December 2000 Preliminary Report:
Task Force on the Environmental Effects of MTBE

TABLE OF CONTENTS

Executive Summary

- The use of Methyl Tertiary Butyl Ether (MTBE) has resulted in cleaner burning gasoline and is an important part of Maryland's comprehensive strategy to clean the air. The current use of MTBE in gasoline is estimated to achieve volatile organic compounds emission reductions equivalent to eliminating approximately 780,000 vehicles from Maryland's roadways. In an average year over 2 billion gallons of gasoline are transferred into the State of Maryland, which results in the consumption of approximately 200 million gallons of MTBE.

- Along with the positive results of MTBE use in reducing the precursors to ozone formation in the atmosphere and in reducing toxic emissions such as benzene, MTBE has been found to have contaminated drinking water across the state of Maryland. In spite of significant efforts to upgrade and replace bare steel underground storage tank systems in Maryland with modern systems, releases from these older tank systems continue to impact groundwater. Even the effectiveness of the modern upgraded underground storage tank systems has become suspect in their ability to prevent and detect releases. However, the characteristics of MTBE that allow it to readily dissolve in groundwater and migrate away from the source make any spillage of petroleum a potential concern. MTBE has been found in other fuels besides gasoline, including the more widely distributed and less controlled petroleum product, home heating oil.

- Maryland has been routinely sampling public drinking water supplies for MTBE since 1995. There is presently no federal primary drinking water standard for MTBE and, therefore, monitoring for its presence in drinking water is not required. The U.S. EPA has said that MTBE has the potential to be a carcinogenic hazard to human health. However, there is no evidence that this pollutant does or does not cause cancer in humans. Studies are underway to provide more conclusive answers to the health risks posed by MTBE but are years away from completion.

- MTBE's presence in drinking water has primarily caused taste and odor concerns. Some people are sensitive and can detect very low concentrations while others do not taste or smell the chemical even at much higher concentrations. For those affected, MTBE in the individual water supply can be both a "quality of life" issue and an economic issue.

- The U.S. EPA's drinking water advisory for MTBE recommended that levels of contamination at or below 20 to 40 parts per billion would provide a large margin of safety from toxic effects and would likely not produce an unpleasant taste and odor in drinking water. Maryland has provided alternative sources of water or treatment by filtration in cases where MTBE has been detected at or above 20 parts per billion in drinking water. The U.S. EPA is expected in the near future to announce the proposal of a secondary maximum contaminant level for MTBE based on the results of a more recent taste and odor study. Secondary maximum contaminant levels are not enforceable standards but represent federal goals for drinking water quality to protect against negative aesthetic qualities related to the public acceptance of drinking water.

- The majority of Maryland residents, 68 percent, are served by public water systems drawing water from surface water sources. MTBE impacts to these surface waters have been negligible. To date, MTBE has only been found twice in surface supplies; both samples were less than 2 parts per billion. Of the remaining 32 percent of Maryland residents, 10 percent obtain water from wells installed in confined aquifers, which provide the highest degree of protection from man-made contaminants. That leaves 22 percent of Maryland residents who are served by private wells (16 percent) and community wells drawing water from less protective unconfined aquifers (6 percent) who are most at risk from drinking water contaminated with MTBE.

- At the time of construction, private wells may be sampled for volatile organic compounds, including MTBE, if the local environmental health agency has reason to suspect that harmful constituents are present in amounts that are significantly adverse to human health, safety, or comfort. After construction, private wells are not routinely, if ever, required to be sampled for MTBE contamination. However, wells are commonly tested during property transfers. The selection of contaminants to be tested is left to the lending institution or the homebuyer. Unconfined public well supplies are required to be sampled at least every three years for a wide range of contaminants referred to as volatile organic compounds, which includes MTBE. A significant number of wells serving restaurants, convenience stores, campgrounds, and gasoline service stations, however, are not required to sample for volatile organic compounds under federal or state regulations. These wells are more likely to be located near potential sources of contamination than other public water supplies.

- MTBE, and other ethers and alcohols used as additives to gasoline, readily dissolve into groundwater. Once MTBE is released into the environment, it can decompose under certain conditions to form another chemical of concern. In groundwater MTBE can decompose and turn into Tertiary Butyl Alcohol (TBA). TBA is also a byproduct of the MTBE production process. This chemical, like MTBE, has no federal primary drinking water standard, and health studies are inconclusive on its potential cancer risks. However, unlike MTBE, TBA cannot be easily detected by taste and odor at similar low concentrations.

- Since 1995, the Maryland Department of the Environment has been periodically sampling community and non-transient, non-community public water systems for MTBE. Of the 1,084 public water systems tested, MTBE has been detected in about 85 systems. Most detections of MTBE are below the taste and odor threshold of 20 parts per billion. Only 11 water systems have had detections above the taste and odor threshold of 20 parts per billion. Of these 11 systems, 10 now have alternate sources or the levels have dropped below 20 parts per billion. MTBE has been detected at approximately 9 percent of monitored systems. However, the levels detected are likely to vary over time.

- In July 1999, the Maryland Department of the Environment established a database within the Oil Control Program to specifically track the presence of MTBE in domestic wells throughout Maryland. The first report from this database, printed July 30, 1999, indicated 149 domestic water wells contaminated with MTBE. Currently the database shows a cumulative total of 267 domestic wells that have at one time sampled positive for MTBE.

Of these 267 domestic wells, 239 are Oil Control Program investigation/remediation cases at various locations, including gasoline service stations, churches, transportation facilities, volunteer fire departments, petroleum bulk plants, country stores, and private residences**.** However, 5 percent of these cases have yet to identify a specific source of contamination.

- MTBE can be remediated or cleaned up once the extent of contamination has been adequately defined. The length of time to achieve cleanup and the complexity of the remediation method used to achieve cleanup are greater when compared to remediating releases of petroleum that do not contain MTBE. MTBE can biodegrade or decompose in the subsurface environment, although at this time knowledge of the specific conditions that must be present for significant biodegradation to occur is limited. This increases the importance of adequate MTBE plume delineation and the selection of appropriate remediation methods to ensure protection of potential drinking water receptors.

- The alternatives to MTBE, including ethanol and other ether oxygenates, which can be used for the purpose of reformulation of gasoline to reduce air toxic emissions and pollutants that form ground level ozone, have yet to be explored by the Task Force. The Task Force's efforts in this area will be included in the final report due on or before December 1, 2001.

I. INTRODUCTION

Background

House Bill 823, signed by Governor Glendening on May 11, 2000, created an MTBE Task Force consisting of 16 members from various government agencies, petroleum industry, health related professionals, and the ethanol industry. The Task Force responsibilities are as follows:

(1) Determine and assess the environmental and health risks associated with ground and surface water contamination from MTBE;
(2) Examine national and regional efforts concerning ground and surface water contamination from MTBE;
(3) Recommend a plan to minimize and counteract the environmental and health risks associated with ground and surface water contamination from MTBE; and
(4) Explore alternatives to MTBE, including ethanol and oxygenated fuel, which can be used for the purpose of reformulation of gasoline to reduce air toxic emissions and pollutants that form ground level ozone.

The Task Force preliminary report is due on or before December 1, 2000 with a final report due on or before December 1, 2001. Appendix A lists the members of the Task Force. The following comprises the efforts of the Task Force since meetings began on October 11, 2000 and meets the requirement of a preliminary report on or before December 1, 2000.

MTBE: Its Nature, Benefits, and Problems

Methyl Tertiary Butyl Ether (MTBE) is a volatile, flammable, colorless, liquid with a turpentine-like odor. It may have a pungent foul odor at low concentrations in drinking water. MTBE is made as a byproduct of petroleum refinery operations by combining methanol derived from natural gas and isobutylene. Generally, *ethers* are organic substances with two groups linked by an oxygen. MTBE is a synthetic chemical [$CH_3OC(CH_3)_3$] that has been added to gasoline as an octane enhancer since the phase-out of lead in the late 1970s.

More recently, MTBE has been used extensively around the country to reduce motor vehicle emissions. The passage of the 1990 Clean Air Act resulted in the increased use of MTBE to reduce carbon monoxide emissions. Beginning in 1995, the Clean Air Act also required that areas with the worst ground-level ozone air pollution (including the Baltimore and Washington metropolitan areas) use gasoline reformulated to reduce air toxics emissions and pollutants that form ground level ozone. MTBE has been the additive most commonly used by gasoline suppliers throughout most of the country. It has been used because it is cost effective in meeting air quality and gasoline performance goals. The use of cleaner burning gasoline is an important part of Maryland's comprehensive strategy to clean the air. In an average year, over 2 billion gallons of gasoline are transferred into the State of Maryland, which results in the consumption of approximately 200 million gallons of MTBE.

MTBE is more soluble in water, has a smaller molecular size, has a low tendency to adhere to soil, and is less biodegradable than other components of gasoline. Consequently, MTBE is more mobile in groundwater than other gasoline constituents and may often be present when other components are not. Significant sources of MTBE in the environment are from leaking underground and aboveground petroleum storage tanks and pipelines. Other sources include atmospheric deposition, stormwater runoff from paved surfaces, watercraft, spills, and improper disposal of fuels. The physical properties of MTBE, combined with the various ways MTBE can be released into the environment, have resulted in the detection of MTBE in drinking water supplies across the country as well as here in Maryland. Figure 1 (page 7) depicts the movement of MTBE in the environment once it is released. Detection of MTBE in private and public water supplies has caused MTBE to become a contaminant of concern and the impetus to the legislation creating this Task Force.

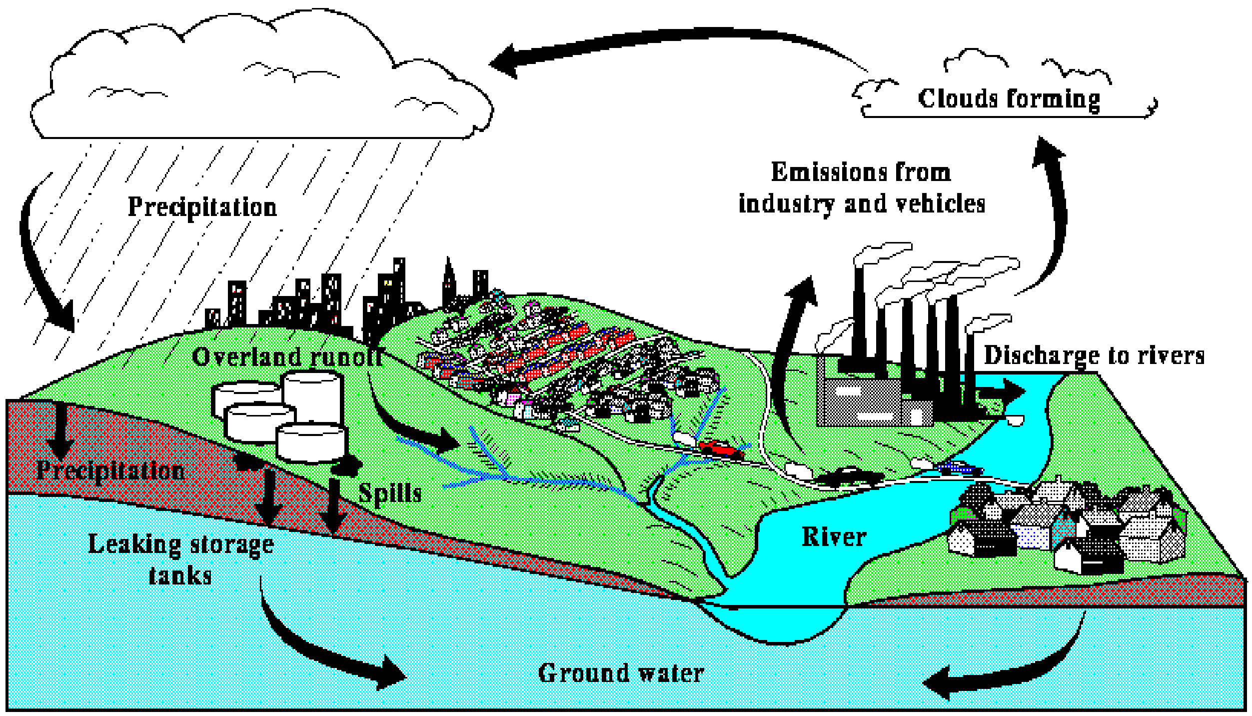
MTBE's Role in Improving Maryland's Air Quality

MTBE has been used by manufacturers to enhance the octane content of gasoline since the early 1970s when lead was being phased out. Its use increased gradually throughout the 1980s as an octane enhancer, typically at 1 to 8 percent by volume. The Clean Air Act Amendments of 1990 created several programs to help reduce emissions from automobiles that have led to significant growth in MTBE use in Maryland and across the country.

The 1990 Clean Air Act created the oxyfuel program, which required gasoline marketers in carbon monoxide non-attainment areas, including parts of Maryland, to add 2.7 percent weight oxygen to reduce carbon monoxide emissions beginning in 1992. MTBE and ethanol, a renewable alcohol fuel derived from grain, are the primary oxygenates used. The 2.7 percent weight oxygen requirement can be met by 15 percent volume MTBE or 7.5 percent volume ethanol. While the oxygen requirement can be met with a smaller volume of ethanol, in reality, ethanol was blended at the 3.5 percent by weight level or about 10 percent volume.

The oxyfuel program has been a tremendous success, reducing ambient carbon monoxide pollution by approximately 14 percent nationwide. Fleet turnover was also a factor in reducing carbon monoxide. As a result, many areas have achieved attainment of the carbon monoxide standard. In 1990 there were 42 carbon monoxide non-attainment areas. Today, in large part because of the success of the oxyfuel program, there are only 12. Additional areas are demonstrating attainment every year. Maryland was able to demonstrate attainment of the carbon monoxide standard in 1995, dropping the oxyfuel program at that time with the understanding that a lower level of oxygen would still be used in the reformulated gasoline sold in the state.

Figure 1:   Movement of MTBE into the Environment
(Ref.: http://sd.water.usgs.gov/nawqa/pubs/factsheet/fs114.95/fig2.gif)



The second fuel program created by the 1990 Clean Air Act was the reformulated gasoline (RFG) program. The Clean Air Act requires refiners distributing gasoline in severe ozone non-attainment areas to reduce volatile organic compounds and toxic emissions by 15 percent (27 percent and 20 percent respectively in Phase 2 RFG, which began January 1, 2000). RFG is required in Maryland's worst ozone non-attainment areas. These areas include the Baltimore region, comprised of Baltimore City and Baltimore County, Anne Arundel, Carroll, Harford, and Howard counties as well as Cecil County due to its inclusion in the Philadelphia ozone non-attainment area. As allowed by the Clean Air Act, then Governor Schaefer opted-in the other areas of the State that had ozone non-attainment problems into the RFG program including the Washington metropolitan area counties of Montgomery, Prince George's, Calvert, Charles, and Frederick, together with Kent and Queen Anne's counties. The remaining counties in the State are only required to use conventional gasoline, however, there is some "spill-over" into these counties especially in locations adjacent to the areas where RFG is required.

A key component of the RFG program also is the addition of oxygenates. The Clean Air Act requires that RFG contain 2.0 percent weight oxygen, which can be met by either 11 percent volume MTBE or 5.7 percent volume ethanol. Oxygenates were seen as a means of providing clean octane to replace components, such as aromatics, which would have to be reduced to meet the volatile organic compounds and toxic performance standards of the RFG program. However, with 500,000 troops stationed in the Persian Gulf at the time and a flagging farm economy, Congress also considered the oxygen content requirement a means of addressing other important public policy goals, including energy security, rural economic development, and diversifying our fuel supply with renewable resources. These ancillary public policy benefits were critical to the adoption of the RFG oxygen content requirement.

From an air quality perspective, the RFG program has been a success. The U.S. Environmental Protection Agency (U.S. EPA) estimates that RFG is the equivalent of taking 16 million vehicles off the road each year. Including areas that opted-in to the program, RFG represents about 30 percent of the nation's total gasoline supply, or about 35 billion gallons annually. Approximately 88 percent of the RFG oxygen market is met with MTBE. The remaining 12 percent is met by ethanol, primarily in Chicago and Milwaukee where ethanol blends are used almost exclusively. Refiners have chosen to use MTBE in RFG markets for a variety of reasons. While ethanol is produced from grain, MTBE is produced from petroleum-based feedstocks. However, MTBE is also easier to use, particularly during the summer months, and can be shipped via pipeline. Refiners and gasoline marketers in Maryland have used MTBE almost exclusively since 1995.

The RFG program has been a critical component in the Maryland Department of the Environment's comprehensive air quality plan. Its use has proven to be a very cost-effective control measure for reducing carbon monoxide and ozone precursor emissions from motor vehicles. In addition, RFG used in lawn and garden equipment and other small engines produces further emission reductions, which also helps air quality during our summertime ozone season.

In Maryland, over a third of our volatile organic compounds and nitrogen oxides emissions comes from motor vehicles. The Department of the Environment estimates that the use of Phase I RFG in the specified areas of Maryland reduced volatile organic compounds emissions from motor vehicles by more than 12 tons per day. This RFG benefit is equivalent to eliminating the emissions from approximately 600,000 of today's vehicles. Currently, the use of Phase II RFG in the specified areas is estimated to reduce volatile organic compounds emissions by more than 14 tons per day and nitrogen oxides emissions by almost 7 tons per day in Maryland compared to using conventional gasoline. The emissions reductions of Phase II RFG are equivalent to eliminating the volatile organic compounds emissions of approximately 780,000 vehicles and the nitrogen oxides emissions of approximately 170,000 vehicles from Maryland's roadways. Only the Vehicle Emissions Inspection Program (VEIP) obtains more reductions from motor vehicles.

In addition to the reduction in emissions of the ozone precursors, volatile organic compounds and nitrogen oxides, the RFG program has also contributed to substantial reductions in the overall emissions of air toxics. Emissions of toxic compounds, such as benzene (a known human carcinogen), were reduced by about 15 percent as a result of the use of Phase I RFG. Toxic compounds in Phase II RFG have been reduced overall by about 25 percent compared to conventional gasoline.

While MTBE has proven to be a great benefit to air quality, it had not been studied for its environmental impact to groundwater until recently. The initial focus of MTBE studies was on MTBE's chemical reactions to improve air quality. The studies required to determine its residual effects in groundwater were not considered at the time, hence, governments are now dealing with this issue.

II. FINDINGS OF THE TASK FORCE

Health and Environmental Risks of MTBE

There is presently no federal primary drinking water standard for MTBE, therefore, it is not a regulated contaminant. The U.S. EPA has said that MTBE has the potential for carcinogenic hazards for humans. However, there is no evidence that this pollutant does or does not cause cancer in humans. Among its other potential effects, MTBE's presence in drinking water has primarily caused odor and taste concerns. In 1997, as a result of its aesthetic problems, the U.S. EPA issued a drinking water advisory for MTBE of 20 to 40 parts per billion. The U.S. EPA's Office of Water has placed MTBE on the contaminant candidate list to further evaluate whether it should be included in the Primary Drinking Water Standards. This evaluation will need further scientific investigation, treatment technologies, and health data.

The U.S. EPA's drinking water advisory further reports that studies have been conducted on the concentrations of MTBE in drinking water at which individuals can detect the odor or taste of the chemical. Humans vary widely in the concentrations they are able to detect. Some who are sensitive can detect very low concentrations, while others do not taste or smell the chemical even at much higher concentrations. Moreover, the presence or absence of other natural or water treatment chemicals can mask or reveal the taste or odor effects.

The U.S. EPA reviewed all available information concerning MTBE and concluded that there was insufficient data to quantify health risks from low level exposures in drinking water. The U.S. EPA's drinking water advisory for MTBE, issued in December 1997, recommends that levels of contamination at or below 20 to 40 parts per billion would provide a large margin of safety from toxic effects and would likely not produce an unpleasant taste and odor in drinking water. Figure 2 (Page 11) depicts the partial diagram of MTBE potential metabolic transformations that can take place in the body when MTBE is consumed. Appendix B provides a more detailed overview on the toxicology of MTBE. The Task Force will continue to review new information as it becomes available.

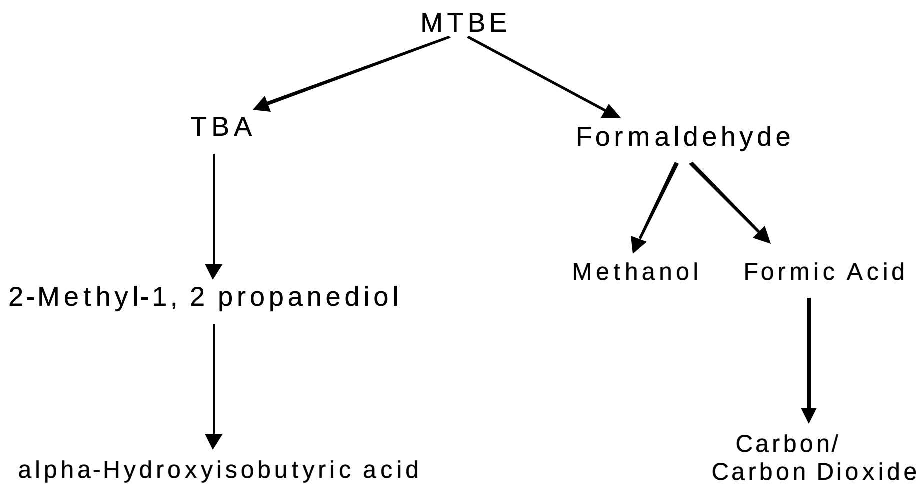
Extent of MTBE Contamination in Maryland

Public Drinking Water Supply Data: Since 1995, the Maryland Department of the Environment has been periodically sampling community and non-transient, non-community public water systems for MTBE. Of the 1,084 public water systems tested, MTBE has been detected in about 85 systems; 11 systems had levels above 20 parts per billion. Of these 11 systems, 10 now have alternate sources or the levels have dropped below 20 parts per billion. Alternative sources of water have been used to replace contaminated sources. To date, MTBE has only been found twice in surface supplies; both samples were less than 2 parts per billion. Figure 3 (Page 12) depicts the locations where MTBE has been detected in Maryland's public water systems. A summary of the findings from the MTBE monitoring of public water systems is as follows:

- Approximately 1,400 public water systems supplied by 2,000 wells and intakes serving 84 percent of the Maryland population are routinely sampled for MTBE.
- MTBE is rarely detected in surface supplies, which serve 68 percent of the population.
- MTBE has not been detected in confined aquifer supplies.
- MTBE has been detected at approximately 9 percent of monitored systems.
- Most detections of MTBE are below the taste and odor threshold of 20 parts per billion.
- Eleven water systems have had detections above the taste and odor threshold of 20 parts per billion as of October 2000.
- Detected MTBE levels are likely to vary over time.

There are several types of public water supply systems that need to be defined to give a frame of reference to the data presented above. A public water supply is a water system that regularly serves an average of 25 people daily at least 60 days of the year. Public water supplies are further grouped into the following categories:

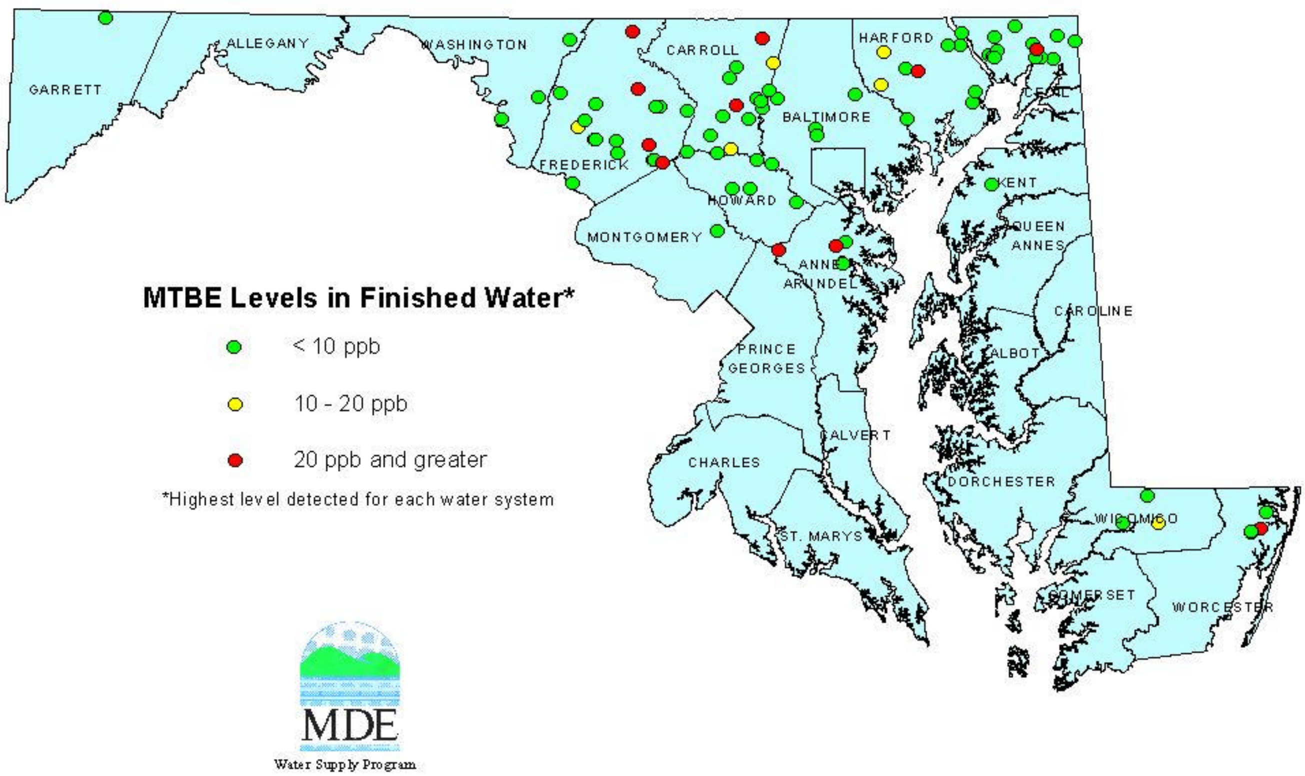
Figure 2
Partial Diagram of MTBE Potential Metabolic Transformations



Reference: L.U.S.T. Line Bulletin 34, February 2000

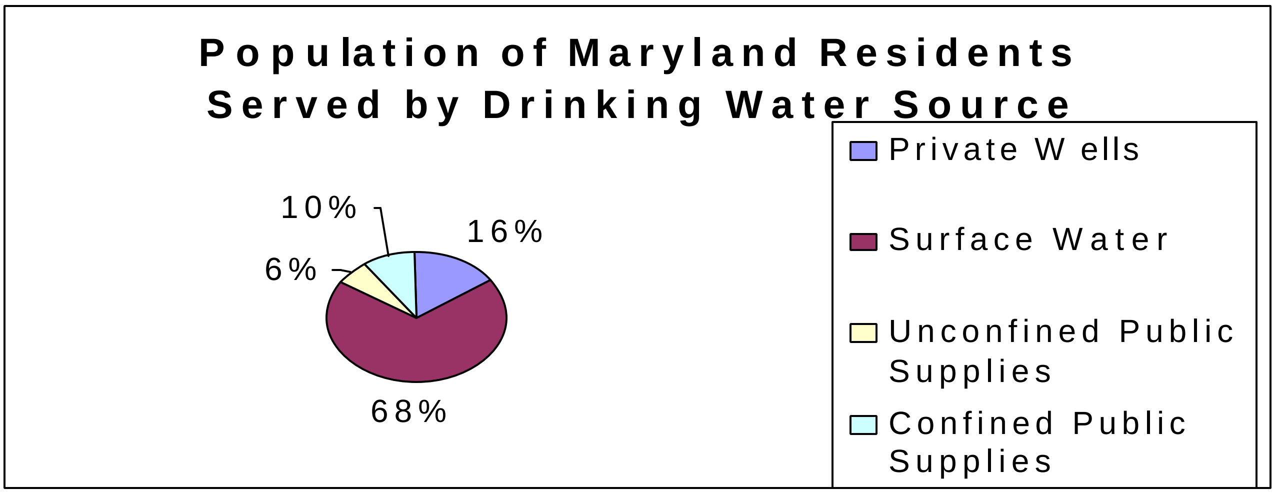
Figure 3

MTBE Detections in Maryland Public Water Systems Since 1995



- A community water system is a public water supply that serves at least 25 residents or has at least 15 service connections throughout the year. There are approximately 511 of these systems in Maryland.
- A non-transient, non-community water system is a public water supply that serves 25 of the same individuals daily for at least 6 months of the year. There are approximately 573 of these systems in Maryland.
- A transient non-community water system is a public water supply that does not serve 25 of the same people on a daily basis. There are approximately 2,738 of these systems in Maryland.

Public water systems get water from both surface water and groundwater. Surface water sources are river intakes and reservoirs. Groundwater sources are springs and wells. As reported above, MTBE has only been detected in two water supplies using surface water.



The public water systems served by wells can be further distinguished between those systems that obtain water from a confined or unconfined aquifer. An unconfined aquifer is defined as a formation capable of transmitting significant quantities of water in which the water table or upper surface forms the upper boundary. In other words, this is the water that would be encountered first when drilling a well. An unconfined aquifer is more easily impacted by sources of contamination.

A confined aquifer is defined as an aquifer bounded between two low permeability layers. The water in a confined aquifer is protected from activity on the surface due to the long travel times needed to recharge the aquifer. Contamination of a confined aquifer is very rare.

Six percent of Maryland residents are supplied by community water systems using unconfined aquifers, and 10 percent of Maryland residents are supplied by community water systems using confined aquifers. Data is not available for the additional 16 percent of Maryland residents that obtain water from a private well. The remaining 68 percent of Maryland residents are served by surface water supplied public water systems.

Another factor influencing the completeness of the MTBE detection data presented above is the requirement for testing of public water systems. Community water systems and non-transient, non-community water systems are required to test for volatile organic compounds, which includes MTBE, at the following frequency: upon well installation; quarterly during the first year; annually for the next two years; and then once every three years. Waivers are permitted for systems using a confined aquifer to extend testing requirements to once every six years. Transient non-community water systems, which are the largest number of public water systems and more often located near potential sources of contamination, are not required under federal or state regulations to test for volatile organic compounds, including MTBE.

Domestic Well Data: There are an estimated 320,000 domestic wells in Maryland. About 8,000 to 10,000 new wells are drilled each year. A portion of these are replacement wells and the remainder are for new development. At the time the well is constructed, private wells may be sampled for volatile organic compounds, including MTBE, if the local environmental health agency has reason to suspect that harmful constituents are present in amounts that are significantly adverse to human health, safety, or comfort. After construction, private wells are not routinely, if ever, required to be sampled for MTBE contamination. However, wells are commonly tested during property transfers. The selection of contaminants to be tested for is left to the lending institution or the homebuyer. Data from testing at the time of construction or during property transfers is not available in a central location for retrieval or analysis.

The Maryland Department of the Environment's Oil Control Program is responsible for performing investigations into the source of petroleum contamination that has impacted domestic water wells. These domestic wells are normally located at a private residence and supply the dwelling with potable water. The Oil Control Program, often in conjunction with local authorities, where possible will determine the source of petroleum contamination and require remediation action to occur.

In July 1999, the Oil Control Program established a database to track the presence of MTBE in domestic wells throughout the State of Maryland. The first report from this database, printed July 30, 1999, indicated 149 domestic water wells contaminated with MTBE. Currently, the database shows a cumulative total of 267 domestic wells that have at one time sampled positive for MTBE. Of the cumulative total, 239 wells are Oil Control Program investigation/remediation cases at various locations, including gasoline service stations, churches, transportation facilities, volunteer fire departments, petroleum bulk plants, country stores, and private residences. These 239 wells are dispersed among 128 sites/cases. The remaining 28 wells associated with closed cases have either been successfully remediated, an alternative water supply provided, or subsequent sampling no longer detected MTBE. The following table lists the numbers of domestic wells and public water systems with MTBE detections by county.

DOMESTIC WELL AND PUBLIC WATER SYSTEMS MTBE DETECTIONS BY COUNTY			
County	Domestic Well Active	Domestic Well Cumulative Total	Public Water Systems Cumulative Total
Anne Arundel	37	42	4
Baltimore	22	23	7
Calvert	2	2	--
Carroll	33	44	16
Cecil	20	20	15
Frederick	42	42	17
Garrett	--	--	1
Harford	48	59	8
Howard	19	19	4
Kent	--	--	1
Montgomery	2	2	2
St. Mary's	2	2	--
Washington	10	10	3
Wicomico	2	2	3
Worcester	--	--	4
Totals	239	267	85

Other Groundwater Impacts: The complete picture of the extent of MTBE contamination in groundwater is greater than the data presented above, which focuses on impacts to public drinking water systems and domestic/private wells. The transportation, storage, and use of petroleum products are common to all areas of Maryland. The groundwater in other counties and in Baltimore City, which are not listed in the above table, has been impacted by MTBE, primarily from leaks from underground storage tank systems. The Maryland Department of the Environment has been approved by the U.S. EPA to implement the Underground Storage Tank Program, authorized by the federal Resource Conservation and Recovery Act, Subtitle I. As part of this authorization, the Department of the Environment is required to routinely report to the U.S. EPA the number of releases from underground storage tanks. To date, the Department of the Environment has reported over 14,500 releases. Not all of these releases were of significant volume to have impacted groundwater, but the potential for MTBE to be a component of these releases is high. For those releases that have reached groundwater and involved petroleum, the groundwater is almost certain to have been impacted by MTBE since it dissolves easily into water relative to other components of gasoline. Figure 4 (Page 17) depicts the partial degradation pathway of MTBE both in the groundwater and in the atmosphere. These natural processes convert MTBE into other chemicals, some of which may present additional risk to human health and the environment. The rate at which these natural processes occur varies greatly, but ultimately MTBE has the potential to degrade to carbon dioxide in both groundwater and the atmosphere.

MTBE, which impacts groundwater in areas where groundwater is not used for drinking water, does not represent as high a risk of exposure as compared to areas where groundwater is directly consumed. However, there remains the possibility of MTBE vapors migrating from released gasoline and, to a lesser extent from the groundwater, accumulating in underground utilities and, in rare cases, in living spaces. Additionally, the presence of MTBE in other petroleum products, such as home heating oil, expands the number of potential sources of contamination well beyond the limits of the federally authorized Underground Storage Tank Program.

Air Data: Although limited national studies, mainly by the U.S. Geological Survey, on the concentrations of MTBE in ambient air have been conducted, the focus of these studies has been primarily on the concentration of MTBE found in precipitation, both rain and snow. Modeling has predicted that MTBE can be scrubbed from the air, returned to the ground, and eventually reach groundwater. The values predicted by modeling and measuring have been in the single digit parts per billion. These concentrations have been highest in urban areas as compared to rural areas. No available data for Maryland has been presented as of the time of this report.

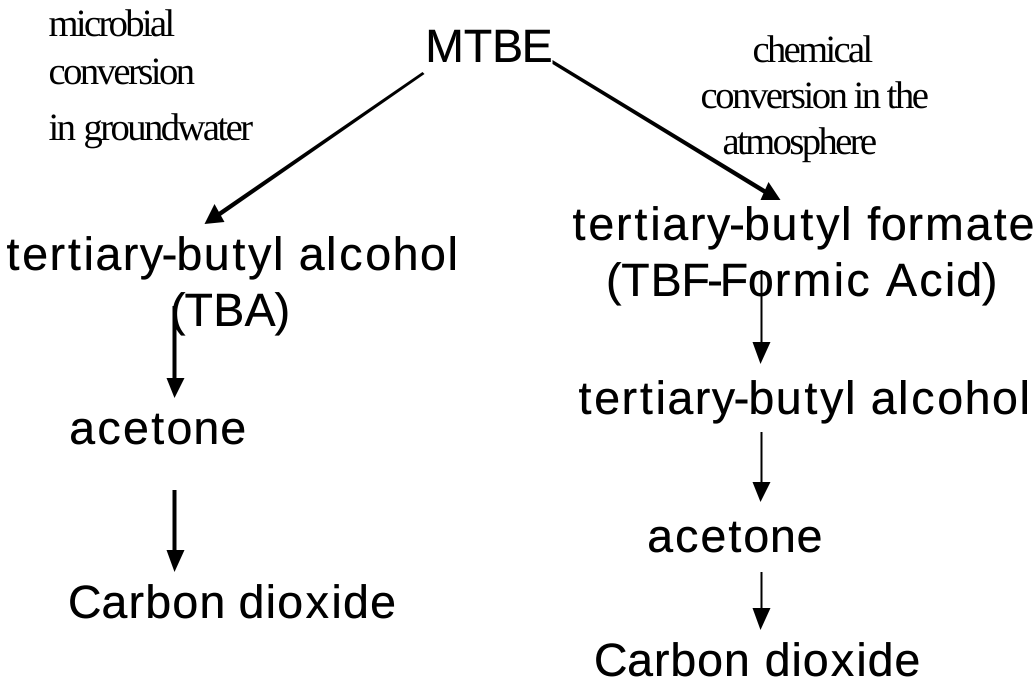
National and Regional Efforts (Legislation in Congress, EPA, and Other States)

In November 1998, the U.S. EPA formed a Blue Ribbon Panel on Oxygenates in Gasoline comprised of leading experts to investigate concerns raised by the discovery of MTBE in some water supplies. Based on its investigations, the Panel recommended in July 1999 that the U.S. EPA work with Congress and the states to implement reforms to ensure that water supplies are better protected while the substantial reductions in air pollution that have resulted from the use of MTBE are maintained. Specifically, the Panel's recommendations included:

- Substantially reducing the use of MTBE while ensuring there is no loss in air quality benefits.
- Enhancing public drinking water monitoring, assessment, and protection programs.
- Enhancing programs for enforcement of underground storage tank replacement and upgrade programs.
- Enhancing public education and cleanup programs for gasoline spills.

The U.S. EPA has already begun to develop a framework for regulatory actions aimed at phasing out this chemical. On March 20, 2000, the U.S. EPA issued a Regulatory Advisory announcing that the federal government would ban the fuel additive, MTBE, under the authority of the Toxic Substances Control Act. The intent of the Toxic Substances Control Act is to control problems at the source rather than legislating corrective actions once pollutants are released into the environment. Although the Toxic Substances Control Act is the environmental regulation presently charged with the compliance monitoring and enforcement activities for MTBE, program offices of other regulations such as the Clean Air Act, the Safe Drinking Water Act, the Clean Water Act, the Resource Conservation and Recovery Act, and the Occupational Safety and Health Act are also actively involved in compliance monitoring activities as a result of this pollutant being released into the environment.

Figure 4
Partial Degradation Pathway of MTBE



Reference: L.U.S.T. Line Bulletin 34 February 2000

At the Congressional level, there have been no fewer than 22 bills introduced that are related to the use of MTBE or alternatives like ethanol. A variety of approaches are reflected in these proposals and include, for example, phasing out the use of MTBE within three years, removing the federal 2.0 percent weight oxygen requirement in reformulated gasoline, and replacing the oxygenate requirement with a national renewable energy standard. A more detailed listing of congressional proposals can be found in Appendix C.

In states across the nation, again, a variety of approaches have been put forth in legislation. No fewer than eleven states (Arizona, California, Colorado, Connecticut, Iowa, Maine, Michigan, Minnesota, Nebraska, New York, and South Dakota) have passed legislation that limits or bans MTBE use. A more detailed listing of State actions is provided in Appendices D and E.

Current Status of Efforts to Minimize and Counteract the Risks of MTBE

Remediation Method Review: During the past decade, several billions of dollars have been invested by federal agencies to develop and test remediation technologies that can be applied to treating or remediating groundwater contaminants. Much of the emphasis of this research and development was focused on organic contaminants, especially gasoline components. Consequently, there are many technologies today that have emerged as standard methods for treating organic compounds found in groundwater. These technologies generally fall into two categories: treatment at the wellhead before it is distributed to the public (ex-situ treatment) or treatment in the ground before it is drawn from the subsurface (in-situ treatment). These technologies have been piloted, field tested, and validated by independent third parties over the past decade for their effectiveness in removing organics from groundwater. Today they are commercially available.

Once MTBE became a contaminant of concern in the early to mid-1990s, it was natural to initially use the technologies that were used to clean up other components of gasoline, such as the BTEX (benzene, toluene, ethylbenzene, and xylene) compounds, for remediating MTBE. The knowledge base developed over the decade regarding how to remove organics from groundwater and soils or surface waters could be applied to MTBE. The proven benefits derived from these technologies were expected to be also applicable to solving the MTBE contamination problem.

However, initial reports have shown that the standard technologies used for removing BTEX are not as effective at removing MTBE. Appendix G compares the physical properties of benzene and other selected gasoline compounds. The difference in properties such as solubility, volatility, and others, however slight, can make a big difference in the effectiveness of the technology applied to the different compounds. For example, MTBE is more soluble in water, is more mobile in water, has a higher vapor pressure, does not absorb onto sediments as well, and biodegrades slower than the BTEX compounds. It is differences such as these that have influenced the effectiveness of the standard BTEX treatment technologies for use on MTBE.

To solve some of these problems, significant research is occurring today to modify the technologies to increase their effectiveness on MTBE. For example, since naturally occurring microorganisms are not effective at breaking down MTBE, other organisms that have proven to be very effective at degrading MTBE are being injected into the subsurface to enhance the biodegradation process. To test many of these new ideas, a large field testing and demonstration site has been set up at the Navy Facilities Engineering Command in Port Hueneme, California, which has a large MTBE plume. Researchers developing technologies specifically adapted for MTBE removal and treatment are testing their new techniques at this site. Universities, research labs, and private companies are testing new methods on MTBE at other sites around the country as well.

In Appendix F a description of the proven technologies used for BTEX treatment and removal are described, as well as descriptions of the innovative technologies that are presently being tested as it applies to MTBE remediation.

Maryland Department of the Environment's Actions and Response: The main goal of the Department of the Environment's efforts has been to define the extent of MTBE contamination in the groundwater of the State. These efforts have consisted of compiling data from public water supplies and release sites, taking follow-up actions as needed, and evaluating data for patterns of occurrence. Efforts to expand the data collection on MTBE occurrence in domestic wells in cooperation with local governments are ongoing.

For water supplies used for providing public drinking water, contamination levels over 10 parts per billion result in an investigation of the contamination source by the Department of the Environment. Sampling frequency increases when MTBE is detected. For private wells, treatment is recommended above 20 parts per billion at the point of use. However, at higher levels well replacement may be needed. Follow-up action has included providing alternative sources of water, adding treatment, conducting additional monitoring, and changing remediation strategies.

On the preventive side, the Department of the Environment's Water Supply Program conducts studies and makes funding available to assist local governments in minimizing the risks of contamination at public supplies. The Department encourages local governments to establish Wellhead Protection Programs to minimize current and future contamination risks. The Department has prepared a model wellhead protection zoning ordinance that recommends not placing any new underground storage tanks within a one year time-of-travel zone to a public supply. A description of the program can be found at the Department's web page (http:/www.mde.state.md.us). Now that MTBE has become more widely known, local government water sampling programs have recently started including MTBE. The Department is gathering additional information available from major oil companies and other sources and is currently assessing the potential health risks from MTBE.

The November 1998 U.S. EPA's Blue Ribbon Panel on Oxygenates in Gasoline Report contains several recommendations that focus on underground storage tank systems. The Department of the Environment responded to the recommendations in this area by seeking funding to supplement its existing inspection program to more adequately address the concerns of undetected MTBE releases into the environment. These concerns were concurrently addressed by the Oil Funding Work Group established pursuant to Section 4, Chapter 532, Acts 1996, which was charged with assessing funding mechanisms for cleanup of contaminated sites and funding levels of oil related activities. The passage of House Bill 457 (2000 legislative session) and its accompanying note provided funding to implement two special projects targeted at collecting additional MTBE data and protecting drinking water supplies from MTBE impacts. These two special projects are described below:

Operational Tank Assessment Project (OTAP): The prevention of releases of gasoline from underground storage tank (UST) systems has been dramatically improved by the upgrade requirements of the 1998 deadline. Maryland has surpassed the U.S. EPA's target of 93 percent compliance with the 1998 upgrade requirements based on UST owner and operator supplied registration information. Leaks due to corrosion, spills and overfills are now thought to be prevented by these new control technologies. In addition, for those leaks that do occur, the required release detection methods are expected to detect a release very quickly and prevent any damage to human health or the environment. Determining the accuracy of the previous statements and identifying other components of an UST system that could be leaking gasoline but might not be detectable by the existing release detection methods is the goal of this project. An example of one area of concern for the project is the liquid tightness of a catchment basin or spill containment bucket required around the fill pipe of an UST. This bucket-type device is designed to catch small volumes of gasoline that may spill out of the delivery hose when the delivery driver disconnects it. We know that gasoline periodically enters this type of device, but it is not required to be tested for liquid tightness except at the time of installation. Over the years of use and change of seasons, the device may not remain liquid tight. Part of the project will be to test these catchment basins with water over a set period of time to determine if they are leaking.

Closed Case Assessment Project (CCAP): Prior to approximately mid-1997, the Oil Control Program did not routinely require the sampling of MTBE at sites with known gasoline releases. Many of these leaking underground storage tank (LUST) sites have since been determined to have completed the required cleanup and have been closed by the Department of the Environment. Since MTBE has been an additive to gasoline at varying percentages since the 1970s, the MTBE impact of these closed LUST sites is unknown. This project will investigate 10 percent of the closed LUST sites (540 of an approximate total of 5,400) over the next three State fiscal years. This will involve a file review of existing information of 180 sites per year along with a best-fit sampling plan to determine the location and method of sampling groundwater for MTBE years after the site was closed. A report will be prepared on the findings of the study.

Also, the November 1998 U.S. EPA's Blue Ribbon Panel on Oxygenates in Gasoline Report included a recommendation which suggested that the U.S. EPA require monitoring and reporting of MTBE and other ethers in groundwater at all underground storage tank release sites. A January 18, 2000 memorandum from the Acting Director of the U.S. EPA's Office of Underground Storage Tanks reinforced the Panel's suggestion by strongly urging all states to begin monitoring and reporting MTBE and other oxygenates in groundwater at all underground storage tank release sites nationwide. The memorandum went on to emphasize that while MTBE has received most of the publicity, it is by no means the only chemical of concern for which states should be monitoring and reporting. These oxygenates include, but are not limited to, Tertiary Amyl Methyl Ether (TAME), Diisopropyl Ether (DIPE), Ethyl Tertiary Butyl Ether (ETBE), ethanol, methanol, and the degradation product of MTBE, Tertiary Butyl Alcohol (TBA). The memorandum served to further emphasize the findings contained in a less widely noticed document published by the U.S. EPA's Office of Research and Development entitled *Oxygenates in Water: Critical Information and Research Needs*. This December 1998 report identified several needs, which recommended be given priority consideration including the inclusion of oxygenate analyses and principal suspected transformation products wherever monitoring of volatile organic compounds in water is performed.

While the Department of the Environment was evaluating the implementation of the U. S. EPA's recommendations, preliminary results of a U.S. EPA study conducted in partnership with BP/Amoco were provided to the Department in June 2000. The study was attempting to define the conditions under which MTBE would naturally degrade in the environment. Three of 74 BP/Amoco stations included in the study are located in Maryland. Groundwater testing conducted as part of the study indicated the presence of the expected constituents of gasoline since these three locations were known to have had a release and were in various stages of remediation. However, testing revealed the presence of the predicted degradation product of MTBE, TBA. This was the first documented detection of TBA in groundwater in Maryland associated with a petroleum release.

During the summer of 2000, the Department began to pilot the expansion of the testing parameters for other gasoline oxygenates, including the MTBE byproduct, TBA. Test results began to support the U.S. EPA's recommendations. DIPE, TAME, and TBA were detected in groundwater. Of additional concern, TBA was detected breaking through a carbon filtration system installed in a residence to remove MTBE and the known carcinogenic constituents of gasoline such as benzene. Replacement of the carbon unit removed TBA but the finding heightened the need to expand the testing parameters to other similar sites. Issues with the analytical method discussed later in the report have slowed the complete expansion of testing requirements.

Mapping and Data Integration: Global positioning systems (GPS) data and graphic information systems (GIS) software have become powerful tools in defining environmental problems and more importantly in defining solutions to these problems. In the case of MTBE, the mapping of potential sources of contamination and the potential receptors, in most cases wells, provides a visual tool to identify drinking water sources at risk. Additional protection strategies or increased monitoring frequency can readily be applied to areas that become identified.

The current challenge is to provide locational data, latitude and longitude for all the items of concern. Public water system locational data has for the most part been collected and is now the most readily available data set for mapping use. However, certain types of wells, specifically domestic wells, have not been mapped. Another missing piece of the equation is the location of all sources of MTBE contamination. The underground storage tank facilities have not, as of this time, been routinely mapped with GPS technology. Efforts are ongoing to convert address information to mapping quality locational data. These types of efforts have had limited success.

An example of a successfully implemented mapping and data integration program is California's Geotracker project. This project was funded by the California legislature and implemented by the Lawrence Livermore National Laboratory. The Geotracker system has received national attention and will be studied by the Task Force during the next year. To view the capabilities of the system via the Internet, log on to http:\\geotracker.llnl.gov. The U.S. EPA Region III office has funded a pilot project in the State of Virginia to test run the development of systems similar to Geotracker for use by other Region states. The U.S. EPA has welcomed the Oil Control Program's participation in the planning stages of the pilot project, which will speed the evaluation of the final product for use in Maryland.

The Maryland Department of Health and Mental Hygiene's Actions and Response: In order to determine the extent of MTBE contamination in the environment, significant reliance on laboratory support is necessary. The majority of MTBE testing currently taking place is being conducted by commercial laboratories upon the request from an underground storage tank (UST) owner or operator. These owners and operators of USTs are considered responsible parties for a release of petroleum from an UST system and are being required to investigate and clean up the release by the Department of the Environment. The cost of this sampling requirement is born by the UST owner/operator. However, testing of community water systems and other drinking water sources relies on the services provided by the Department of Health and Mental Hygiene. In contrast to the commercial laboratories, any significant increase in the number or frequency of MTBE testing will greatly stress existing non-commercial testing laboratory services. The following provides additional background and information on existing non-commercial laboratory services and capacity:

Operational Profile: The Division of Environmental Chemistry, a unit in the Laboratories Administration of the Department of Health and Mental Hygiene, is located in the J. Mehsen Joseph Laboratory Tower of the O'Conor Building at 201 West Preston Street in Baltimore. The Division serves as a public health analytical laboratory for various State departments and program offices such as Environment, Natural Resources, General Services, Licensing and Regulations, Office of the Attorney General, Food Control, Drug Control, Oil Control, Hazardous Waste Enforcement, Water Quality Monitoring, Maryland Occupational Health Administration, and the State Highway Administration. Laboratory services are also provided to each of the State's 23 county health departments as well as the Baltimore City Health Department.

The Sample Management Area is staffed with experienced personnel and is responsible for sample receipt and registration, handling, distribution to appropriate labs, forms review and documentation, workload tabulation, sample tracking, storage of results, and chain-of-custody protocols required to ensure an effective quality assurance program. The Office of the Division Chief serves as the main customer interface for all laboratory activities with regards to sampling, test scheduling, test methods, quality assurance/quality control protocols, turnaround times, data reporting formats, and sample retention and storage. The Trace Organics Section is the laboratory that routinely analyzes multi-media samples for volatile organic compounds such as MTBE.

Trace Organics Section: The Trace Organics laboratory routinely analyzes volatile and semi-volatile organic compounds in drinking water, wastewater, soils, sediments, sludges and hazardous wastes. The laboratory also analyzes petroleum contamination (gasoline or fuel oil) samples as a result of leaking underground storage tanks in water, groundwater and soils. The laboratory is presently equipped with purge and traps attached to capillary gas chromatographs and purge and traps attached to capillary gas chromatographs/mass spectrometers. U.S. EPA Methods 524.2, 624, 8260 and 8270 are currently the test methods being employed for the analysis of volatiles and semi- volatiles in multi-media samples. MTBE is currently added in the mixture of standard compounds being analyzed in environmental samples submitted for volatile organics testing using U.S. EPA Methods 524.2, 624 and 8260. The laboratory can analyze an average of 90 environmental multi-media samples per week for volatile organics, which includes MTBE. The laboratory has provided various program offices in the Maryland Department of the Environment with MTBE data since 1995.

Presently, the Trace Organics Section is carrying out revalidation studies for U.S. EPA Methods 524.2, 624, and 8260 with Ethyl Tertiary-Butyl Ether (ETBE), Tertiary-Amyl Methyl Ether (TAME), and Dissopropyl Ether (DIPE) included in the mixes. Method development and validation for Tertiary Butyl Alcohol (TBA) will begin after completion of the revalidation studies for the ethers. These studies will ensure a high level of precision and accuracy of results when determining the extent of contamination from the various gasoline oxygenates. The results will be repeatable and will ensure quality data is used to support the decision making process. However, in order to provide analytical services for TBA and to increase capacity beyond 90 samples per week for the gasoline oxygenates, MTBE, ETBE, and TAME, funding in the amount of $265,000 is needed to obtain the following additional resources:

- Gas chromatograph/mass spectrometer equipped with a headspace analyzer for the analysis of TBA in multi-media environmental samples. ($130,000)
- In the event of increased workload, i.e., more than 90 samples/week, additional gas chromatograph/spectrometer equipped with purge and trap for the analysis of MTBE, ETBE, and TAME in multi-media environmental matrices. ($120,000)
- Explosion-proof Refrigerator (1) and Freezer (1) with electronic security locks for the storage of samples and chemicals. ($7,200)
- Laboratory Supplies and Reagents including solvents, columns, chemicals, etc. ($7,800)

III. RECOMMENDATIONS FOR FUTURE STUDY

A. MTBE and Other Oxygenates of Concern

There are several other chemicals that have been less widely used to satisfy the oxygenate requirement. Like MTBE, they are commonly identified by the use of acronyms. These other chemicals include, but are not limited to, Ethyl Tertiary-Butyl Ether (ETBE), Diisopropyl Ether (DIPE), and Tertiary-Amyl Methyl Ether (TAME) and are collectively referred to as oxygenates. The Task Force will more fully identify issues relating to the use of these other oxygenates, including MTBE’s byproduct, Tertiary-Butyl Alcohol (TBA), in the coming year. A table comparing the properties of MTBE with these other oxygenates can be found in Appendix G. It should be noted that the presence of TBA has been detected in groundwater associated with petroleum releases in Maryland. The Task Force recommends the Maryland Department of the Environment continue its efforts to determine the extent of TBA contamination as well. The Task Force recognizes that specific sampling protocols normally published as U.S. EPA methods are not uniformly available for all of these other oxygenates, including MTBE’s byproduct, TBA. The Task Force encourages the Maryland Department of Health and Mental Hygiene to complete its revalidation study and TBA method development as soon as possible. The Task Force understands that the U.S. EPA is also moving in this direction to ensure that precision and accuracy of these sampling methods will yield repeatable consistent results.

B. MTBE Drinking Water Advisory Levels

The Task Force will continue to evaluate available MTBE health studies and will assist the Maryland Department of the Environment in reviewing the appropriateness of the use of the U.S. EPA’s current or future health advisory, presently at 20 to 40 parts per billion. At the time of the report preparation it was learned that the U.S. EPA intends on issuing a secondary drinking water advisory that is anticipated to be lower than the 20 to 40 parts per billion advisory level. This may have significant impact on the Department of the Environment’s and drinking water providers’ response to MTBE detection in drinking water. The Task Force will review the proposal and provide appropriate comment as necessary.

C. MTBE Investigation and Characterization Issues

The Task Force is encouraged by the reports of successful remediation of MTBE impacted groundwaters. It acknowledges the challenges of adequately characterizing the horizontal and vertical extent of an MTBE plume as a critical first step in selecting the appropriate remediation remedy. The Task Force encourages the Maryland Department of the Environment to continue its efforts to refine MTBE investigation techniques required of responsible parties with known petroleum releases into the environment. The Task Force recognizes that the results of the Department of the Environment’s Closed Case Assessment Project may significantly alter the known extent of MTBE/TBA groundwater contamination.

D. MTBE Sampling at Public and Domestic Wells

The Task Force recognizes that most domestic well supplies and transient non-community water systems that serve water to the public are not routinely sampled for MTBE. The Task Force believes that guidance should be developed for sampling these wells in areas of highest risk of contamination. Future recommendations should address issues related to laboratory capacity, sampling costs, and sampling responsibility.

E. MTBE Plan and Alternatives

The Task Force has determined that item nos. (3) and (4) outlined in the enabling legislation will be fully addressed in 2001. These items are: (3) Recommend a plan to minimize and counteract the environmental and health risks associated with ground and surface water contamination from MTBE; and (4) Explore alternatives to MTBE, including ethanol and other ether oxygenates, which can be used for the purpose of reformulation of gasoline to reduce air toxic emissions and pollutants that form ground level ozone. It is also recognized that the current state of MTBE knowledge is very dynamic and that updates to the information presented in this preliminary report will be necessary.

Appendix A

Task Force on the Environmental Effects of MTBE
Task Force Members

Task Force Members:

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District 30
Anne Arundel County

Delegate Mary Ann Love
District 32
Anne Arundel County

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District 16
Montgomery County

Senator Nancy Jacobs
District 34
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APPENDIX B

Brief Overview on the Toxicology of MTBE

Prepared by: James D. Yager, Ph.D., Professor of Toxicology, Johns Hopkins School of Public Health

The following definitions are provided to assist the reader:

- Carcinogenicity – the ability of an agent to cause a significant increase in the incidence of cancers.
- Dose response – the relationship between the dose of an agent to which a group of individuals (or sub-populations) is exposed and the responses being measured.
- Mutagenicity – the ability of an agent to cause the formation of mutations in genes encoded in DNA, typically by causing damage to the DNA molecule.
- Neurotoxicity – the ability of an agent to cause adverse effects on the nervous system, including death of nerve cells.
- No Observable Adverse Effect Level (NOAEL) – In any given dose response study, the NOAEL is the highest dose (level) administered where an adverse effect is not observed and an adverse effect is observed at an even higher dose or level.
- Toxicity – represents the spectrum of adverse biological effect(s) of an agent.
- Toxicokinetics – the study of various parameters that determine exposure of a substance to a target cell, organ, etc., including how and at what rates the substance is absorbed, distributed, metabolized, and eliminated by the organism.

Toxicokinetics of MTBE: (*Ref. 2*)

In humans, it has been determined that absorption after exposure by inhalation is rapid, as is absorption in experimental animals exposed by oral or inhalation routes. Metabolism and elimination in animals occurs rapidly. MTBE is O-demethylated to form Tertiary-Butyl Alcohol (TBA) and formaldehyde. TBA is also further metabolized in rodents to formaldehyde. TBA also undergoes conjugation with glucuronic acid and the conjugate is then eliminated through the kidney. TBA is also biotransformed to other metabolites, and formaldehyde is biotransformed to methanol, formic acid, and carbon dioxide. MTBE has a short 10-30 minute half-life in blood, although in humans, there is evidence that some tissue deposition does take place. There is no evidence that MTBE bioaccumulates in the food chain.

<u>Determination of the Human Equivalent Dose</u>

Insufficient data is available for development of an adequate toxicokinetic model for MTBE exposure. Thus, the U.S. EPA used a method selected by an interagency task force on MTBE to convert inhalation exposure concentration to dose values. This method was developed by the National Science and Technology Council and is referred to as the NSTC conversion method. The method assumes 100 percent absorption of the exposure. For a MTBE concentration of 1 part per million with exposure for 24 hours/day, 7 days/week, a human respiration rate of 20,000 liters/day and an average body weight of 70 kg, the human equivalent dose (HED) is 1.05 mg/kg body weight per day. For exposure conditions of 1 part per million for 6 hours/day, 5 days/week, which represents an occupational scenario, the HED calculates to be 0.1875 mg/kg per day.

Human Exposure:

MTBE has a distinct odor that can first be detected as an unidentifiable compound at approximately 0.18 mg/m^3 (approximately 50 parts per billion) and as MTBE at approximately 100 parts per billion (3). (Calculations based on m^3 being 1,000 liters (l) and 1 parts per billion equal to 1 ul/l [microliter/liter] or 1 ug/l assuming a density of one.)

Adverse effects of MTBE acute exposure on humans were first reported in 1992 in Alaska shortly after its use in reformulated gasoline was introduced to the region (*Ref. 3*). Several epidemiological studies were initiated in various areas including Alaska; Stamford, Connecticut; Albany, New York; and New Jersey. In these studies, blood levels of MTBE and categorization of possible levels of exposure based on occupation of amount of driving were compared with the various "illnesses" reported. The data is summarized in *Ref. 3* and in general, because of the limitations of the studies, the results of these studies to determine associations of exposures to MTBE with neurological effects (headache, dizziness, disorientation, fatigue, etc.), gastrointestinal disorders (nausea, diarrhea), and respiratory irritation symptoms were inconclusive (*Ref. 2*).

Studies were done with human volunteers exposed to low levels (1.4 or 1.7 parts per million) of MTBE for 1 hour. No significant adverse effects were detected (*Ref. 2*).

Non-cancer toxicity studies in experimental animals (*summarized in Ref. 2*) Because of the short time period required for preparation of the Preliminary Report, the primary references cited in the review have not been reviewed.

Acute and subchronic studies have been conducted in rats and mice using oral and inhalation exposure routes. The oral doses range from 100 mg/kg body weight per day to slightly over 1,400 mg/kg body weight per day. The main and most consistent effect detected was increased kidney weight. Because increased organ weight may reflect organ toxicity, this effect is considered an adverse effect. A No Observable Adverse Effect Level (NOAEL) of 100 mg/kg body weight per day was determined from these studies for increased kidney weight. These data were used to calculate a human no-effect drinking water concentration of 3,500 ug/l (3,500 parts per billion or 3.5 parts per million).

Reproductive effects of MTBE have been conducted using inhalation exposure. In a two-generation reproductive study, rats were exposed to MTBE at 0, 400, 3000, or 8,000 parts per million for 6 hours/day, 5 days/week for 10 weeks before mating and then during mating, gestation, and lactation days 5-21. Clinical signs of toxicity including reduced body weight were observed. The NOAEL for both parental and pup toxicity was 400 parts per million and the Lowest Observable Adverse Effect Level (LOAEL) was 3,000 parts per million. In a second similar one-generation study, a NOAEL of 300 parts per million and a LOAEL of 1,300 parts per million were observed, based on pup viability.

Developmental effects were investigated in 4 inhalation studies, one in rats, two in mice, and one in rabbits. The lowest MTBE concentration was 250 parts per million and the highest was 8,000 parts per million. No developmental toxicity was observed in the rats or the rabbits. Various effects were observed in the mice including dose-related skeletal malformations and resorptions. Based on the incidence of skeletal malformations, a NOAEL for developmental effects in mice was observed to be in the range of 250-1,000 parts per million. The developmental NOAEL values were used to calculate human no-effect drinking water concentrations of 2.3 to 9.2 mg/l (2.3 to 9.2 parts per million).

Neurotoxicity studies were done with acute inhalation exposure. At high concentrations, 4,000 and 8,000 parts per million, various effects including ataxia, labored respiration, decreased muscle tone, abnormal gait, etc. were observed. A NOAEL of 800 parts per million was observed, which calculates to a dose of 210 mg/kg body weight per day. This value allows calculation of a projected human no-effect concentration for neurologic effects of MTBE in drinking water of 7.4 mg/l (7.4 parts per million).

Mutagenicity studies were conducted using various test systems. With one exception, positive results in a mouse lymphoma assay (possibly due to the formaldehyde produced in the presence of microsomal enzymes), the overall weight of evidence indicates that MTBE is not mutagenic (*Ref. 2*).

Carcinogenicity studies, one inhalation study in mice, one in rats, and one oral dosing by gavage in rats, have been conducted. The results of the oral study were reported by Belpoggi et al. (*Ref. 4*). The doses used were 0, 250, or 1,000 mg/kg body weight/day, 4 days/week for 2 years. A dose-related increase in leukemia and lymphomas in females and an increase in testicular Leydig cell adenomas in the high dose males was observed. Survival was reduced in the low and high dose females. This report has been criticized, mainly because of the lack of inclusion of important experimental details in the report. In particular, there was no description of the morphological criteria used to classify the histopathological lesions.

In the inhalation studies in rats, F344 rats were exposed to 0, 400, 3,000, and 8,000 parts per million MTBE, 6 hrs/day, 5 days/week for 2 years. Survival time was significantly reduced in the males as a function of increased dose. Both males and females developed chronic, progressive nephropathy, and the males developed a dose-related increase in renal tumors. However, MTBE has been shown to be a mild inducer of alpha-2u-globulin (*Ref. 2 and 5*), although the extent to which this can account for or contribute to the kidney tumors in the male rats is unknown and requires further study. An increase in incidence of Leydig cell tumors was also detected. While male F344 rats have a high "spontaneous" incidence of these tumors, the increase observed in this study was statistically significant (*Ref. 2*). Furthermore, since the report by Belpoggi et al. (*Ref. 4*) also indicated that MTBE induced Leydig cell tumors in Sprague-Dawley rats, which have a low "spontaneous" incidence, it is likely that the increase in incidence of these tumors was due to the MTBE treatment (*Ref. 2*).

In the inhalation study in mice, CD1 mice were exposed to 0, 400, 3,000 or 8,000 parts per million MTBE for 6 hours/day, 5 days/week for 18 months. The high dose was clearly beyond the maximum tolerated dose since body weight and mortality at this exposure level were decreased. A significant increase was observed in hepatocellular carcinomas in the males and of hepatocellular adenomas in the females, although this was only at the highest level of exposure. Because MTBE is not a mutagen, it has been suggested by the National Research Council that MTBE is a "non-genotoxic" carcinogen (*Ref. 2*).

The U.S. EPA has used data from these three studies to calculate slope factors; although given the limitations of each of the studies, there is not a high level of confidence in these values. Furthermore, these values are likely overestimates of the true risk for developing cancer and thus the actual increase in risk for MTBE exposure may be lower or near zero. For the Belpoggi et al. (*Ref. 4*) study, the calculated slope factor is 2.8×10^{-3} to 4×10^{-3} mg/kg body weight per day, depending on the body weight scaling factor used. (The slope factor, calculated using the linearized multistage model, is the slope of the line of the upper bound confidence limit and represents the percent change in risk/mg/kg body weight). An LED10 of 35.6 mg/kg body weight per day and a drinking water concentration of 12 ug/l (12 parts per billion) for a risk of one in a million using the 2.8×10^{-3} slope factor was calculated. The slope factor from the renal tumors in male rats was calculated at 6×10^{-4} per parts per million, and from the CD1 mouse hepatocellular tumor incidence the calculated slope factor is 3×10^{-4} per parts per million.

Carcinogenicity of MTBE metabolites: Both TBA and formaldehyde have been investigated for carcinogenicity.

TBA studies have been done where F344 rats were exposed to TBA in their drinking water at 0, 1.25, 2.5 or 5 mg/ml for 2 years (*Ref. 2*). TBA caused an increase in nephropathy in all animals and an increase in renal tubular hyperplasia and adenomas and carcinomas in males. However, TBA has also been shown to increase alpha 2u-globulin levels (*Ref. 5*) and this may cause or contribute to the development of these tumors.

B6C3F1 mice were also studied. TBA was given in their drinking water at concentrations of 0, 5, 10 or 20 mg/l for 130 weeks. There was a suggestion of an increased in incidence of thyroid tumors in males and of thyroid follicular cell hyperplasia and adenomas in females. Survival was reduced in the high dose group. Together, these studies fail to show clear evidence of carcinogenicity (*Ref. 2*).

Formaldehyde has been tested for carcinogenicity in several studies using inhalation in rats and mice. Nasal tumors were produced in both male and female F344 rats at the highest dose (14.6 parts per million for 6 hrs/day, 5 days/week), but not in female B6C3F1 mice. In other studies, nasal tumor incidence was also increased in Sprague-Dawley rats at 14 parts per million and in Wistar rats at 10 parts per million. The International Agency for Research on Cancer (IARC) has concluded that there is sufficient evidence for the carcinogenicity of formaldehyde in rats. In drinking water studies with formaldehyde, the results have been mixed (*Ref. 2*).

Summary

A number of studies have been conducted to determine the non-carcinogenic toxicities, mutagenicity, and carcinogenicity of MTBE. For the non-carcinogenic toxicities, including effects on the kidney, reproduction, development and neurotoxicity, the lowest NOAEL was 100 milligrams/killigrams body weight per day for kidney toxicity. This value was used to determine a human no-effect level in drinking water of 3,500 parts per billion. The weight of evidence indicates that MTBE is not mutagenic. The carcinogenicity studies indicate that in two studies MTBE caused an increase in Leydig cell tumors, although the dose response nature of this effect was absent or weak in the studies. The effect of MTBE on leukemia and lymphoma requires independent conformation, and the effects on liver tumor incidence do not show a dose response. Finally, the increased incidence of renal tumors in male rats is accompanied by an increase in alpha 2u-globulin. The degree to which this effect contributes to the renal tumors caused by MTBE is unclear and requires further investigation. Since humans lack this protein, if the increase in renal tumors in the male rats is linked to the induction of this protein, it would be inappropriate to use this renal tumor data in a human exposure risk estimate.

While there are concerns with carcinogenicity data in hand to date, using the leukemia data from the Belpoggi et al (*Ref. 4*) study, the U.S. EPA estimated a very safe dose level for exposure to MTBE in water of 12 parts per billion. That is, it is estimated that this is the highest dose that would not increase the likelihood of increasing the incidence of cancer in exposed humans above one in one million.

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Appendix C

STATES THAT HAVE LIMITED MTBE USE	
Arizona	Phases out MTBE completely effective 180 days following phase-out in California
California	Phases out MTBE completely by December 31, 2002
Colorado	Phases out the use of MTBE by April 3, 2002
Connecticut	Phases out the use of MTBE by October 1, 2003
Iowa	Prohibits sale of gasoline containing more than 2 vol. % MTBE by February 1, 2000
Maine	Established a goal of phasing out MTBE use by January 1, 2003. Has pump labeling in the interim.
Michigan	Phases out MTBE use by June 1, 2003
Minnesota	Prohibits sale of gasoline containing more than 0.3 vol. % MTBE, ETBE, TAME. No amount of MTBE can be used to meet state's oxygenate requirement.
Nebraska	Prohibits sale of any petroleum product containing more than 1 vol. % MTBE
New York	Prohibits sale of gasoline containing MTBE effective January 1, 2004
South Dakota	Prohibits sale of gasoline containing 2 vol. % or more MTBE effective July 1, 2000

Reference: Renewable Fuels Association, October 31, 2000

APPENDIX D: Federal MTBE/Ethanol Legislation

Bill Number	Sponsor	Summary	Status
H.R. 11	Bilbray, CA	Amends Clean Air Act to permit the exclusive application of California State regulations regarding reformulated gasoline (RFG) in certain areas within the State. Would remove the federal 2.0 weight percent oxygen requirement in RFG.	House Commerce Health & Environment Subcommittee approved 9/30/1999. Pending before full Committee.
Hcon Res 256	Ewing, IL	Sense of Congress that Federal government should promote the continued use of ethanol in RFG; allow States the option of limiting the use of MTBE; and require U.S. EPA to revise Phase II RFG rules to allow ethanol to remain a viable oxygenate.	Referred to House Commerce Committee.
H.R. 1398	Pombo, CA	Would phase out "as promptly as possible" the use of MTBE as a fuel additive. Directs U.S. EPA to prohibit *any* additive in gasoline unless it has been determined not to have adverse effects on the public.	Referred to House Commerce Committee.
H.R. 1367	Franks, NJ	Amends Section 211 of the Clean Air Act to prohibit the use of MTBE in gasoline. Phases out the use of MTBE nationwide within 3 years.	Referred to House Commerce Committee.
H.R. 1705	Pallone, NJ	Amends the Clean Air Act to waive the oxygen content requirement for RFG and phase-out the use of MTBE nationwide within 3 years. Includes provisions to ensure current air quality benefits of RFG are maintained.	Referred to House Commerce Committee.
H.R. 3449	Greenwood, PA	Amends the Clean Air Act to provide northeast states a waiver of the requirements concerning the oxygen content of RFG. Limits MTBE to 5 percent by volume, and caps toxics at 27 percent.	Referred to House Commerce Committee.
H.R. 3798	Forbes, NY	Prohibits the use of MTBE with a nationwide phase-out no later than 1/1/2004. Amends the Solid Waste Disposal Act to accelerate the cleanup of MTBE and amends the Safe Drinking Water Act to assist communities with MTBE contamination.	Referred to House Commerce Committee.
H.R. 4011	Ganske, IA	Phases out the use of MTBE nationwide within 3 years. Provides flexibility within the RFG oxygenate requirement, caps aromatic content, and promotes the use of ethanol.	Referred to House Commerce Committee.
H.R. 4303	Ewing, IL	Prohibits the use of MTBE nationwide within 3 years and provides for remediation of water contaminated by MTBE.	Referred to House Commerce Committee.
S. Amdt. 1521	Boxer, CA	Sense of Senate to phase out MTBE use nationwide, promote ethanol as a replacement, and provide assistance for MTBE remediation.	Passed the Senate by a vote of 51-44, August 1999
S.645	Feinstein, CA	Amends Clean Air Act to waive the oxygen content requirement for RFG that results in no greater emissions of air pollutants than RFG meeting the oxygen content requirement.	Referred to Senate Environment & Public Works Committee.

Bill Number	**Sponsor**	**Summary**	**Status**
S. 1037	Boxer, CA	Amends the Toxic Substances Control Act to provide for a gradual reduction in the use of MTBE: 1/3 by 1/1/2001; 2/3 by 1/1/2002; eliminated by 1/1/2003.	Referred to Senate Environment & Public Works Committee.
S. 1886	Inhofe, OK	Permits the Governor of a State to waive oxygen content requirement for RFG and encourages development of voluntary standards to prevent and control releases of MTBE from underground storage tanks.	Referred to Senate Environment & Public Works Committee.
S. 2233	Fitzgerald, IL	Prohibits the use of MTBE nationwide within 3 years and provides for remediation of water contaminated by MTBE.	Referred to Senate Environment & Public Works Committee.
S. 2503	Daschle	Authorizes states to both control MTBE use and waive the RFG oxygen content standard. Caps aromatic content. Provides a national renewable energy standard and allows refiners to meet this standard by trading credits nationally. Provides for a nationwide MTBE phase-out by 1/1/2005.	Referred to Senate Environment & Public Works Committee.
S.2546	Bond	Phases out the use of MTBE within 3 years and provides pump labeling in the interim. Maintains the oxygen content requirement in RFG. Maintains air quality benefits of RFG and caps aromatic content.	Referred to Senate Environment & Public Works Committee.
S. 2723	Inhofe	Phases down the use of MTBE to 1 volume percent after 4 years and allows governors to waive the RFG oxygen content requirement.	Referred to Senate Environment & Public Works Committee.
S.2962	Smith	Phases out MTBE use in 4 years. Creates a national Clean Alternative Fuel Program, which includes a renewable fuel requirement. Allows governors to request a waiver from the RFG oxygenate requirement. Caps aromatic content and requires the U.S. EPA to study air quality impacts of eliminating the oxygen requirement (with authority to regulate to preserve emissions benefits of RFG).	Approved by Senate Environment & Public Works Committee by vote of 11-6 on 9/7/2000.
S. 2971	Harkin	Phases out the use of MTBE in 3 years with pump labeling in the interim. Maintains oxygenate requirement in RFG. Provides a renewable fuel content requirement. Maintains air quality benefits of RFG and caps aromatics and olefins. Prohibits MTBE in non-RFG areas by 1/1/2001.	Referred to Senate Environment & Public Works Committee.
S. 2884	Grams	Amends the Internal Revenue Code of 1986 to allow allocation of small ethanol producer credit to patrons of a cooperative.	Pending in the Senate Finance Committee.
H.R. 5279	Minge	Amends the Internal Revenue Code of 1986 to allow allocation of small ethanol producer credit to patrons of a cooperative.	Pending in the House Ways & Means Committee

Appendix E

State House Bills Introduced

Prepared by Renewable Fuels Association, Print Date: 10/31/2000

State	Bill	Introduced	Sponsor	Bill Title	Latest Action
ARIZONA	HB 2386 (Amendment)	02/02/2000	Government Reform Committee	Bill to prohibit sale of gasoline containing MTBE by 1/1/03; requires gasoline to meet EPA standards or qualify for waiver.	Pending in House Government Reform Committee
	SB 1504	01/27/2000	Bowers, Guenther	Bill to completely phase out the use of MTBE in the state no later than 180 days following complete phase-out of MTBE in California. Phase-out schedule due to Legislature and Governor by 1/1/01. Eliminates minimum oxygen requirement for RFG in the summer months.	**Signed by the Governor into law 4/28/2000.**
	HB 2652	01/26/2000	McGrath, Marsh et al	Bill to prohibit sale of gasoline containing MTBE by 1/1/01.	Session adjourned. No carryover.
	HB 2671	01/26/2000	Weason	Bill to prohibit sale of gasoline containing MTBE by 5/1/02 if EPA provides oxygenate waiver. Directs DEQ, Weights & Measures, and Air Quality planning organizations to coordinate waiver request.	Session adjourned. No carryover.
CALIFORNIA	A 129	01/06/1999	Oller	Makes it a misdemeanor to add MTBE to gasoline during the manufacturing or refining process or to sell or offer for sale gasoline containing MTBE.	Died in committee.
	A 1812	02/03/2000	Oller	Requires State Dept. of Health Services and Water Control Board to study effects on human health from MTBE leakage into groundwater and migration to surface water. Results due to Legislature by 1/1/02.	Pending in Appropriations Committee.
	A 2666	02/25/2000	Battin	Requests the University of California to study impacts of allowing gasoline that doesn't comply with CA's RFG standards to be used in the state. Provides that any gasoline approved for sale in the state by EPA be allowed for sale.	Pending in Appropriations Committee.
	S 272	02/01/1999	Leslie	Makes it a misdemeanor for any person to sell gasoline containing MTBE.	Returned to Secretary of Senate pursuant to Senate rules.
	SB 989	02/26/1999	Sher	Act requiring Water Resources Control Board to initiate UST program by 6/1/00. Authorizes state EPA to prohibit MTBE use prior to 12/31/02.	**Signed by Governor 10/10/1999.**

State	Bill	Introduced	Sponsor	Bill Title	Latest Action
CALIFORNIA	SB 529	02/19/1999	Bowen	Act prohibiting ARB from adopting any fuel regulations unless reviewed by Environmental Policy Council. Requires ARB to conduct peer review of Predictive Model and submit findings to Legislature by 7/1/00.	**Signed by Governor 10/10/1999.**
	SB 1971	02/25/2000	Mountjoy	Bill to amend Health & Safety Code. Requires State Energy Resources Conservation & Development Commission to develop timetable to phase out the use of MTBE between effective date of enactment of bill and 12/30/00. Requires total elimination of MTBE no later than 12/31/00.	Passed by Senate Environmental Quality Committee 7-3 with amendments 4/5/2000. Re-referred to Committee. Failed passage 4/24/2000. Reconsideration granted.
	SB 1972	02/25/2000	Mountjoy	Act appropriating $500,000 to University of California to study human health and environmental risks and benefits, as well as economic analysis to include transportation risks, oxygenates/alkylates, other than MTBE. Report due to Governor by 1/1/02.	Approved by Senate Environmental Quality Committee 10-1. Amended and re-referred to Committee.
	SB 1001	02/26/1999	Burton	Act requiring Energy Resource Development Commission to submit quarterly reports to Legislature summarizing MTBE use in gasoline.	**Signed by Governor 10/10/1999**
COLORADO	SB 190	02/07/2000	Feeley, Kaufman	Bill to prohibit sale of gasoline containing MTBE by 9/1/00. Amended to include MTBE phase-out by 4/3/02. Changes definition of alternative fuel to exclude RFG with MTBE. Institutes alcohol (but not MTBE) pump labeling for 2 vol. % and greater, effective 9/1/00.	**Signed by Governor 5/23/2000.**
	HJR 1042	04/13/2000	Paschall	Resolution recommending Congress amend Clean Air Act pursuant to recommendations of Blue Ribbon Panel. Amended to include concerns regarding limited research of health effects of ethanol.	Signed by President of the Senate 5/30/2000. Signed by Speaker of the House 6/1/2000.
CONNECTICUT	Raised SB 166	02/14/2000	DeLuca, Fritz	Bill to prohibit sale of gasoline containing MTBE.	Senate recommitted to Joint Committee on Environment 4/28/2000.
	SB 571		Nafis, DeLuca et al	Bill to phase out MTBE as gasoline additive over 5-year period to establish effective education campaign on proper handling and increase penalties for unlawful gasoline discharges. Amended to phase out MTBE by 10/1/03 and seek oxygenate waiver from EPA for purpose of discontinuing use of MTBE.	**Became Public Act 00-175 on 5/16/2000.**
	HB 5558	02/16/2000	DeLuca	Bill to prohibit use of MTBE as gasoline additive.	Passed House 4/28/00. Pending in Joint Environment Committee.

State	Bill	Introduced	Sponsor	Bill Title	Latest Action
DELAWARE	HR 77	04/05/2000	Oberle	Requests Division of Public Health set drinking water standard for MTBE.	Passed House 4/20/00.
FLORIDA	H 2447	04/28/2000	Lacasa	Requires Dept. of Environmental Protection conduct study relating to use of MTBE in the state and report findings to Legislature.	Identical to S 2484. Died in House 5/5/00. Reference deferred.
HAWAII	HB 3021	01/27/2000	Stegmaier	Bill to prohibit sale of gasoline containing MTBE, effective 7/1/00.	Passed by Senate 4/11/00. Approved by House with Senate amendments 5/2/00. Governor vetoed 6/8/00.
	H2205	01/25/2000	Morita	Authorizes counties to enact and enforce ordinances to require gasoline sold in county not contain more than 10% ethanol by vol.	Pending in House Agriculture Committee.
	SB 2221	01/21/2000	Chumbley, Matsunaga	Bill to provide credit for investment in qualifying ethanol production facility. Credit period provides maximum of 8 years for facilities with investment less than $50 million and 10 years for facilities with more than $50 million total investment.	**Became Public Act 289 on 6/30/00.**
	HB 2204	01/25/2000	Morita et al	Bill to create ethanol production tax credit, providing 40 cents/gallon qualified ethanol produced by qualified production facility.	Passed by the House on 3/7/00.
ILLINOIS	HB 2909	10/25/1999	Curry	Bill requiring fuel containing at least 2% vol. MTBE be labeled.	**Signed by the Governor 6/2/00.**
	H 2908	11/04/1999	Mitchell B	Provides that labels should be displayed on retail motor fuel dispensing equipment for fuel containing MTBE.	Pending in House Rules Committee.
	HR 377	05/29/1999	Granberg	Bill requesting Illinois EPA and Pollution Control Board ban the use of MTBE.	Pending in House Rules Committee.
	H 4712	03/23/2000	Mitchell B	Creates a $1.5 million appropriation to DNR to conduct comprehensive survey of MTBE in groundwater in the state.	Pending in House Rules Committee.
	H 4713	03/23/2000	Mitchell B	Amends Motor Fuel & Petroleum Standards Act to clarify state MTBE ban intended to aid phase-out of MTBE and protect groundwater, not restrict legitimate interstate commerce.	Pending in House Rules Committee.
	H 4718	05/15/2000	Mitchell B	Amends Motor Fuel & Petroleum Standards Act to clarify state MTBE ban intended to aid phase-out of MTBE and protect groundwater, not restrict legitimate interstate commerce. Requires retailers to display statement that fuel does not contain MTBE.	Filed with Clerk.

State	Bill	Introduced	Sponsor	Bill Title	Latest Action
ILLINOIS	H 4719	05/18/2000	Curry	Creates MTBE Elimination Act. Provides that 3 years after enactment of bill no person shall use, manufacture, or sell MTBE as a fuel additive or transport it in Illinois.	Filed with Clerk
	HJR 52	03/23/2000	Mitchell B	Requests State Water Survey Division of DNR conduct comprehensive survey of presence of MTBE in groundwater.	Pending in House Rules Committee.
	H 1279	02/17/1999	Johnson, Tim	Provides that EPA establish program of matching grants to retailers of E85 fuel for installation of tanks; grant shall be for lesser of 50% of cost of installation or $20,000.	Pending Senate Rules Committee.
	H 2937	11/16/1999	Johnson, Tim	Provides that EPA establish program of matching grants to retailers of E85 fuel for installation of tanks; grant shall be for lesser of 50% of cost of installation or $20,000; authorizes Agency to make grants to not more than 20 retailers begin FY 2000 and end 2003.	Pending in House Rules Committee.
	H 2938	11/16/1999	Johnson, Tim	Creates Agriculture Research Fund, which includes money for ethanol research.	Pending in House Rules Committee.
	HJR 69	04/13/2000	Mitchell B	Urges EPA to keep oxygenate requirement in Phase 2 RFG.	Pending in House Rules Committee.
	HR 303	05/14/1999	Curry	Supports Governor's decision to engage Administrator of EPA in dialogue regarding Phase 2 RFG.	**Adopted by House 5/21/99.**
	HR 637	02/29/2000	Smith	Supports Governor's decision to engage Administrator of EPA in dialogue in reading Phase 2 RFG.	Pending in House Rules Committee.
	HR 645	03/02/2000	Smith	Supports technical challenge of using ethanol in Phase 2 RFG; memorializes EPA to permit continued use of ethanol.	Pending in House Rules Committee.
	SR 133	05/14/1999	Noland	Supports Governor's decision to engage Administrator of EPA in dialogue regarding Phase 2 RFG.	**Adopted. Effective 5/26/99.**
	HR 578	02/09/2000	Woolard-Curry et al	Bill urging U.S. Congress to pass legislation banning the use of MTBE.	Pending in House Rules Committee.
IOWA	HF 772			Bill to prohibit the sale of fuel containing more than 2% vol. MTBE beginning 2/1/00.	**Adopted. Effective 7/1/99.**
	H 2304	02/16/2000	Agriculture	Requires retail dealers to install only motor vehicle fuel and storage tank equipment compatible with ethanol	Second session adjourned. No Carryover.
	HSB 772	02/22/2000	Agriculture	Requires availability for sale of ethanol blended gasoline.	Second session adjourned. No Carryover.

State	Bill	Introduced	Sponsor	Bill Title	Latest Action
IOWA	SF 2448	04/05/2000	Ways & Means	Bill requiring ethanol be offered for sale in one of the blends available at each service station by Jan. 2001. Also includes tax refund for businesses that promote value-added agricultural projects, ban on MTBE use in gasoline, and two studies of ethanol availability and marketing.	Passed Senate by vote of 28-20 on 4/17/00. Referred to House Appropriations Committee.
	SF 2356	02/28/2000	Agriculture	Bill to prohibit sale of MTBE in gasoline.	Second session adjourned. No Carryover.
	SCR 102	01/10/2000	Iverson	Urges the Present and Congress to immediately take action to prohibit use of MTBE.	Second session adjourned. No Carryover.
	SCR 111	03/13/2000	Natural Resources	Requests U.S. Congress to maintain commitment to clean air and ethanol industry by maintaining oxygenate requirement in RFG.	Second session adjourned. No Carryover.
	SSB 3139	02/15/2000	Natural Resources	Requests U.S. Congress to maintain commitment to clean air and ethanol industry by maintaining oxygenate requirement in RFG.	Second session adjourned. No Carryover.
	HSB 537	01/31/2000	Agriculture	Requests Congress maintain commitment to clean air and ethanol industry by maintaining federal oxygenate requirement in Clean Air Act.	Second session adjourned. No Carryover.
	H 290	02/16/1999	Greiner	Prohibits a person from dispensing gasoline other than oxygenated gasoline on retail basis.	Second session adjourned. No Carryover.
	H 2107	02/01/2000	Greiner	Requires retailers to install only motor vehicle fuel storage tank equipment compatible with storage and dispensing of ethanol.	Second session adjourned. No Carryover.
	SR 127	04/24/2000	Natural Resources	Resolution requesting study relating to increased demand and availability of renewable and reformulated fuel.	**Adopted by Senate 4/25/00.**
	SSB 3238	04/24/2000	Natural Resources	Requests an interim study of issues relating to increasing the demand and availability of renewable reformulated fuel.	Second session adjourned. No Carryover.
	SSB 3118	02/09/2000	Natural Resources	Provides rebates for purchase of gasoline blended with ethanol.	Second session adjourned. No Carryover.
	HF 2294	02/16/2000	Kuhn	Bill prohibiting sale or storage of MTBE after 12/31/00 requiring additional testing and labeling of gasoline containing 1% vol. oxygenates.	Second session adjourned. No Carryover.
KANSAS	H 2859	02/03/2000		Bill prohibiting sale of motor vehicle fuel containing MTBE and providing penalties for violations.	Died in House Environment Committee 5/24/00.
	HCR 5077	03/23/2000	Environment	Encourages U.S. Congress to authorize the use of ethanol in RFG.	Pending in Committee.

State	Bill	Introduced	Sponsor	Bill Title	Latest Action
KANSAS	S 469 Substitute	01/24/2000	Corbin	Bill prohibiting on or after 7/1/02 delivery of fuel containing more than 0.5% by vol. MTBE to service stations. On or after 7/1/03 prohibits delivery of fuel containing more than 0.5% by vol. MTBE to pump.	Died in Committee on Energy and Natural Resources 5/24/00.
KENTUCKY	HB 849	02/25/2000	Fischer	Bill to ban the use of MTBE in gasoline. Allows counties to ban the use of MTBE if approved by a majority of the public.	Regular session adjourned; No carryover.
	HB 781	02/22/2000	Clark, Stacy	Bill to ban the sale of motor fuel containing MTBE after 12/31/00.	Regular session adjourned; No carryover.
	SJR 68	02/14/2000	Seum	Bill prohibiting sale of MTBE; directs Natural Resources and Environmental Protection Cabinet to determine the presence of MTBE in State's drinking water and to develop MTBE drinking water standards; report due to Assembly 1/1/01.	Regular session adjourned; No carryover.
	HR 151	03/09/2000	Richards	Bill to encourage recognition of the benefits of ethanol as an effective alternative to MTBE.	**Adopted by House unanimously 3/23/00.**
	HRJ 70	01/17/2000	Webb et al	Resolution directing Public Protection and Regulation and Natural Resources and Environment Protection Cabinet to enter into a memorandum of understanding to better coordinate underground petroleum storage tank program responsibilities; requires reporting to General Assembly.	**Signed by Governor 3/15/00.**
MAINE	H 11 (LD 21)	12/21/1998	Tripp	Bill prohibiting sale of gasoline containing MTBE. Amended to require MTBE pump labeling and require state Dept. of Environmental Protection to monitor and report levels of MTBE brought into the state; directs DEP to develop alternatives to MTBE; establishes goal for MTBE phase-out of 1/1/03.	**Signed by Governor 4/14/00; Public Law 709.**
	H 855 (LD 1212)	02/11/1999	Tripp	Requires Board of Environmental Protection to adopt rules requiring use of low-sulfur fuel; fuel cannot contain MTBE.	Second session adjourned; No carryover.
	H 908	02/16/1999	Green	Adds ethanol production or processing facilities as business that qualifies for funding under Small Enterprise Growth Program.	Second session adjourned; No carryover.
	H 1492	03/30/1999	Daigle	(Joint Resolution) Memorializes Congress to remove 2% weight oxygenate requirement.	**Adopted by Senate 4/5/99.**
	H 1032 (LD 1454)	02/23/1999	Kneeland	Establishes Agriculturally Derived Fuel Fund to promote production and use of ethanol and methanol from agricultural biomass.	**Signed by Governor 6/11/99; Public Law No. 474**

State	Bill	Introduced	Sponsor	Bill Title	Latest Action
MAINE	LR 3724	11/15/1999	Carey	Encourages biomass ethanol in Maine.	Second session adjourned; no carryover.
	H 665 (LD 921)	02/02/1999	Goodwin	Requires Governor to petition federal government to end requirement for sale of RFG in certain counties of the state.	Second session adjourned; no carryover.
MARYLAND	HB 823	02/11/2000	Clagett et al	Bill to establish Task Force on effects of MTBE; assess risks associated with ground and surface water contamination; requires recommendation of plan to counteract health risks associated with MTBE groundwater contamination.	**Signed by the Governor 5/11/2000.**
	H 1372	02/23/2000	Guns	Establishes Task Force to study potential to expand the use of ethanol as an alternative fuel.	Regular session adjourned; no carryover.
	HJR 13	02/11/2000	Owings	Resolution requesting Congress repeal Clean Air Act oxygenate requirement. Urges EPA to provide more aggressive enforcement of underground storage tank regulations.	Regular session adjourned; no carryover.
MASSACHUSETTS	H 5245	06/14/2000	Atsalis	Regulates sale of gasoline in Barnstable County and all other areas in the state most vulnerable to MTBE contamination.	Pending in Joint Commerce and Labor Committee.
MICHIGAN	HB 4805	06/17/1999	Johnson et al	Bill to amend motor fuel quality act to require labeling of "additives" in fuel.	Pending in Committee on Transportation
	HB 5570	04/12/2000	Julian et al	Bill to establish standards for amount/type of additives allowed in gasoline; prohibits use of MTBE in the state as of 6/1/03.	**Signed by Governor 6/26/00; Public Act No. 206**
	HCR 34	04/28/1999	Ehardt	Urges state government agencies to use bio-based products as a source of oil and diesel fuel whenever possible.	Passed Senate 5/13/99.
	HR 77	04/28/1999	Ehardt	Urges state government agencies to use bio-based products as a source of oil and diesel fuel whenever possible.	Passed House 4/28/99.
	S 1270	05/16/2000	Rogers	Prohibits the use of MTBE.	Pending in Senate Transportation and Tourism Committee.
MINNESOTA	HF 3131	02/10/2000	Osthoff	Bill to prohibit use of MTBE as an oxygenate in gasoline.	Session adjourned; no carryover.
	SF 2946		Vickerman	Bill prohibiting sale of gasoline containing MTBE. No amount of MTBE can be used to meet state's oxygenate requirement. Conference Committee limited use of MTBE, ETBE, and TAME to 0.3% by vol. Effective 7/1/00.	**Signed by Governor 4/24/00.**
	HF 3292		Dorman	Bill prohibiting sale of more than 0.1 of 1% MTBE, ETBE, or TAME in gasoline after 7/1/00.	Session adjourned; no carryover.

State	Bill	Introduced	Sponsor	Bill Title	Latest Action
MINNESOTA	HF 3702	02/21/2000	Harder	For individuals, estates, and trusts, there shall be subtracted from federal taxable income the amount of the federal alcohol fuel credit included in gross income under Section 87 of Internal Revenue Code.	Session adjourned; no carryover.
	SF 3305	02/16/2000	Price	Bill to prohibit retail sale of gasoline containing MTBE.	Session adjourned; no carryover.
MISSOURI	HB 1801	01/27/2000	Myers, Black	Bill requiring metropolitan areas with more than 300,000 inhabitants to phase out RFG with MTBE and use RFG containing 10% ethanol. Replacement process to begin 1/1/02 and be completed by date established in rules by the Dept. of Agriculture. Other counties and municipalities may adopt this replacement plan or develop their own plan.	Public hearing in Environment and Energy Committee 2/17/00.
	SCR 23	01/18/2000	Klarich	Resolution directing DNR to assess contamination of ground and surface water from MTBE in St. Louis. Report findings to Legislature and Governor no later than 4/15/00.	Adopted by Senate, sent to House 2/23/00. Referred to Environment and Energy Committee 2/23/00.
	HB 1601		Leake	Bill to require sellers of motor fuel containing an oxygenate to label type of oxygenate used.	Passed Environment and Energy Committee with amendments 4/6/00.
	SB 966	02/03/2000	Kinder	Bill similar to HB 1801. Requires metropolitan areas with more than 300,000 inhabitants to phase out RFG with MTBE and use RFG containing 10% ethanol. Replacement process to begin 1/1/02 and be completed by date established in rules by the Dept. of Agriculture. Other counties and municipalities may adopt this replacement plan or develop their own plan.	Referred to Senate Commerce Environment Committee 2/14/00.
	HCR 32	04/03/2000	Loudon	Urges Governor to allow St. Louis to opt out of RFG program until a safer substitute for MTBE is found.	Pending in House Environment and Energy Committee.
	HB 2039	02/17/2000	Wiggins	Bill requiring 50% of gasoline sold in Missouri after 8/28/03 contain at least 2.7% oxygen by weight. After 8/28/05, requirement is 75%. After 8/28/07, all gasoline sold in Missouri must contain this amount of oxygen, with exceptions.	Environment and Energy Committee; public hearing held 3/2/00.
NEBRASKA	LB 1234	01/12/2000	Schrock, Aguilar, Baker, et al	Bill requiring all gasoline stations offer ethanol-blended gasoline in lowest octane rating available by 10/1/00. Amended to create Ethanol Pricing Task Force to examine practices, policies, and methods prices are set, including comparison of ethanol prices to other motor fuels in the state.	**Signed by Governor 4/12/00.**

State	Bill	Introduced	Sponsor	Bill Title	Latest Action
NEBRASKA	LB 1234	01/12/2000	Schrock, Aguilar, Baker, et al	Report due to Legislature on 12/1/00. Also bans sale of any petroleum product containing more than 1% vol. MTBE.	**Signed by Governor 4/12/00.**
	LR 382	03/27/2000	Schrock	Studies the effects of MTBE on the environment.	2nd session adjourned; no carryover
	L 389	01/13/1999	Schrock	Provides oxygenated gasoline sale requirements.	2nd session adjourned; no carryover
NEW HAMPSHIRE	HB 1569	01/05/2000	Martin et al	Bill to require DES to propose voluntary testing program of public water supplies for MTBE and study the amount of MTBE in gasoline.	**Signed by the Governor 4/12/00.**
	HB 1414	08/01/1999	Bradley	Bill to authorize DES to discuss with other northeastern states the use of a regional gasoline with less or no MTBE. Extends reporting date of MTBE study to 11/1/00.	**Signed by the Governor 6/21/00.**
	HJR 24	01/05/2000	Bradley	Resolution urging EPA and Congress to work with northeastern states and gasoline refiners to authorize the use of a regional gasoline containing less or no MTBE and eliminate the Clean Air Act requirements for oxygenates in gasoline.	**Signed by the Governor 6/1/00.**
	SB 70		Wheeler	Act requiring Commission of Health and Human Services to initiate drinking water standards for MTBE no later than 1/1/00. Requires any public water system delivering water having greater than 5 ppb MTBE to notify customers of MTBE content.	**Signed by the Governor 7/16/99.**
	HJR 9	02/10/1999	MacGillivray	Urges Congress to eliminate the oxygenate requirement of Clean Air Act; urges EPA to grant waivers to permit substitution of conventional gasoline for RFG without requiring substitute air emission reduction strategies.	**Signed by the Governor 6/25/99.**
	SB 71	05/20/1999	Wheeler	Bill to prohibit sale of gasoline containing MTBE and requiring Commissioner of Environmental Services to develop timetable for removal of MTBE from gasoline by 4/1/00, but not later than 1/1/03.	Passed by Senate 5/20/99. Defeated by House 1/6/00.
NEW JERSEY	A 218	01/11/2000	Gregg et al	Bill to prohibit sale of gasoline containing MTBE after enactment of certain federal legislation.	Referred to Assembly Environment Committee.
	A 1667	01/11/2000	Asselta	Bill to direct DEP to phase out the use of MTBE in gasoline.	Referred to Assembly Environment Committee.
	A 1923	01/27/2000	Rooney	Bill to prohibit sale of gasoline containing MTBE or any other ether.	Referred to Assembly Environment Committee.
	A 2282	03/23/2000	Asselta	Directs DEP to assess groundwater contamination from MTBE; determines measures to mitigate and remediate contamination; appropriates funds.	Pending in Assembly Environment Committee.

State	Bill	Introduced	Sponsor	Bill Title	Latest Action
NEW JERSEY	AR 112	03/27/2000	Merkt	Memorializes Congress to enact legislation to repeal all federal mandates requiring the use of oxygenates.	Pending in Assembly Environment Committee.
	AR 124	05/22/2000	Crecco	Opposes the use of MTBE and urges all branches of federal and state government to work towards limiting and banning the use of MTBE.	Pending in Assembly Environment Committee.
	S 527	01/11/2000	Littell, Bennett	Bill to prohibit sale of any gasoline containing MTBE or any other ether.	Referred to Senate Environment Committee.
NEW YORK	AB 5513	02/25/1999	DiNapoli	Bill to prohibit sale of MTBE by 1/1/04; imposes civil penalties of between $500 and $10,000.	**Signed by the Governor 5/24/00.**
	AB 9215	01/05/2000	Labriola	Bill to create the MTBE Public Health & Environmental Protection Act of 2000 to assess health and environmental risks and benefits of MTBE compared with ETBE, TAME, and ethanol. Appropriates $500,000.	Referred to Environmental Conservation Committee.
	S 6137	09/20/1999	Marallino	Bill to prohibit sale and dispensing of gasoline containing MTBE. Imposes civil fine of $500 to $10,000.	Substituted by A5513.
	SB 1369		Johnson	Bill to prohibit the import, sale, dispensing, and offering for sale of gasoline ethanol; imposes civil penalty of $500 to $10,000 for violation.	Amended and recommitted to Environmental Conservation Committee 5/10/00.
PENNSYLVANIA	H 2506	05/02/2000	Melio	Prohibits sale of liquid fuels and fuels containing MTBE.	Pending in House Judiciary Committee.
	SR 142	03/08/2000	Wagner	Memorializes the President and Congress to repeal oxygenate content requirements of Clean Air Act. Encourages reliance instead on clean-burning non-oxygenate fuel formulations that meet air quality standards of Clean Air Act.	**Adopted by Senate 3/21/00.**
RHODE ISLAND	HR 6989	01/26/2000	Montanaro et al	Resolution requesting Dept. of Environmental Management to investigate MTBE and determine if state should regulate or ban its use.	**Adopted by House 2/1/00.**
	H 7999	03/07/2000	Ginaitt	Resolution requesting Congress remove 2.0 % weight oxygen requirement in gasoline.	**Adopted by House 6/7/00.**
SOUTH DAKOTA	HB 1124	01/18/2000	Diedrich et al	Bill to prohibit sale of gasoline containing 2% or more by volume MTBE.	**Signed by Governor 2/16/00.**
	SB 121	01/19/2000	Kloucek et al	Bill to require sale of gasoline containing at least 2.7% oxygen by weight beginning 7/1/01.	Legislative Assembly adjourned; no carryover.
	H 1132	01/18/2000	Nachtigal	Prohibits use of MTBE as a gasoline oxygenate.	Legislative Assembly adjourned; no carryover.
	S 91	01/18/2000	Hutmacher	Requires the use of ethanol blended fuel in certain state vehicles.	Legislative Assembly adjourned; no carryover.

State	Bill	Introduced	Sponsor	Bill Title	Latest Action
VIRGINIA	HB 909	01/24/2000	Cranwell	A substitute amendment to provide localities authority to regulate and inspect public and private water supplies. Requires testing for MTBE and notification of MTBE in excess of 15 ppb. Effective 7/1/00.	**Signed by Governor 4/9/00.**
WASHINGTON	HB 2421	01/12/2000	Pennington Et al	Prohibits intentional addition of MTBE to gasoline as of 12/31/02. MTBE may not be present above 0.6 of 1% volume.	Passed by Agriculture and Ecology Committee 2/4/00. Referred to Transportation Committee.
WEST VIRGINIA	SB 441	02/10/2000	Kessler, Snyder	Bill to prohibit sale of gasoline, liquid fuels, lubricating oils or similar products containing MTBE.	Legislature adjourned; no carryover.
WISCONSIN	AB 838	03/07/2000	Hoven	Bill prohibiting sale of gasoline to which MTBE has been added.	Failed to be considered before end of session.
	AJR 12-	03/22/2000	Kedzie	Requests Congress and EPA act to bring about elimination of use of MTBE and to ensure it is not used in RFG in the non-attainment area this summer (2000).	Failed to be considered before end of session.
	AB 718		Huebsch	Bill to provide a producer incentive payment of 20 cents/gallon to qualified ethanol producers during first 60 months of production, for not more than 15 million gallons beginning 7/1/00. Producers must produce a minimum of 10 million gallons/year. Program expires 6/30/05.	**Signed by Governor 4/11/00.**

APPENDIX F

REMEDIATION METHOD REVIEW

Ex-situ or Aboveground Treatment Technologies

The most common remediation method used today for contaminated groundwater is a "pump and treat" system where contaminated groundwater is withdrawn from the subsurface and then treated above ground before it is re-injected back into the ground. The treatment technologies used for removal of organics or MTBE from the groundwater are given below with a brief description:

- Granular activated carbon (GAC) is a standard adsorption medium to remove any organic from groundwater. A typical system will take groundwater as it is being pumped from the subsurface and pass it through a unit containing activated carbon that in turn adsorbs the organics from the water. The GAC canister, once completely saturated with contaminants, must be either recharged by removing the contaminants or disposed of properly such as in an appropriate landfill. Activated carbon has been found to be less effective at removing MTBE than compared to other organic contaminants.

- Synthetic resin sorbents are an option to the GAC technology. They have proven very successful with MTBE removal since MTBE has a higher absorption coefficient for these sorbents.

- Airstripping has proven very successful for removing organics in general, but it has been less effective with MTBE due to its higher solubility than other volatile contaminants. In this system, water passes through a packed column in which air is injected against the flow. Due to the volatilization characteristics of organics, the contaminants volatilize out of the water.

- Oxidation processes are typically used to treat groundwater, either as stand-alone systems or in conjunction with GAC units. These processes include chemical or advanced oxidation that use compounds such as hydrogen peroxide, ozone or catalysts to oxide the organics in the groundwater to carbon dioxide, and water. UV light and thermal catalytic oxidation are other oxidative methods. By passing groundwater through GAC units and then oxidation processes, up to 100 percent of the contaminants can be removed before the water is pumped to users. Many of these methods have proven very effective against MTBE. However, in initial studies, the formation of MTBE byproducts or intermediates during the oxidation process remains a concern.

- High-energy electron injection (sometimes called electron beam technology) is an advanced oxidation process that is extremely effective at destroying MTBE. Additionally, the degradation intermediates of MTBE, which are tertiary butyl alcohol (TBA) and tertiary butyl formate (TBF), are also degraded in the process. More research and testing of this technology is occurring at the Port Hueneme test facility.

- A Hollow Fiber Membrane coupled with an internal combustion unit (ICU) is an innovative technology for MTBE removal presently being tested by the University of California Santa Barbara and Remediation Service International at Port Hueneme. Contaminated water passes through hollow fibers while a vacuum is applied to outer fibers. The vacuum draws out the organics in the water and then the organics are destroyed in the ICU.

- Biofilters are used to biodegrade MTBE in the air phase. In this technology, biodegradation occurs by passing air through filters treated with appropriate microbial cultures. This technology has been successfully used in Richmond, California, and by the Los Angeles County Sanitation Districts Joint Water Pollution Control Plant in Carson, California.

Surface waters, such as rivers or lakes, can also be treated with the same technologies. MTBE concentrations tend to be much lower in these reservoirs, however compared to groundwater due to the volatilization of MTBE at the air/water interface.

In-situ or Subsurface Treatment Technologies

Some of the most successful and cost-effective technologies for treating gasoline components in groundwater are listed below. These remediation techniques are readily available today and are frequently used on the worse contamination problems. In this section they are divided into physical treatment processes: bioremediation techniques and phytoremediation processes.

Physical treatment process:

- Soil Vapor Extraction (SVE) is applied to the vadose, or unsaturated, zone in the ground. A vacuum is applied in the subsurface to remove gas-phase volatiles from the soil through extraction wells. Sometimes this removal process is greatly enhanced by adding thermal systems. The heat drives the volatiles off of the soils and then the vacuum system draws the volatiles out of the soils. Heat is added to the subsurface by radio frequency heating, resistance heating, or through steam injection.

- Air Sparging is a technique that injects compressed air into the saturated zone or below the water table. This method removes organic contaminants from soils and groundwater by: 1) volatilizing the organics in the water or trapped in the soils or capillary fringes; 2) stripping the dissolved organics out of the water; and 3) enhancing the natural biodegradation of the contaminants. The technique is most effectively used in soils that are loosely packed, such as sand and gravel, where the air can freely migrate to the surface carrying the volatile compounds with it. Sometimes SVE and air sparging are applied together for more effective treatment.

- Bioventing is another technique of injecting air or oxygen, but the emphasis in this method is on low flow rates to supply oxygen where the microbial activity is occurring in the unsaturated zone for the purpose of enhancing any ongoing natural bioremediation.

- Dual Phase Vaccum Extraction (DPVE) uses one pump to extract both groundwater and vapors, thus increasing the zone of influence for one well.

- In-situ soil flushing involves injecting surfactants, which are compounds used to breakup solvents, and then pumping the residual contaminated groundwater back out of the ground. This process is considered an in-situ soil-washing scheme. The selection of an appropriate surfactant must be carefully matched with the target contaminant for effective removal.

- In-situ chemical oxidation can be applied to the subsurface in both the vadose and saturated zones. The technique is designed to chemically breakdown the contaminants within the soils. The chemicals used for ex-situ oxidation, cited above, are the same chemicals selected for injection into the subsurface and operate on the same principles. Chemical oxidation, whether above ground or in-situ, has been shown to be an effective remedy for MTBE.

In-situ Bioremediation

- By far the most cost-effective treatment for contaminants trapped in soils or groundwater is bioremediation. Natural attenuation (or bioremediation) is a natural process occurring in the ground, which decreases contaminant concentrations by degradation from subsurface microorganisms. The natural indigenous microbes typically degrade the BTEX compounds more effectively however than MTBE. Case studies have shown that a BTEX subsurface plume might be retarded from migration by bioremediation, but MTBE continues to migrate from the source.

- Enhanced bioremediation schemes are used to increase the effectiveness of the degradation by the soil microbes. Enhancing techniques include injecting air or oxygen for aerobic biodegradation, or hydrogen or nitrogen for anaerobic biodegradation. Some microbial activity is enhanced in oxidative or oxygen environments while others are enhanced in reductive or hydrogen environments. In the case of MTBE, the most effective remediation methodology demonstrated today is oxygen-enhanced bioremediation or aerobic remediation. Anaerobic methods have proven effective at breaking down other organics, particularly chlorinated solvents, but not MTBE.

- Other bioremediation enhancing methods include injecting nutrients for the microbes, or injecting specific microbes known to preferentially breakdown MTBE. Several studies are being tested today with specific isolated microbes known to effectively degrade ethers in general or MTBE specifically. For example:

  1) Equilon Enterprises and Arizona State University are presently testing the effectiveness of MC-100, ether-degrading microbes at the Navy testing facility. They are injecting into the ground a biomass slurry suspension containing MC-100 and a pure strain of PC-100, another isolated ether-degrading microbe taken from the MC-100 culture.

2) The University of California at Davis and the University of Waterloo are jointly conducting a study at the Navy facility on the effectiveness of a pure bacterial culture of PM1 on MTBE. This bacteria has been shown to be very effective against MTBE since it uses MTBE as its carbon or energy source.

3) Envirogen Inc. is testing at the Navy facility the viability of a propane-oxidizing bacteria which produces an enzyme that catalyzes the destruction of MTBE. In this case, propane and oxygen are being injected into the groundwater, which promotes the growth of the propane-oxidizing bacteria.

A complete listing of MTBE biodegradation studies are given in Anthony et al., (1999).

Studies have shown that microbe enhanced biodegradation can significantly reduce or eliminate organics, including MTBE, in a matter of weeks as compared to years! Thus there is enormous effort in the research community to find and isolate the appropriate microbes that can degrade MTBE specifically.

Phytoremediation

- This is another in-situ method where trees are used to reduce contaminants in the soil. This can occur via three processes:

1) Trees can uptake the contaminant in their root systems and eventually release the contaminant vapor to the atmosphere by transpiration of water through the leaves;

2) By stimulating microbial activity around the root system, which in turn degrades the contaminant; or

3) By mineralization of the contaminants within the vegetative tissues after uptake by the roots. Alternatively, the trees can take up the groundwater and effectively de-water the area, which has the effect of retarding the migration of the contaminant.

The effectiveness of phytoremediation is also being studied at the Navy facility.

This description of MTBE remediation techniques is not intended to be inclusive of all methods, but rather to give a sense of the many techniques that have been tried and found successful at treating or destroying MTBE. Equally important is the extensive amount of research that is being performed today to increase our knowledge base of what methods are most effective and which ones should no longer be considered for use against MTBE. Additionally, there are studies that provide comparisons of costs for each type of MTBE remediation method [Jacobs, et. al. (2001); Stocking, et. al. (2000); Keller, et. al. (1998)].

References:

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4. James Jacobs, Jacques Guertin, and Christy Herron, editors; *MTBE: Effects on Soil and Groundwater Resources*; Lewis Publishers, 2001.

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Appendix G

The Properties of Benzene, MTBE, TBA, ETBE, DIPE, and TAME

	Benzene	Methyl Tertiary Butyl Ether (MTBE)	Tertiary Butyl Alcohol (TBA)	Ethyl Tertiary Butyl Ether (ETBE)	Diisopropyl Ether (DIPE)	Tertiary Amyl Methyl Ether (TAME)
Synonyms		1) Tertiary butyl methylether 2) 2-methoxy-2-methl propane	1) Tertiary butanol 2) Trimethyl methanol 3) Tertiary-butanol 4) 1,1-Dimethyl ethanol	1) Tertiary-butyl ethyl ether 2) Ether, tertiary-butyl ether	1) Isopropyl ether 2) 2,2'-oxybispropane 3) 2-isopropoxypropane	1) Methyl tertiary-pentyl ether 2) Ether methyl tertiary pentyl 3) 1,1-dimethyl propyl methyl ether
Molecular Weight (g/mol)	78.11	88.15	74.12	102.2	102.2	102.2
Density (g/L)	0.88	0.74	0.79	0.74	0.77	
Chemical Formula	C_6H_6	$CH_3OC(CH_3)_3$	$(CH_3)_3COH$	$(CH_3)_3COCH_2CH_3$	$(CH_3)_2CHOCH(CH_3)_2$	$CH_3CH_2C(CH_3)_2OCH_3$
Boiling Point (°C)	80.1	55.2	82.4	72.2	68.2	86.3
Neat Solubility (g/100g H_20)	0.178	4.8	Miscible	1.2	0.2	1.2
Vapor Pressure (mm Hg @ 20°C)	73	240	41	130	159	75
Taste Threshold in Water (ug/L)	500	20-40	N/A	47		128
Odor Threshold (ppm)	0.5	0.053	21	0.013		0.027
CAS Registry No.	71-43-2	1634-04-4	75-65-0	637-92-3	108-20-3	994-05-8
State	Liquid	Liquid	Crystal	Liquid	Liquid	Liquid

References: U.S. EPA Blue Ribbon Panel on Oxygenates in Gasoline Report, September 15, 1999
EPA Doc/600/R-98/048, Oxygenates in Water: Critical Information and Research Needs