is used here as an odor threshold, based on its use in Komex (2001) and its adoption by the State of California as a secondary MCL to protect the taste and odor of drinking water. The California MCL is in turn based on a study by Shen et al. (1997), in which MTBE odor was detected at levels as low at 2.5 µg/L in water (the lowest concentration tested).

3.2 Evaluation of Komex Inputs and Results

It is difficult to find data to assess or update the estimates applied by Komex. We looked at four MTBE occurrence studies, three national and two state-wide, and used data from these studies to establish a reasonable range.

First, we looked at a more recent USGS survey, completed in 2002, after the Komex estimates were calculated (USGS, 2003). This survey sampled 954 CWS in 50 states and found 0.5% of all sampled systems and 0.3% of groundwater samples contained MTBE of at least 5 µg/L.

We also looked at data compiled by the Environmental Working Group (EWG) of voluntary PWS reporting data from 29 states (EWG, 2005). The reports included data from both surface and groundwater systems, so we adjusted the number of results above 5 µg/L by the proportion of systems in the state that use groundwater sources. These results are in Table 2.

Table 2. EWG voluntary monitoring results

	# systems ≥ 5 ppb	% GW source	Pr (≥ 5 µg/L), based on EWG report
Alabama	5	59%	0.70%
Alaska	0	84%	0.00%
Arkansas	2	63%	0.18%
California	53	86%	0.70%
Delaware	3	99%	0.60%
Florida	2	99%	0.03%
Illinois	11	87%	0.20%
Indiana	4	97%	0.09%
Iowa	3	92%	0.15%
Maine	6	96%	0.30%
Maryland	32	97%	0.85%
Massachusetts	40	89%	2.37%
Michigan	6	97%	0.05%
Minnesota	12	99%	0.15%
Missouri	8	91%	0.30%
Nebraska	1	95%	0.07%
Nevada	2	95%	0.32%
New Hampshire	60	97%	2.75%
New Jersey	77	98%	1.87%
New Mexico	4	94%	0.30%
New York	61	88%	0.60%

Table 2. EWG voluntary monitoring results (cont.)

	# systems ≥ 5 ppb	% GW source	Pr (≥ 5 µg/L), based on EWG report
Ohio	1	92%	0.02%
Oklahoma	3	56%	0.18%
Pennsylvania	12	94%	0.12%
Rhode Island	8	95%	1.67%
South Carolina	2	85%	0.14%
Texas	11	82%	0.17%
Virginia	14	88%	0.43%
Wisconsin	8	100%	0.07%

The average probability of finding MTBE concentrations of at least 5 µg/L for PWS in these states is 0.5%. The USGS survey found more detects in surface water than in groundwater (14% vs. 5.4%), but the adjustment we made to these EWG numbers assumes that surface and groundwater systems are equally likely to be contaminated by MTBE. Therefore the average of 0.5% may overestimate the actual probability for this sample for groundwater only.

The third national study we reviewed was the U.S. EPA (2005b) summary of data collected as part of the Unregulated Contaminant Monitoring Rule (UCMR). The UCMR data on MTBE reflect sampling at 1,859 groundwater-based PWS (96% of which were CWS). The sampled systems consist of all larger groundwater-based PWS in the U.S., plus a representative sample of smaller systems. At a detection limit of 5 ppb, the EPA data reveal 14 out of 1,859 relevant PWS systems had MTBE at one or more wells (U.S. EPA, 2005b). Thus, 0.75% of these public water *systems* had MTBE above 5 ppb in at least one well. Since many of these PWS have more than 1 well, a higher percentage of PWS *wells* may have MTBE at 5 ppb or higher.

The two statewide sampling studies we reviewed also included PWS with both surface and groundwater. Therefore, their results may reflect likely upper bounds for the currently detected rates of MTBE contamination in groundwater. We looked at updated data from the California DHS study that Komex originally used (CA DHS, 2005). In this sample of 13,300 sources (both surface and groundwater), 0.7% had MTBE levels of at least 5 µg/L. The State of Florida Department of Environmental Protection has also been monitoring PWS since the early 1990s. Of 1692 sources sampled, 0.5% had MTBE concentrations of at least 5 µg/L (FL DEP, 2004).

Table 3 summarizes the contamination probabilities from these five studies. These results are consistent with the lower portion of the Komex range.

Table 3. Range of contamination probabilities

Study	Pr (≥ 5 μg/L)	PWS source
USGS	0.3%	GW (CWS only)
EWG	0.5%	GW and SW
EPA	0.8%	GW (PWS)
CA DHS	0.7%	GW and SW
FL DEP	0.5%	GW and SW

3.3 Conclusions about Potential Accuracy of Komex Findings

Given the range of probabilities in the reviewed studies, and the fact that several of these numbers may be a high estimate due to the inclusion of surface water, it is likely that Komex, at the high end of its range, may have overestimated the current probability of contamination of PWS wells having MTBE at concentrations of at least 5 μg/L.

At the same time, the available groundwater data reflect a very static view of MTBE contamination at PWS wells. The data collection efforts are not very extensive, and they reflect a snapshot at one point in time. The data do not reflect the dynamic nature of groundwater contamination. As time passes, it is likely that future leaks, spills and/or continued movements of existing MTBE plumes in groundwater will lead to more wells having MTBE contamination at levels of concern. In some states, the probability of PWS having MTBE above 5 ppb is already at or above the Komex upper end value of 2.2% (see Table 2). Also, it is worth noting that in some states the number of PWS wells with detected levels of MTBE is approaching or in excess of 15% (Delzer and Ivahnenko, 2003). While PWS wells with detected MTBE may not all currently display MTBE concentrations above 5 ppb, there is a chance that the concentrations may increase over time as plumes grow and move through aquifers.

Therefore, based on the limited available information and the dynamic nature of groundwater contamination, we believe the Komex (2001) range – of a 0.4% to 2.2% probability of MTBE contamination of PWS wells at 5 ppb or greater – may reflect a reasonable projection. Therefore, we retain this range in our preliminary assessment. Because existing data, though static and limited in sample size, tend toward the lower end of the range, we suggest using a 1.0% probability as a reasonable best estimate at this time.

3.4 Potential Next Steps to Bolster the Analysis

Estimating MTBE contamination probabilities for PWS wells is perhaps the most difficult and uncertain component of this cost analysis. Some options that might bolster or improve the existing estimates would be to examine estimates of groundwater-only PWS contamination probabilities where these might be obtained by cross-referencing statewide monitoring data with PWS inventory data. A number of other states have also been monitoring MTBE occurrence in PWS, and results from these surveys would give us a richer understanding of national PWS contamination probabilities.

3.5 Sensitivity Analysis for Odor Threshold

A key factor in this assessment is the concentration at which MTBE in drinking water wells becomes a cause for mitigating action by the impacted PWS. In the review above, we have assumed that an MTBE concentration of 5 ppb would act as a threshold for PWS action because that is the threshold concentration applied by Komex, and because 5 ppb is the current odor-based regulatory standard (Secondary Maximum Contaminant Level, SMCL) for MTBE in the State of California.

However, scientific evidence suggests that a reasonably high proportion of tested consumers can correctly detect the odor of MTBE in water at concentrations far lower than 5 ppb. For example, Shen et al. (1997) found that MTBE odor was detected at levels as low at 2.5 μg/L in water. Because this was the lowest concentration tested, it is possible that MTBE could be detectable at concentrations below 2.5 ppb. Stocking et al. (2001) conducted odor detection experiments using a test panel of 50 consumers. They found that nearly 20% of the panelists correctly identified MTBE in water at concentrations of 2 ppb (the lowest level tested). Assuming a log normal distribution, the authors convert this result to a detectable threshold of 1.4 ppb.

To the extent that the odor threshold for MTBE in a reasonable proportion of the consuming public is at a level of 2 ppb (or, perhaps, less), then this will have a significant impact on the cost of MTBE contamination for PWS wells. This is because a lower odor threshold increases the percentage of PWS wells at which treatment or other mitigating actions will need to be taken.

Occurrence data on MTBE concentrations in PWS is summarized in Table 4, reflecting monitoring data assembled from 29 states by the EWG. As of 2003, four states (California, New Hampshire, New Jersey, and New York) had required monitoring and set state MCLs for MTBE (Delzer and Ivahnenko, 2003). Therefore, the samples reported in the EWG report for these states are more likely to be statistically random and representative of actual contamination levels in these states. The data in Table 4 suggest that the proportion of MTBE-impacted PWS wells requiring treatment would at least double (relative to the number at 5 ppb) if the MTBE odor

Table 4. Percent of PWS with MTBE at various concentrations

	% of PWS with MTBE at levels exceeding:				Ratio of % PWS above threshold, to % PWS ≥ 5 ppb			
	5 ppb	**2 ppb**	**1 ppb**	**Detection**	**5 ppb**	**2 ppb**	**1 ppb**	**Detection**
All States	0.53	1.09	1.82	2.21	–	2.1	3.4	4.2
CA, NH, NJ, NY	1.48	3.17	4.82	6.71	–	2.1	3.3	4.5

Source: EWG, 2005.

threshold for some consumers is 2 ppb. These data also suggest that the number of impacted wells requiring treatment would more than triple if the odor threshold is at the 1 ppb level. This implies that a reasonable best estimate of the proportion of PWS wells requiring treatment may double or triple, from 1.0% (as discussed above) to a level in the range of 2.0% to 3.0%, or higher. This would increase our reasonable best estimate of MTBE-related costs on PWS wells to at least $50 billion at an odor threshold of 2 ppb and perhaps as high as $85 billion for odor thresholds at 1 ppb or lower.

4. Cost per MTBE-Contaminated PWS Well

The third step in the Komex approach assigns a range of treatment costs per well, where treatment is designed to remove MTBE effectively to suitable concentrations. There are many factors that impact the cost to treat MTBE-contaminated water at a PWS well, and these factors need to be considered when evaluating the Komex estimates. These cost-impacting factors include:

1. The size of the well (e.g., in gallons per minute, gpm)

2. The treatment technology deployed to remove MTBE (e.g., GAC, aeration, advanced oxidation)

3. The influent level of MTBE (e.g., 10 µg/L, 100 µg/L, 200 µg/L)

4. The target for MTBE removal efforts (e.g., to below detection levels, or to less than the 5 µg/L benchmark used by Komex)

5. The presence of co-occurring compounds (e.g., tertiary butyl alcohol, or TBA, a production component of and degradation byproduct of MTBE)

6. The period over which treatment must be applied (e.g., a 30 year period)[4]

7. The interest rate applied to capital investments in treatment (e.g., 7% real rate)

8. How the well is operated (e.g., in an on/off drinking water production mode, or as part of a continuously operating plume management strategy).

Our scoping analysis does not allow us to investigate all these factors in any detail, but we raise them here to alert readers of the many factors that will significantly influence the cost per well of MTBE removal.

4. The period of treatment may be longer or shorter than 30 years, and depends on many case-specific factors including the size of the contaminant plume, the types and concentrations of constituents in the contaminant plume, local hydrological conditions, and the manner in which the well is operated. For periods shorter than 30 years, the total lifecycle treatment cost per well would be lower as there would be a fewer years in which annual operating expenses would be incurred (and the converse is true for periods greater than 30 years).

4.1 Review of Komex Data, Assumptions, and Results

Komex cites two sources to develop lower and upper bound estimates of the cost of MTBE removal treatment per well; a University of California Davis report (Fogg et al., 1998) for the lower boundary estimate and a California MTBE Partnership (2000) report for the upper boundary estimate. Each reference is discussed briefly in the following paragraphs.

Komex cites pages 25 and 60 of Fogg et al. (1998) as the basis of the $1 million per well cost estimate for MTBE removal from public wells. Examination of this document indicates that page 25 contains a table that provides information on estimates of the number of MTBE groundwater sites, but no cost information, while page 60 contains information on treatment costs associated with extraction, treatment, and disposal or reinjection, ranging from $250,000 to $1million per site. Komex presumably applied the upper end of this range to affected public drinking water wells. Fogg et al. (1998) do not provide any basis for these cost estimates; however, they do provide undocumented unit treatment costs (dollars per thousand gallons) ranging from $0.5 to $0.6/1,000 gallons using air stripping (presumably without off gas treatment) to $1.2 to $1.4/1,000 gallons for GAC/resin based treatment. Without knowing the production rate of the well, the length of time treatment is required, or the interest rate used for amortization, it is impossible to relate the unit costs to the overall treatment costs.

Komex's basis for the upper boundary estimate is much clearer. Specifically, Komex indicates that the $11 million per well value is based on the California MTBE Partnership (2000) estimate. This includes capital and operations and maintenance costs over a 30 year period, for granular activated carbon (GAC) adsorption with an influent level of 200 µg/L MTBE and a non-detectable effluent level of MTBE. Inspection of the Partnership report suggests that a 600 gpm well was used as the basis for the cost estimate. For this case, the unit cost is $1.15/1,000 gallons, with capital costs of $1,019,000, annual operations and maintenance (O&M) costs of $282,000, and total annual cost (annual O&M plus capital cost amortized at 7% for 30 years) of $364,000.

4.2 Evaluation of Komex Inputs and Results

The basis of the Komex assumptions on treatment costs were examined further to determine their reasonableness for a national cost estimate. This was easier to do for the upper boundary estimate, as its basis is more transparent than the lower boundary estimate.

The Fogg et al. (1998) citation for the lower boundary estimate is part of a report prepared by the University of California (1998), submitted in November 1998, entitled "Health and Environmental Assessment of MTBE: Report to the Governor and Legislature of the State of California as Sponsored by SB 521." Volume V.3 of the UC report is entitled "Cost and

Performance Evaluation of Treatment Technologies for MTBE-Contaminated Water" (Keller et al., 1998). Costs are presented as unit costs ($/1,000 gallons) for air stripping, GAC, advanced oxidation (UV-hydrogen peroxide and ozone-hydrogen peroxide), and hollow fiber membrane stripping (a variant of air stripping). The unit costs shown include capital cost amortized at 4% for 20 years plus annual O&M costs, but the capital costs and O&M costs are not broken out in this document. Costs were developed for systems with flows of 10 gpm (influent MTBE of 100, 500, 1,000, and 5,000 µg/L), 100 gpm (MTBE influent of 100, 500, 1,000, and 5,000 µg/L), and 1,000 gpm (MTBE influent of 100 µg/L only). Inspection of this evaluation suggests that Fogg et al. (1998) used unit costs for 100 gpm systems for air stripping and GAC technologies with MTBE in the 100 to 500 µg/L range. Selecting a 100 gpm well to represent all drinking water wells most likely underestimates the costs of treating affected wells.

The California MTBE Partnership (2000) citation for the upper-boundary estimate is for a 600 gpm system with GAC treating an influent MTBE concentration of 200 µg/L. This document also provides cost estimates for air stripping, advanced oxidation processes, GAC, and resin sorbents for flow rates of 60 gpm, 600 gpm, and 6,000 gpm, and MTBE influent concentrations of 20, 200, and 2,000 µg/L and effluent concentrations of 20, 5, or < 0.5 µg/L. Thus, a range of technologies, flow rates, and MTBE influent concentrations, and treated water goals are available for analysis. By selecting a moderate flow rate, influent MTBE concentration, and a technology that achieves non-detect concentrations efficiently, the upper range is reasonably representative for a drinking water well.

A major issue is whether 100 gpm and 600 gpm wells truly represent drinking water wells that can range from small wells (e.g., 20-50 gpm) to very large wells (2,000-3,000 gpm). The well size often reflects the size of the PWS. At Santa Monica, some of the MTBE-affected wells are over 2,000 gpm, while at South Lake Tahoe, affected wells range from 60 gpm to about 400 gpm, with one threatened well of 2,500 gpm capacity. This is a major issue that must be addressed if more accurate cost estimates are desired.

Another issue concerning the cost estimates is the treatment system capacity and the annual average flow treated. The unit costs in the references cited by Komex appear to assume that the average flow rate is equal to the well capacity. This is not usually the case for PWS groundwater systems, unless the well is being used to control the MTBE plume. Average annual flows are typically 30 to 50 percent of the well capacity, although there are exceptions.

Another factor that can adversely influence treatment costs is the co-occurrence of MTBE and TBA. We know of one site in California where over $2.8 million has been spent in five years for a 140 gpm system, that treats an average of 40 gpm. Thus, sensitivity analyses may be required to better understand treatment cost variability.

4.3 Conclusions about Potential Accuracy of Komex Findings

Our review of the basis of the Komex treatment cost estimates, coupled with our review of other readily available data on MTBE removal costs, suggests that:

- The low end Komex estimate probably is too low for treating most PWS wells
- The upper end Komex estimate may be a more reasonable cost figure for many moderately sized MTBE-impacted PWS wells
- There may be many PWS wells for which MTBE-related costs are higher than the Komex assigned upper bound cost, particularly if larger systems are impacted by MTBE.

Overall, the upper boundary is the more realistic of the two estimates.

4.4 Potential Next Steps to Bolster the Analysis

Improvements in the cost estimates depend largely on examining assumptions of PWS well sizes, the annual water production, influent MTBE concentrations, and treated water goals. The California MTBE Partnership (2000) cost estimates provide a robust enough basis for developing costs for modified well conditions. The costs from the UC report would be a useful comparison if the detailed basis for the costs can be obtained.

The following sensitivity analyses should be considered:

- Develop costs for various technologies and flow scenarios (different design to average flows)
- Develop costs for different treatment periods and interest rates
- Develop costs for a mixture of different MTBE concentrations and treated water goals that represent potential national picture.

In addition, it may be fruitful to examine in-field experiences and cost levels at PWS well sites where MTBE contamination has occurred and treatment options have been explored in some detail.

5. Other MTBE-Relevant Cost Factors Omitted from the Komex Approach

The preceding text reviews the basic elements of the Komex estimation approach and its results for MTBE costs for PWS wells. However, there are several elements and factors that are not considered in the Komex approach, and these add to the cost of MTBE contamination of PWS wells.

The key point here is that the Komex estimates only reflect the cost of treating PWS wells to reduce MTBE concentrations from 5 μg/L or higher to some acceptable level. There are other MTBE-related costs borne by PWS with MTBE-threatened wells, and these are not considered in the Komex assessment. These additional costs include:

1. The cost of pilot studies, groundwater investigations, permits, and other technical activities typically associated with MTBE contamination. The Komex costs only reflect the cost of treatment, once treatment is selected, equipment purchased, facilities constructed, and the system is up and running.

2. The cost of replacement water, for the period during which the well is shut down (or its use diverted to plume management purposes). These omitted costs reflect the impact of having a well shut down due to MTBE, as will typically occur until a suitable treatment approach is selected and fully operational. In Santa Monica, CA, for example, the cost of purchasing replacement water for MTBE-impacted wells is reportedly $300,000 per month ($3.6 million per year).

3. Where estimates of MTBE-impacted wells are based on contamination only from LUSTs, they will omit other potential sources of MTBE groundwater contamination, such as refinery operations, pipelines, fuel spills, and so forth.

4. The estimates do not reflect how MTBE contamination impacts surface water supplies of PWS. Surface water contamination by MTBE is not uncommon, and may arise from a number of causes (including fuels used, shipped, and/or and spilled by motorized vessels; and by groundwater interactions with surface waters).

5. The co-occurrence of degradation products and other contaminants along with MTBE, especially those also associated with motor fuels and, in the case of TBA, associated with MTBE itself. Co-occurrence often complicates and increases the cost of treatment.

6. The timeframe over which costs are incurred by PWS, and hence their customers, for dealing with MTBE-related contamination. The duration of costs may exceed the 30-year timeframe that appears to be embedded in the Komex approach.

At the same time, we need to acknowledge that some factors may help contain or even reduce MTBE-related costs on PWS. For example, if the phase down in MTBE usage continues and/or LUST releases become less frequent and/or better contained, then the future extent of MTBE contamination may decrease. This may be the case for surface waters. However, current data may suggest that contamination is more broadly observed now, especially in groundwater, even though MTBE use has dropped considerably and LUST performance and remediation have improved. Also, if advances in treatment processes reduce the cost of MTBE removal from drinking waters, then the costs may decline; however, considerable research in this field has not yet yielded much in the way of cost saving prospects.

6. Conclusions

Komex (2001) developed rough estimates of the cost imposed by MTBE contamination of groundwater. The Komex effort considered three cost-generating components: (1) LUST remediation, (2) treating contaminated drinking water at private wells, and (3) treating contaminated drinking water at wells serving Public Water Systems. Our review has focused solely on the latter component – the impact on PWS wells.

Our review reveals that Komex probably underestimated the costs of MTBE contamination at PWS wells. There are more PWS wells than Komex estimated, and the cost to treat an MTBE-contaminated well is probably much closer to the high end value used by Komex than its low end value (and the cost for treating many PWS wells may be far greater than the upper end cost Komex applied).

Our assessment suggests that the cost of MTBE contamination of PWS is likely to be in the range of $4 billion to $85 billion. A "reasonable best estimate" of cost, given the limited data at hand, is on the order of $25 billion.

If the odor threshold for MTBE in water is less than the 5 ppb assumed in the Komex study, then the number of PWS wells impacted will increase significantly. At an odor threshold at 2 ppb or lower (as supported by scientific investigations), our reasonable best estimate increases to $50 billion or more and at 1 ppb or lower the cost could be as high as $85 billion.

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