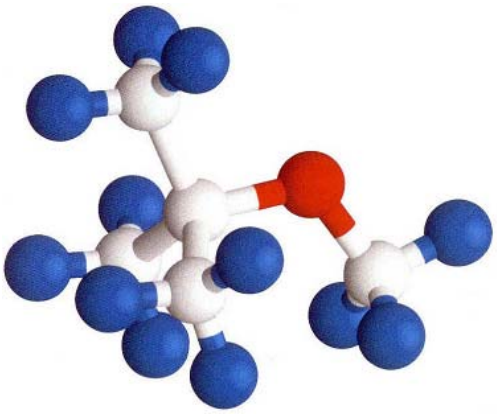
Water Quality Impacts of MTBE: An Update Since the Release of the UC Report



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Executive Summary

Occurrence of MTBE in Drinking Water in California. The UC report suggested that MTBE would contaminate a significant number of surface and ground water resources in California projected through the year 2010. Since 1998, several mitigation measures and a large amount of monitoring data indicate that future MTBE contamination of groundwater and surface waters in California is likely to be much less severe than predicted by the UC researchers. Recent monitoring data released by the California Department of Health Services (CalDHS) shows that MTBE detections in both surface water sources and public water supply wells have steadily decreased since 1998.

Declining Detections of MTBE in Groundwater from Public Water Supply Wells. At the time of publication of the UC report (1998), the number of MTBE detections in drinking water sources, both groundwater and surface water, was increasing fairly rapidly. Based on information available at the time, the UC report suggested that between 60 and 340 public drinking water wells would become contaminated by MTBE in the future, in addition to the 35 wells that had already been impacted for a total of about 100 to 400 public water supply (PWS) wells. In 1998, CalDHS monitored 2,988 public water supply wells for MTBE, representing 21% of the total public drinking water wells. Of these wells, 1.2% (35) contained detectable levels (greater than 1 to 5 ppb) of MTBE. The UC report therefore concluded that 1.2% of the entire population of untested wells could become contaminated in the future, using this as an upper bound estimate for future impacts of MTBE, in the absence of a ban on the use of the chemical. However, since 1998, and as more wells were tested, the percentage of newly contaminated wells decreased. For example, 7,981 sources were sampled in June 2001 and MTBE was only detected in 0.6 % of the wells tested. The percentage of new wells contaminated with MTBE between March 2000 and the present (June 2001) is 0.15 %. This number is approximately one order of magnitude lower than that used by UC researchers (1.2%). Using this new number, and assuming a total of 10,931 unsampled active public water supply wells in California, only 16 new wells are projected to be impacted compared to the UC estimate of 60 to 340 wells.

In addition, the UC report suggested that MTBE plumes will generally grow in length three to four-fold by 2010 compared to plume sizes in 1998 and could extend up to 7000 feet from the release points to impact a volume of groundwater over 100,000 acre-ft. This analysis also assumed that these plumes would not be actively remediated by responsible parties and that MTBE does not naturally biodegrade. Since 1998, MTBE has been shown to biodegrade under a

range of environmental conditions, both in laboratory samples and in the field. Several studies of MTBE plumes from other states suggest that many plumes are stabilizing and are not likely to expand indefinitely. In addition, for those MTBE plumes posing significant threats to groundwater supplies, active remediation is being initiated by responsible parties. Thus, the total volume of groundwater predicted by the UC Report substantially overestimates the probable future impacts.

Declining Detections of MTBE in Surface Water. The UC report suggested that surface water resources used as motorized recreational areas and drinking water sources would require treatment for removal of MTBE. Since 1998, the continued phase-out of two-stroke engines on many of California's drinking water reservoirs has greatly reduced the risk of MTBE contamination. In addition, since the publication of the UC report, several peer-reviewed studies were published which illustrated that MTBE will not persist in surface waters but will volatilize within a relatively short period (< 40 days). Finally, since 1998 only 5 new surface water sources have been identified as containing elevated concentrations of MTBE. In addition, since 1999, none of the monitored surface water sources had an MTBE concentration greater than 5 µg/L (CalDHS).

Cost Impacts. In an attempt to quantify the total costs to California's economy resulting from the continued use of MTBE in gasoline, UC researchers prepared a cost/benefit analysis of fuel alternatives. Much of the analysis performed was based on assumptions regarding the movement of MTBE in surface waters and in the subsurface, and the subsequent contamination of drinking water supplies. The key assumptions were as follows: **1)** no remediation of existing plumes, **2)** no biodegradation or adsorption of MTBE, **3)** current detection trends for public water supply systems should be extrapolated to 2010, and **4)** contamination of surface water sources would continue due boating use.

As discussed in this report, more recent data show that none of these assumptions is correct. Existing known plumes posing threats to water supplies are or will be remediated. Bioattenuation of MTBE plumes appears to be occurring at varying rates at multiple sites suggesting that many plumes are not likely to expand significantly from their current size. The frequency of detection of MTBE in public water supply wells is decreasing with time, and the frequency of detection in new wells recently sampled has decreased substantially compared to results reported prior to the UC study. Finally, the ban on 2-stroke engines has essentially eliminated the threat of MTBE to surface sources of water supply.

While this review did not attempt to reassess the UC cost analyses, it clearly reveals that a number of the costs reported by the UC report will be far less than predicted. For example, there will be no annual costs for loss of recreational use of surface water sources (estimated to be between $160 and $200 million). Monitoring costs should also be decreasing rapidly as the MTBE threat to surface water fades. Finally, drinking water costs will be less than predicted by the UC report because of fewer impacts to public water supply wells. No assessment of the incremental costs for remediation of underground tanks has been made in this analysis. However, new technologies, particularly in-situ biodegradation are likely to result in significant decreases in overall remediation costs for MTBE impacted sites.

Introduction

In March 1999, the University of California released a comprehensive evaluation of the health and environmental effects of the use of MTBE and other oxygenates in California entitled "Health and Environmental Assessment of MTBE: Report to the Governor and Legislature of the State of California as Sponsored by SB 521." The Report concluded that "on balance, there is significant risk to the environment from using MTBE in gasoline in California." In particular, the Report predicted that there was a significant threat to water quality in the State and that a large number of public water supply systems and private drinking water wells would be contaminated by the continued use of MTBE in gasoline. The findings of the report prompted the Governor to issue Executive Order D-5-99, which requires the complete removal of MTBE from gasoline sold in California by December 31, 2002.

Since the publication of the UC Report, several new studies and additional groundwater and surface water monitoring data in California, as well as other states in the U.S. have significantly improved the knowledge base on the behavior of MTBE in the aquatic environment. In addition, conventional and emerging soil and groundwater remediation technologies have been assessed for their effectiveness at remediating MTBE-impacted sites, and several of these technologies have been successfully applied at the field-scale level to remove MTBE from soil and groundwater.

Based on this new information obtained since the release of the UC Report, it is now possible to assess whether the assumptions made by the UC team are accurate or whether these assumptions, and subsequent conclusions regarding the future impacts of MTBE on water quality should be modified. This memorandum focuses on the following issues:

1. The implications of monitoring data since 1998 regarding MTBE in surface and groundwaters in California, and the likely overall future impacts on public water supply systems in California;
2. The implications of more recent findings regarding the fate of MTBE plumes in groundwater on the likelihood of future impacts to public water supply systems;
3. Remediation of MTBE-impacted soil and groundwater, and treatment technologies for the removal of MTBE from water.

The overall objective of this evaluation is to determine whether the assumptions made in the UC Report are still valid given the advances made in MTBE research and new monitoring data, and whether appropriate changes to those assumptions lead to different conclusions regarding the magnitude of the MTBE threat to public and private water supplies in California.

MTBE Occurrence in California: Statewide Drinking Water Detections, Groundwater Plume Lengths and Cost Impacts

Overview of Statewide Drinking Water Detections

The UC report concluded that the contamination of public and private drinking water supplies with MTBE in California was widespread and growing. However, at the time of the UC study, the available monitoring data on public water supply systems collected from 1995 to 1998 by the California Department of Health Services (CalDHS) indicated that only about 2% of all sampled drinking water sources had detectable levels (approximately 1 to 5 ppb) of MTBE. Most importantly, more recent monitoring data clearly show that the frequency of detections for MTBE has decreased as more public water supply systems have been sampled. Thus, predictions of future impacts based on extrapolation of monitoring data taken between 1995 and 1998 overestimate the likely impacts of MTBE on California public water supply systems, as is discussed subsequently in this memorandum.

In the UC report, researchers relied on drinking water monitoring data provided by CalDHS up to August of 1998. Although the UC report recognized that the percentage of drinking water sources with detectable levels of MTBE was low (about 1.2%), UC researchers predicted that there would be a significant increase in the number of drinking water sources impacted by MTBE in future years (assuming that the percentage of detections would remain the same indefinitely).

For the purposes of the analysis performed in the UC study, California's water supply was divided into surface water and groundwater sources. The UC report indicated that both sources are highly susceptible to widespread and long-term contamination by MTBE. This was a key assumption that formed the basis for overall conclusions regarding the future threats of MTBE to water supply systems. The more recent data strongly indicate that this assumption significantly overstates the future impacts of MTBE on public drinking water systems as will be discussed in detail in the next several sections.

Surface Water Sources

UC Report Conclusions. To quantify the adverse effects related to the use of MTBE-blended fuel in surface water recreational vehicles, UC researchers defined three distinct cost impacts related to surface waters. First, UC researchers stated that every surface water source used as both a motorized recreational area and a drinking water source would require treatment for the removal of MTBE. Second, the UC report suggested that as a result of this extensive MTBE contamination, recreational boating would be banned on all drinking water reservoirs thereby incurring significant costs associated with the loss of these recreational areas. Finally UC researchers predicted that water utilities would incur large incremental monitoring costs due to the usage of MTBE in gasoline.

Current Observations. Recent events and recent monitoring data do not support the worst-case assumptions made by the UC team. First, many water utilities have either banned or severely restricted the use of two-stroke engines on many of California's drinking water reservoirs. The criticism of the use of these highly polluting engines began well before 1995. Two-stroke engines are known to emit as much as 30% of their fuel directly into the water as unburned fuel (Bluewater Network). Consequently, recreational crafts with two-stroke engines were banned in at least nine high-profile public surface waters in California since 1998. These include Anderson and Calero Reservoirs, all waterways in Marin, Coyote Lake, Donner Lake, Lake Tahoe, Modesto Reservoir, and San Pablo Reservoir. Most of the other large reservoirs in California had either previously banned two-stroke engines or never allowed it.

The UC report also expressed some uncertainty regarding the persistence of MTBE once dissolved in surface water. Since the publication of the UC report, several peer-reviewed studies have been published which demonstrate that MTBE will not persist in surface waters but will volatilize relatively quickly, depending on a number of factors related to the physical features of the reservoir and the wind conditions. Once MTBE sources are eliminated, these studies suggest that MTBE would not persist indefinitely and would likely be completely dissipated within several months following cessation of the use of two-stroke engines (Stocking et al., 2000 and references therein).

The findings on the fate of MTBE in reservoirs have been confirmed by recent data on surface water sources. The surface water monitoring data available at the time of publication of the UC report can be compared with current data made available since 1998. As Table 1 illustrates, only five new surface water sources have been identified since 1998 as containing elevated concentrations of MTBE, and no surface waters have been monitored with concentrations greater than 5 µg/L (the California SMCL) since 1999.

Table 1. Surface Water Reservoir Contamination

	1996	1997	1998	1999	2000	2001
Newly Identified SW sources with MTBE detects	9	4	7	4	1	0
Newly Identified SW sources with MTBE detects > 5 µg/L	2	3	2	3	0	0

Surface Water Cost Impacts. In an attempt to quantify the total costs to California's economy resulting from the continued use of MTBE in gasoline, UC researchers prepared a cost/benefit analysis of fuel alternatives. The analysis included direct and indirect costs including air quality benefits, health costs, fuel price increases, water monitoring costs, and other costs. Following this analysis, UC researchers suggested that the continued use of MTBE will result in increased incremental costs (aggregated annualized costs) specifically related to surface water, a recreational cost ($160 to $200 million) and a water treatment cost ($4 - $30 million). While it is beyond the scope of this memorandum to reassess the cost analysis performed by the UC researchers, a review of the predicted costs due to surface water contamination in California suggests that these costs are significantly overestimated, and are likely to be negligible over time. Without MTBE impacts (due to the ban of two-stroke engines at drinking water reservoirs in California), no treatment will be needed and monitoring requirements and costs will decrease with time.

Groundwater Sources

UC Report Conclusions. The UC report divides groundwater contamination into two categories: public and private drinking water wells. At the time of publication of the UC report, it appeared that MTBE detections in drinking water sources were increasing fairly rapidly. Both Santa Monica and South Lake Tahoe had recently been identified as highly impacted drinking water utilities in previous years. These high profile contamination scenarios set the stage for the assumption that many of the state's public drinking water resources would become contaminated by MTBE in the near future. Based on the information available at the time, UC researchers projected that between 60 and 340 public drinking water wells would become contaminated by MTBE, and that an additional 1000 to 5000 private drinking water wells would also become contaminated.

The predictions of the UC researchers were based on CalDHS public drinking water well monitoring data. At the time of publication, CalDHS had monitored approximately 2,988 public drinking water wells for MTBE contamination representing 21% of total public drinking water wells in California. Of these wells, 35 (or 1.2%) contained detectable levels of MTBE. While UC researchers noted that much of the DHS testing "has presumable targeted wells near suspected sources, hence it probably represents a biased sample," they went on to extrapolate that 1.2% of the entire community of untested wells could become contaminated in the future.

Current Observations. With several additional years of drinking water monitoring data, it is possible to review the accuracy of the UC predictions. Table 2 presents past and current public drinking water well MTBE contamination data in California. As suggested by the UC researchers, it appears that the most vulnerable or already contaminated sources were monitored first thus accounting for the initially high percentage of MTBE contaminated sources and the steady decline in this percentage as more sources are sampled. Thus, if the data were extrapolated based on current monitoring results, the UC authors would likely select a range much closer to their lower bound of contamination and likely below their lower bound.

Table 2. Declining Percent of MTBE Detections in Public Water Supply (PWS) Wells Between 1995 and the Present

Date	1995 – 9/1998	9/1998 – 3/1999	3/1999 – 6/2001
Number of new PWS wells sampled	2,988	1,567	3,426
Total number of PWS sampled to date	2,988	4,555	7,981
Number of PWS wells with MTBE detects	35	41	46
% of total wells with MTBE detects	1.2 %	0.9 %	0.6 %
Number of new wells with MTBE detects	-	6	5
% of new wells with MTBE detects	-	0.4 %	0.15 %

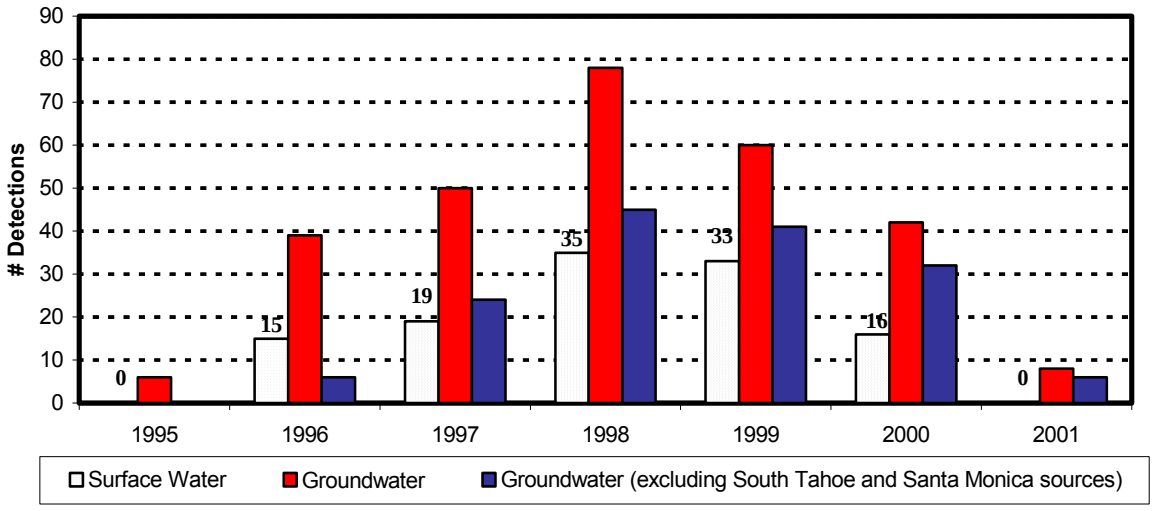
As shown in Table 2, the incremental increase in the number of new wells contaminated with MTBE between March 2000 and the present (June 2001) is 0.15%. This number is one order of

magnitude lower than that used by UC researchers (1.2%). It is very probable that the percentage of new wells with MTBE detections will continue to decrease over time. Using the current incremental increase in new wells with MTBE detections (0.15 % between March 1999 and June 2001, and assuming a total of 10,931 unsampled active public water supply wells in California, the estimated number of new wells projected to be impacted by MTBE should be 16 compared to the UC estimate of 60 to 340 wells.

Gaining an accurate picture of private well contamination is much more complicated. Due to the large number of private wells in California and the lack of monitoring and regulatory oversight, no data are readily available on private well contamination except on a hearsay basis or if reported to the state or county in an effort to recover treatment costs. In preparation for this memorandum, a review of five counties in the Bay Area– a region noted for its use of MTBE-blended fuel – was completed. Three counties reported no known private well contaminated by MTBE. The other two counties reported that a few private wells were contaminated with MTBE. However, due to the lack of any compiled information or formal database, the total number of private wells contaminated by MTBE remains unknown in California.

Combining all of the data currently available from CalDHS, one can clearly see a trend in MTBE detections across the state since 1998. As Figure 1 illustrates, 1998 represented the apex in MTBE detections statewide. Since then, both surface water and groundwater detections have decreased steadily. This most likely resulted from testing the most vulnerable or already contaminated sources first, and using those sources as an indication of future contamination.

Figure 1. MTBE Detections at Public Water Supply Sources of Drinking Water



Notes. Maximum of 1 Detection per month
Detection requires at least two positive findings at a source

Groundwater Cost Impacts. In the UC report, a cost/benefit analysis of fuel alternatives revealed that utilities in California will incur substantial costs due to potential water treatment for the removal of MTBE. A considerable portion of this cost is associated with the treatment of groundwater relative to surface water. Cost assumptions were based on a predicted number of sites requiring treatment, in addition to a large volume of groundwater requiring treatment at each site due to the continued expansion of MTBE plumes. As shown in this memorandum, the number of impacted sites is not as large as predicted by the UC report. In addition, MTBE plumes (as will be discussed below) are not expected to expand as predicted by the UC report. Finally, advances in technologies for the removal of MTBE from water suggest that treatment costs are not as prohibitive at MTBE-impacted sites relative to BTEX-only sites when the rapid detection of MTBE takes place.

Growth of MTBE Plumes

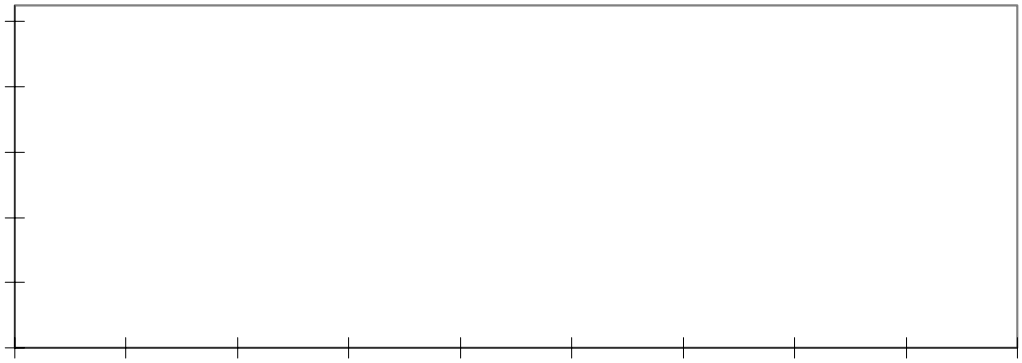
UC Report Conclusions. One of the foundations for concluding that MTBE poses a significant risk to California's environment comes from assumptions made by UC researchers regarding the movement of MTBE through the subsurface following the release of MTBE-blended gasoline from leaking underground fuel tanks (LUFTs). By assuming no biodegradation and no adsorption, UC researchers concluded that MTBE plumes will grow three to four-fold and could extend up to 7000 feet from a release site to impact a volume of groundwater of over 100,000 acre-ft by 2010.

Current Observations. Three years after publication of the UC report, the current picture of MTBE plume behavior in the field has not changed significantly. Several MTBE plumes remain long (Port Hueneme, Vandenberg Air Force Base). However, most MTBE plumes do not appear to elongate at the rate predicted by the UC report. Recently, plume studies were conducted in three states (California, Florida, and Texas) to determine the apparent distribution of BTEX and MTBE in groundwater. Figure 2 represents a compilation of data from several hundred benzene plumes and approximately 130 MTBE plumes. The results of these studies contrast directly with predictions made by UC researchers based solely on MTBE's physical and chemical properties. Based on its properties, MTBE was predicted to move at the speed of groundwater with little or no retardation. However, most of the studies reviewed to date suggest that MTBE plumes neither elongate indefinitely as predicted, nor do they span substantially longer distances than BTEX plumes (Figure 2). These studies suggest that, depending on gasoline spill history and on site geology and hydrogeology, MTBE plumes may often stabilize at a fixed distance from a point of release.

That being said, the data presented in Figure 2 are still mostly from sites with relatively recent spills. It is therefore possible that MTBE plumes at these sites did not have sufficient time to elongate significantly beyond the BTEX constituents. Figure 2 indicates that the relative volume of groundwater requiring remediation at LUST sites following the addition of MTBE to gasoline does not dramatically change immediately after a spill. Therefore, if active remediation is rapidly implemented following an accidental release of MTBE-blended gasoline, the incremental groundwater impacts associated with the presence of MTBE can be minimized.

Finally, a heightened awareness of the importance of identifying and curtailing any releases of MTBE into surface water and groundwater would suggest that accidental gasoline releases impacting drinking water resources in California will be detected earlier and stopped sooner. This more rapid control of MTBE plumes will reduce the overall impact of MTBE releases to groundwater.

Figure 2. MTBE and benzene plume studies (Texas and California)



Bioattenuation Potential of MTBE in Subsurface Environments

UC Report Conclusions. One of the major conclusions of the UC report was based on the assumption that MTBE does not biodegrade naturally. Prior to 1998, only a few cultures were reported to biodegrade MTBE (Hardison et al., 1997; Mo et al., 1997; Salanitro et al., 1994; Steffan et al., 1997). Moreover, MTBE biodegradation in the field had not been observed at more than a handful of sites. As a result, several studies during that timeframe suggested that the bioattenuation of MTBE did not occur at significant enough rates to prevent MTBE plume elongation.

Current Observations. In contrast to the scientific understanding in 1998, several studies have recently shown that MTBE can biodegrade under a range of environmental conditions, both in laboratory samples and in the field. In addition to a significant increase in publications reporting the biodegradation of MTBE and its byproducts under anaerobic conditions (Deeb et al., 2001 and references therein), MTBE has been recently shown to biodegrade under methanogenic (Hurt et al., 1999; Wilson et al., 1999), nitrate-reducing (Landmeyer et al., 2001) and iron-reducing conditions (Finneran et al., 2001). In addition, the biodegradation of MTBE has been demonstrated in sediment samples under denitrifying conditions (Bradley et al., 2001).

These recent results suggest that MTBE has the potential to naturally biodegrade under a range of environmental conditions. Thus, the assumption made in the UC report regarding the lack of biodegradation of MTBE in groundwater is no longer valid. While the exact consequences of these findings have not yet been quantified, the assumption that all MTBE plumes will grow indefinitely is clearly incorrect. Ongoing research efforts in the near future are likely to provide a quantitative basis for analyzing the future fate of existing MTBE plumes.

Remediation of MTBE-Impacted Soil and Groundwater, and Treatment Technologies for the Removal of MTBE from Water

UC Report Conclusions. In the "Summary" section of the UC Report, it was stated that the properties of MTBE present challenges for conventional water treatment processes while emerging technologies such as bioremediation have not yet been proven effective. The Report concluded that incremental costs for soil, groundwater and drinking water treatment would be very high due in part to the technical challenges of remediating MTBE impacted sites.

Current Observations. The UC review of the effectiveness of a range of MTBE remediation and treatment technologies was very thorough, but actual field experience with MTBE remediation was discussed only briefly since such information was not readily available at that time. Since the publication of the Report, many of these technologies have been tested at the field-scale for MTBE removal. The knowledge gained from these case studies demonstrates that many MTBE sites can be effectively remediated at a cost less than projected using conventional technologies.

A current evaluation of MTBE remediation technologies reveals that conventional technologies are effective at MTBE-impacted sites and that they are being widely applied on a national basis. Demonstrated remediation technologies include air sparging, pump-and-treat, multi-phase extraction and soil vapor extraction, all of which have been widely applied at gasoline-contaminated sites prior to the widespread use of MTBE in gasoline. Case studies demonstrate that conventional technologies can be very effective at removing MTBE from soil and groundwater relative to BTEX removal from environmental media (CA MTBE Research Partnership, 2001). The successful removal of NAPL sources is not impacted by the presence of MTBE.

In addition to conventional technologies used at gasoline-contaminated sites, emerging technologies or modifications to existing technologies can greatly reduce the life cycle remediation costs at MTBE-impacted sites. For example, while the use of in-situ technologies such as bioremediation was emerging in 1998, recent successful field applications (Salanitro et al., 2000; Mackay et al., 2000) suggest that bioremediation and other emerging technologies have great potential for success at MTBE-impacted sites. Such a technology is now commercially available, and on-going research studies are promising with respect to the efficiency and relative cost effectiveness of bioremediation.

In summary, unit costs for remediation of MTBE impacted sites, and unit costs for MTBE removal from groundwater are likely to decrease in the future as a consequence of research efforts since the UC Report, and research studies now under way funded by federal, state and private entities are likely to reduce unit costs.

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