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Achieving Clean Air and Clean Water:

The Report of the Blue Ribbon Panel on Oxygenates in Gasoline

September 15, 1999

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CHAPTER 1. EXECUTIVE SUMMARY

The Federal Reformulated Gasoline Program (RFG) established in the Clean Air Act Amendments of 1990, and implemented in 1995, has provided substantial reductions in the emissions of a number of air pollutants from motor vehicles, most notably volatile organic compounds (precursors of ozone), carbon monoxide, and mobile-source air toxics (benzene, 1,3-butadiene, and others), in most cases resulting in emissions reductions that exceed those required by law. To address its unique air pollution challenges, California has adopted similar, but more stringent requirements for California RFG. In addition, areas in both California and elsewhere in the nation that have not attained the National Ambient Air Quality Standard for carbon monoxide are required in the Act to implement the Wintertime Oxyfuel program.

The Clean Air Act requires that RFG contain 2 percent oxygen by weight. Over 85 percent of RFG contains the oxygenate methyl tertiary butyl ether (MTBE) and approximately 8 percent contains ethanol -- a domestic fuel-blending stock made from grain and potentially from recycled biomass waste. The Act requires Wintertime Oxyfuel to contain 2.7 percent oxygen by weight.

There is disagreement about the precise role of oxygenates in attaining the RFG air quality benefits, although there is evidence from the existing program that increased use of oxygenates results in reduced carbon monoxide emissions, and it appears that additives contribute to reductions in aromatics in fuels and related air benefits. It is possible to formulate gasoline without oxygenates that can attain similar air toxics reductions, but it is less certain that given current Federal RFG requirements all fuel blends created without oxygenates could maintain the benefits provided today by oxygenated RFG.

At the same time, the use of MTBE in the program has resulted in growing detections of MTBE in drinking water, with between 5 percent and 10 percent of community drinking water supplies in high oxygenate use areas[1] showing at least detectable amounts of MTBE. The great majority of these detections to date have been well below levels of public health concern, with approximately one percent rising to levels above 20 parts per billion (ppb). Detections at lower levels have, however, raised consumer taste and odor concerns that have caused water suppliers to stop using some water supplies and to incur costs of treatment and remediation. Private wells have also been contaminated, and these wells are less protected than public drinking water supplies and not monitored for chemical contamination. There is also evidence of contamination of surface waters, particularly during summer boating seasons.

The major source of groundwater contamination appears to be releases from underground gasoline storage systems. These systems have been upgraded over the last decade, likely resulting in reduced risk of leaks. However, approximately 20 percent of the storage systems have not yet been upgraded, and there continue to be reports of releases from some upgraded systems, due to inadequate design, installation, maintenance, and/or operation. In addition, many fuel storage systems (e.g. farms, small above-ground tanks) are not currently regulated by the U.S. Environmental Protection Agency. Beyond groundwater contamination from underground storage tank (UST) sources, the other major sources of water contamination appear to be small and large gasoline spills to ground and surface waters, and recreational water craft -- particularly those with older motors -- releasing unburned fuel to surface waters.

[1] Areas using RFG (2% by weight oxygen) and/or Oxyfuel (2.7% by weight Oxygen)

The Blue Ribbon Panel

In response to the growing concerns from State and local officials and the public, U.S. EPA Administrator Carol M. Browner appointed a Blue Ribbon Panel in November 1998, to investigate the air quality benefits and water quality concerns associated with oxygenates in gasoline, and to provide independent advice and recommendations on ways to maintain air quality while protecting water quality. The Panel members consisted of leading experts from the public health and scientific communities, automotive fuels industry, water utilities, and local and State governments. The Panel was charged to: (1) examine the role of oxygenates in meeting the nation's goal of clean air; (2) evaluate each product's efficiency in providing clean air benefits and the existence of alternatives; (3) assess the behavior of oxygenates in the environment; (4) review any known health effects; and (5) compare the cost of production and use and each product's availability -- both at present and in the future. Further, the Panel studied the causes of ground water and drinking water contamination from motor vehicle fuels, and explored prevention and cleanup technologies for water and soil. The Panel was established under EPA's Federal Advisory Committee Act's Clean Air Act Advisory Committee, a policy committee established to advise the U.S. EPA on issues related to implementing the CAAA of 1990. It met six times from January - June, 1999, heard presentations in Washington, the Northeast, and California about the benefits and concerns related to RFG and the oxygenates; gathered the best available information on the program and its effects; identified key data gaps; and evaluated a series of alternative recommendations based on their effects on:

- air quality
- water quality
- stability of fuel supply and cost

This report consists of five issue summaries: water contamination; air quality benefits; prevention; treatment and remediation; fuel supply and cost; and comparing the fuel additives. In addition, this report contains the findings and recommendations of the Panel, dissenting opinions, list of Panel members, references, and glossary of terms.

The Findings and Recommendations of the Blue Ribbon Panel

Findings

Based on its review of the issues, the Panel made the following overall findings:

- The distribution, use, and combustion of gasoline poses risks to our environment and public health.

- RFG provides considerable air quality improvements and benefits for millions of US citizens.

- The use of MTBE has raised the issue of the effects of both MTBE alone and MTBE in gasoline. This Panel was not constituted to perform an independent comprehensive health assessment and has chosen to rely on recent reports by a number of state, national, and international health agencies. What seems clear, however, is that MTBE, due to its persistence and mobility in water, is more likely to contaminate ground and surface water than the other components of gasoline.

- MTBE has been found in a number of water supplies nationwide, primarily causing consumer odor and taste concerns that have led water suppliers to reduce use of those supplies. Incidents of MTBE in drinking water supplies at levels well above EPA and state guidelines and standards have occurred, but are rare. The Panel believes that the occurrence of MTBE in drinking water supplies can and should be substantially reduced.

- MTBE is currently an integral component of the U.S. gasoline supply both in terms of volume and octane. As such, changes in its use, with the attendant capital construction and infrastructure modifications, must be implemented with sufficient time, certainty, and flexibility to maintain the stability of both the complex U. S. fuel supply system and gasoline prices.

The following recommendations are intended to be implemented as *a single package* of actions designed to simultaneously maintain air quality benefits while enhancing water quality protection and assuring a stable fuel supply at reasonable cost. The majority of these recommendations could be implemented by federal and state environmental agencies without further legislative action, and we would urge their rapid implementation. We would, as well, urge all parties to work with Congress to implement those of our recommendations that require legislative action.

Recommendations to Enhance Water Protection

Based on its review of the existing federal, state and local programs to protect, treat, and remediate water supplies, the Blue Ribbon Panel makes the following recommendations to enhance, accelerate, and expand existing programs to improve protection of drinking water supplies from contamination.

Prevention

1. EPA, working with the states, should take the following actions to enhance significantly the Federal and State Underground Storage Tank programs:

    a. Accelerate enforcement of the replacement of existing tank systems to conform with the federally-required December 22, 1998 deadline for upgrade, including, at a minimum, moving to have all states prohibit fuel deliveries to non-upgraded tanks, and adding enforcement and compliance resources to ensure prompt enforcement action, especially in areas using RFG and Wintertime Oxyfuel.

    b. Evaluate the field performance of current system design requirements and technology and, based on that evaluation, improve system requirements to minimize leaks/releases, particularly in vulnerable areas (see recommendations on Wellhead Protection Program in 2. below).

    c. Strengthen release detection requirements to enhance early detection, particularly in vulnerable areas, and to ensure rapid repair and remediation.

    d. Require monitoring and reporting of MTBE and other ethers in groundwater at all UST release sites.

    e. Encourage states to require that the proximity to drinking water supplies, and the potential to impact those supplies, be considered in land-use planning and permitting decisions for siting of new UST facilities and petroleum pipelines.

f. Implement and/or expand programs to train and license UST system installers and maintenance personnel.

g. Work with Congress to examine and, if needed, expand the universe of regulated tanks to include underground and aboveground fuel storage systems that are not currently regulated yet pose substantial risk to drinking water supplies.

2. EPA should work with its state and local water supply partners to enhance implementation of the Federal and State Safe Drinking Water Act programs to:

a. Accelerate, particularly in those areas where RFG or Oxygenated Fuel is used, the assessments of drinking water source protection areas required in Section 1453 of the Safe Drinking Water Act, as amended in 1996.

b. Coordinate the Source Water Assessment program in each state with federal and state Underground Storage Tank Programs using geographic information and other advanced data systems to determine the location of drinking water sources and to identify UST sites within source protection zones.

c. Accelerate currently-planned implementation of testing for and reporting of MTBE in public drinking water supplies to occur before 2001.

d. Increase ongoing federal, state, and local efforts in Wellhead Protection Areas including:

- enhanced permitting, design, and system installation requirements for USTs and pipelines in these areas;
- strengthened efforts to ensure that non-operating USTs are properly closed;
- enhanced UST release prevention and detection; and
- improved inventory management of fuels.

3. EPA should work with states and localities to enhance their efforts to protect lakes and reservoirs that serve as drinking water supplies by restricting use of recreational water craft, particularly those with older motors.

4. EPA should work with other federal agencies, the states, and private sector partners to implement expanded programs to protect private well users, including, but not limited to:

a. A nationwide assessment of the incidence of contamination of private wells by components of gasoline as well as by other common contaminants in shallow groundwater;

b. Broad-based outreach and public education programs for owners and users of private wells on preventing, detecting, and treating contamination; and

c. Programs to encourage and facilitate regular water quality testing of private wells.

5. Implement, through public-private partnerships, expanded Public Education programs at the federal, state, and local levels on the proper handling and disposal of gasoline.

6. Develop and implement an integrated field research program into the groundwater behavior of gasoline and oxygenates, including:

   a. Identifying and initiating research at a population of UST release sites and nearby drinking water supplies including sites with MTBE, sites with ethanol, and sites using no oxygenate; and

   b. Conducting broader, comparative studies of levels of MTBE, ethanol, benzene, and other gasoline compounds in drinking water supplies in areas using primarily MTBE, areas using primarily ethanol, and areas using no or lower levels of oxygenate.

Treatment and Remediation

7. EPA should work with Congress to expand resources available for the up-front funding of the treatment of drinking water supplies contaminated with MTBE and other gasoline components to ensure that affected supplies can be rapidly treated and returned to service, or that an alternative water supply can be provided. This could take a number of forms, including but not limited to:

   a. Enhancing the existing Federal Leaking Underground Storage Tank Trust Fund by fully appropriating the annual available amount in the Fund, ensuring that treatment of contaminated drinking water supplies can be funded, and streamlining the procedures for obtaining funding;

   b. Establishing another form of funding mechanism which ties the funding more directly to the source of contamination; and

   c. Encouraging states to consider targeting State Revolving Funds (SRF) to help accelerate treatment and remediation in high priority areas.

8. Given the different behavior of MTBE in groundwater when compared to other components of gasoline, states in RFG and Oxyfuel areas should reexamine and enhance state and federal "triage" procedures for prioritizing remediation efforts at UST sites based on their proximity to drinking water supplies.

9. Accelerate laboratory and field research, and pilot projects, for the development and implementation of cost-effective water supply treatment and remediation technology, and harmonize these efforts with other public/private efforts underway.

Recommendations for Blending Fuel for Clean Air *and* Water

Based on its review of the current water protection programs, and the likely progress that can be made in tightening and strengthening those programs by implementing Recommendations 1 - 9 above, the Panel agreed broadly, although not unanimously, that even enhanced protection programs will not give adequate assurance that water supplies will be protected, and that changes need to be made to the RFG

program to reduce the amount of MTBE being used, while ensuring that the air quality benefits of RFG, and fuel supply and price stability, are maintained.

Given the complexity of the national fuel system, the advantages and disadvantages of each of the fuel blending options the Panel considered (see Appendix A), and the need to maintain the air quality benefits of the current program, the Panel recommends an *integrated package* of actions by both Congress and EPA that should be *implemented as quickly as possible*. The key elements of that package, described in more detail below, are:

- Action agreed to broadly by the Panel to reduce the use of MTBE substantially (with some members supporting its complete phase-out), and action by Congress to clarify federal and state authority to regulate and/or eliminate the use of gasoline additives that threaten drinking water supplies;

- Action by Congress to remove the current 2 percent oxygen requirement to ensure that adequate fuel supplies can be blended in a cost-effective manner while quickly reducing usage of MTBE; and

- Action by EPA to ensure that there is no loss of current air quality benefits.

<u>The Oxygen Requirement</u>

10. The current Clean Air Act requirement to require 2 percent oxygen, by weight, in RFG must be removed in order to provide flexibility to blend adequate fuel supplies in a cost-effective manner while quickly reducing usage of MTBE and maintaining air quality benefits.

    The Panel recognizes that Congress, when adopting the oxygen requirement, sought to advance several national policy goals (energy security and diversity, agricultural policy, etc) that are beyond the scope of our expertise and deliberations.

    The Panel further recognizes that if Congress acts on the recommendation to remove the requirement, Congress will likely seek other legislative mechanisms to fulfill these other national policy interests.

<u>Maintaining Air Benefits</u>

11. Present toxic emission performance of RFG can be attributed, to some degree, to a combination of three primary factors: (1) mass emission performance requirements; (2) the use of oxygenates; and (3) a necessary compliance margin with a per gallon standard. In Cal RFG, caps on specific components of fuel is an additional factor to which toxics emission reductions can be attributed.

    Outside of California, lifting the oxygen requirement as recommended above may lead to fuel reformulations that achieve the minimum performance standards required under the 1990 Act, rather than the larger air quality benefits currently observed. In addition, changes in the RFG program could have adverse consequences for conventional gasoline as well.

Within California, lifting the oxygen requirement will result in greater flexibility to maintain and enhance emission reductions, particularly as California pursues new formulation requirements for gasoline.

In order to ensure that there is no loss of current air quality benefits, EPA should seek appropriate mechanisms for both the RFG Phase II and Conventional Gasoline programs to define and maintain in RFG II the real world performance observed in RFG Phase I while preventing deterioration of the current air quality performance of conventional gasoline.[2]

There are several possible mechanisms to accomplish this. One obvious way is to enhance the mass-based performance requirements currently used in the program. At the same time, the Panel recognizes that the different exhaust components pose differential risks to public health due in large degree to their variable potency. The Panel urges EPA to explore and implement mechanisms to achieve equivalent or improved public health results that focus on reducing those compounds that pose the greatest risk.

Reducing the Use of MTBE

12. The Panel agreed broadly that, in order to minimize current and future threats to drinking water, the use of MTBE should be reduced substantially. Several members believed that the use of MTBE should be phased out completely. The Panel recommends that Congress act quickly to clarify federal and state authority to regulate and/or eliminate the use of gasoline additives that pose a threat to drinking water supplies.[3]

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[2] The Panel is aware of the current proposal for further changes to the sulfur levels of gasoline and recognizes that implementation of any change resulting from the Panel's recommendations will, of necessity, need to be coordinated with implementation of these other changes. However, a majority of the Panel considered the maintenance of current RFG air quality benefits as separate from any additional benefits that might accrue from the sulfur changes currently under consideration.

[3] Under §211 of the 1990 Clean Air Act, Congress provided EPA with authority to regulate fuel formulation to improve air quality. In addition to EPA's national authority, in §211(c)(4) Congress sought to balance the desire for maximum uniformity in our nation's fuel supply with the obligation to empower states to adopt measures necessary to meet national air quality standards. Under §211(c)(4), states may adopt regulations on the components of fuel, but must demonstrate that 1) their proposed regulations are needed to address a violation of the NAAQS and 2) it is not possible to achieve the desired outcome without such changes.

The Panel recommends that Federal law be amended to clarify EPA and state authority to regulate and/or eliminate gasoline additives that threaten water supplies. It is expected that this would be done initially on a national level to maintain uniformity in the fuel supply. For further action by the states, the granting of such authority should be based upon a similar two part test:

1) states must demonstrate that their water resources are at risk from MTBE use, above and beyond the risk posed by other gasoline components at levels of MTBE use present at the time of the request.

2) states have taken necessary measures to restrict/eliminate the presence of gasoline in the water resource. To maximize the uniformity with which any changes are implemented and minimize impacts on cost and fuel supply, the Panel recommends that EPA establish criteria for state waiver requests including but not limited to:

a. Water quality metrics necessary to demonstrate the risk to water resources and air quality metrics

(continued...)

Initial efforts to reduce should begin immediately, with substantial reductions to begin as soon as Recommendation 10 above - the removal of the 2 percent oxygen requirement - is implemented[4]. Accomplishing any such major change in the gasoline supply without disruptions to fuel supply and price will require adequate lead time - up to 4 years if the use of MTBE is eliminated, sooner in the case of a substantial reduction (e.g. returning to historical levels of MTBE use).

The Panel recommends, as well, that any reduction should be designed so as to not result in an increase in MTBE use in Conventional Gasoline areas.

13. The other ethers (e.g. ETBE, TAME, and DIPE) have been less widely used and less widely studied than MTBE. To the extent that they have been studied, they appear to have similar, but not identical, chemical and hydrogeologic characteristics. The Panel recommends accelerated study of the health effects and groundwater characteristics of these compounds before they are allowed to be placed in widespread use.

In addition, EPA and others should accelerate ongoing research efforts into the inhalation and ingestion health effects, air emission transformation byproducts, and environmental behavior of <u>all</u> oxygenates and other components likely to increase in the absence of MTBE. This should include research on ethanol, alkylates, and aromatics, as well as of gasoline compositions containing those components.

14. To ensure that any reduction is adequate to protect water supplies, the Panel recommends that EPA, in conjunction with USGS, the Departments of Agriculture and Energy, industry, and water suppliers, should move quickly to:

a. Conduct short-term modeling analyses and other research based on existing data to estimate current and likely future threats of contamination;

b. Establish routine systems to collect and publish, at least annually, all available monitoring data on:

- use of MTBE, other ethers, and Ethanol;
- levels of MTBE, Ethanol, and petroleum hydrocarbons found in ground, surface and drinking water;
- trends in detections and levels of MTBE, Ethanol, and petroleum hydrocarbons in ground and drinking water;

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[3] (...continued)

to ensure no loss of benefits from the federal RFG program.

b. Compliance with federal requirements to prevent leaking and spilling of gasoline.

c. Programs for remediation and response.

d. A consistent schedule for state demonstrations, EPA review, and any resulting regulation of the volume of gasoline components in order to minimize disruption to the fuel supply system.

[4] Although a rapid, substantial reduction will require removal of the oxygen requirement, EPA should, in order to enable initial reductions to occur as soon as possible, review administrative flexibility under existing law to allow refiners who desire to make reductions to begin doing so.

c. Identify and begin to collect additional data necessary to adequately assess the current and potential future state of contamination.

The Wintertime Oxyfuel Program

The Wintertime Oxyfuel Program continues to provide a means for some areas of the country to come into, or maintain, compliance with the Carbon Monoxide standard. Only a few metropolitan areas continue to use MTBE in this program. In most areas today, ethanol can and is meeting these wintertime needs for oxygen without raising volatility concerns given the season.

15. The Panel recommends that the Wintertime Oxyfuel program be continued (a) for as long as it provides a useful compliance and/or maintenance tool for the affected states and metropolitan areas, and (b) assuming that the clarification of state and federal authority described above is enacted to enable states, where necessary, to regulate and/or eliminate the use of gasoline additives that threaten drinking water supplies.

Recommendations for Evaluating and Learning From Experience

The introduction of reformulated gasoline has had substantial air quality benefits, but has at the same time raised significant issues about the questions that should be asked before widespread introduction of a new, broadly-used product. The unanticipated effects of RFG on groundwater highlight the importance of exploring the potential for adverse effects in all media (air, soil, and water), and on human and ecosystem health, before widespread introduction of any new, broadly-used, product.

16. In order to prevent future such incidents, and to evaluate of the effectiveness and the impacts of the RFG program, EPA should:

a. Conduct a full, multi-media assessment (of effects on air, soil, and water) of any major new additive to gasoline prior to its introduction;

b. Establish routine and statistically valid methods for assessing the actual composition of RFG and its air quality benefits, including the development, to the maximum extent possible, of field monitoring and emissions characterization techniques to assess "real world" effects of different blends on emissions;

c. Establish a routine process, perhaps as a part of the Annual Air Quality trends reporting process, for reporting on the air quality results from the RFG program; and

d. Build on existing public health surveillance systems to measure the broader impact (both beneficial and adverse) of changes in gasoline formulations on public health and the environment.

Summary of Dissenting Opinion
By Todd C. Sneller, Member
EPA Blue Ribbon Panel

The complete text of Mr. Sneller's dissenting opinion on the Panel's recommendation to eliminate the federal oxygen standard for reformulated gasoline is included in Chapter 4 of this report.

In its report regarding the use of oxygenates in gasoline, a majority of the Blue Ribbon Panel on Oxygenates in Gasoline recommends that action be taken to eliminate the current oxygen standard for reformulated gasoline. Based on legislative history, public policy objectives, and information presented to the Panel, I do not concur with this specific recommendation. The basis for my position follows:

The Panel's report concludes that aromatics can be used as a safe and effective replacement for oxygenates without resulting in deterioration in VOC and toxic emissions. In fact, a review of the legislative history behind the passage of the *Clean Air Act Amendments of 1990* clearly shows that Congress found the increased use of aromatics to be harmful to human health and intended that their use in gasoline be reduced as much as technically feasible.

The Panel's report concludes that oxygenates fail to provide overwhelming air quality benefits associated with their required use in gasoline. The Panel recommendations, in my opinion, do no accurately reflect the benefits provided by the use of oxygenates in reformulated gasoline. Congress correctly saw a minimum oxygenate requirement as a cost effective means to both reduce levels of harmful aromatics and help rid the air we breathe of harmful pollutants.

The Panel's recommendation to urge removal of the oxygen standard does not fully take into account other public policy objectives specifically identified during Congressional debate on the *1990 Clean Air Act Amendments*. While projected benefits related to public health were a focal point during the debate in 1990, energy security, national security, the environment and economic impact of the *Amendments* were clearly part of the rationale for adopting such amendments. It is my belief that the rationale behind adoption of the *Amendments* in 1990 is equally valid, if not more so, today.

Congress thoughtfully considered and debated the benefits of reducing aromatics and requiring the use of oxygenates in reformulated gasoline before adopting the oxygenate provisions in 1990. Based on the weight of evidence presented to the Panel, I remain convinced that maintenance of the oxygenate standard is necessary to ensure cleaner air and a healthier environment. I am also convinced that water quality must be better protected through significant improvements to gasoline storage tanks and containment facilities. Therefore, because it is directly counter to the weight of the vast majority of scientific and technical evidence and the clear intent of Congress, I respectfully disagree with the Panel recommendation that the oxygenate provisions of the federal reformulated gasoline program be removed from current law.

LYONDELL CHEMICAL COMPANY
SUMMARY OF DISSENTING REPORT

The complete text of Lyondell's dissenting report is in Chapter 4 of this report.

While the Panel is to be commended on a number of good recommendations to improve the current underground storage tank regulations and reduce the improper use of gasoline, the Panel's recommendations to limit the use of MTBE are not justified.

Firstly, the Panel was charged to review public health effects posed by the use of oxygenates, particularly with respect to water contamination. The Panel did not identify any increased public health risk associated with MTBE use in gasoline.

Secondly, no quantifiable evidence was provided to show the environmental risk to drinking water from leaking underground storage tanks (LUST) will not be reduced to manageable levels once the 1998 LUST regulations are fully implemented and enforced. The water contamination data relied upon by the panel is largely misleading because it predates the implementation of the LUST regulations.

Thirdly, the recommendations fall short in preserving the air quality benefits achieved with oxygenate use in the existing RFG program. The air quality benefits achieved by the RFG program will be degraded because they fall outside the control of EPA's Complex Model used for RFG regulations and because the alternatives do not match all of MTBE's emission and gasoline quality improvements.

Lastly, the recommendations will impose an unnecessary additional cost of 1 to 3 billion dollars per year (3 – 7 c/gal. RFG) on consumers and society without quantifiable offsetting social benefits or avoided costs with respect to water quality in the future.

Unfortunately, there appears to be an emotional rush to judgement to limit the use of MTBE. For the forgoing reasons, Lyondell dissents from the Panel report regarding the following recommendations:

- **The recommendation to reduce the use of MTBE substantially is unwarranted given that no increased public health risk associated with its use has been identified by the Panel.**

- **The recommendation to maintain air quality benefits of RFG is narrowly limited to the use of EPA's RFG Complex Model which does not reflect many of the vehicle emission benefits realized with oxygenates as identified in the supporting panel issue papers. Therefore, degradation of air quality will occur and the ability to meet the Nation's Clean Air Goals will suffer under these recommendations.**

CHAPTER 2. ISSUE SUMMARIES

In the course of its deliberations, the Blue Ribbon Panel heard from a number of experts in the field, and reviewed a large number of analyses and reports compiled by a range of organizations and individuals on the topics of air quality, water contamination, prevention and remediation, fuel supply and price, and health effects (see *References* below). In order to guide its development and evaluation of the range of options, and the selection of its recommended option, the Panel worked with its own staff, staff of a number of federal agencies, and consultants assigned to it from ICF Consulting to compile the following Issue Summaries.

These Issue Summaries are *not* intended to be complete reproductions of the many analyses and reports the Panel reviewed, nor did the Panel necessarily have the charter or the expertise to conduct an entire *de novo* review of all of the evidence on any one topic (e.g. health effects). Rather, these summaries are designed to summarize all of the available information in a relatively neutral manner, capturing those areas where the scientific and technical community have come to some conclusions about these topics, and noting those areas where either there is not agreement, or where additional information is needed.

For example, the Panel provides in *Issue A. Water Contamination*, the first systematic summary of water contamination data from the states of Maine and California and from the U.S. Geological Survey. This data, which emerged beginning late last year, was augmented substantially by analyses completed by USGS, and a summary of the relevant data was presented to the Panel in April. The Panel did not, however, conduct a detailed review of the analytic techniques, assumptions, and methods of each study, but rather accepted them as valid efforts to attempt to characterize an emerging situation, and refers the readers to the original studies for further detail.

A. Water Contamination

I. Introduction

There have been increasing detections of methyl tertiary butyl ether (MTBE) in ground waters and in reservoirs. Overall, approximately 90 percent of tested waters have no detects, with remaining waters generally exhibiting relatively low level contamination. As sources of water contamination are identified, the behavior of oxygenates in ground water needs to be analyzed in order to understand the extent of contamination. The following is a summary of what is known today concerning water contamination.

II. Contamination

A. Concentration Levels in Public and Private Wells

The use of MTBE in the RFG program has resulted in growing detections of MTBE in drinking water, with between 5 percent and 10 percent of community drinking water supplies in high oxygenate use areas[5] showing at least detectable amounts of MTBE. The great majority of these detections to date have been well below levels of public health concern, with between 0.3 percent to 1.5 percent rising to levels above 20 parts per billion (ppb). Detections at lower levels have, however, raised consumer taste and odor concerns that have caused water suppliers to stop using some water supplies and to incur costs of treatment and remediation. Private wells have also been contaminated and these wells are less protected than public drinking water supplies and not monitored for chemical contamination. There is also evidence of contamination of surface waters, particularly during summer boating seasons. A variety of studies, summarized in Table 1, have sought to determine the extent of MTBE contamination of drinking water sources. In addition, the USGS 12 Northeastern State Study has compiled data for MTBE levels in community drinking water.

Although there are no nation-wide drinking water data sets from which to fully characterize MTBE detections in the United States, a recent United States Geological Survey (USGS) report examines this issue with respect to ambient ground water. This report assessed studies conducted between 1985 and 1995 by USGS-NAWQA (National Water Quality Assessment Program), local, State, and Federal agencies by examining sampling data from 2,948 urban & rural, drinking water, and non-drinking water wells. Projections from these data sets suggest that up to 7 percent of the nation's ground water resources could potentially contain a volatile organic compound (VOC) such as MTBE at concentrations of at least 0.2 ppb. At this time it is difficult to project future trends of contamination due to the lack of time-series data.

[5] Areas using RFG (2% by weight oxygen) and /or Oxyfuel (2.7% by weight Oxygen).

Table 1. Summary of Studies Examining MTBE Contamination of Drinking Water Sources

Concentration Range (ppb)	California Public Water Sources[1] (wells)	Maine Public Water Sources[2] (wells)	Maine Private Water Sources[3] (wells)[4]	USGS/NAWQA Studies[5] (wells)	USGS/EPA 12 Northeastern State Study[6] (systems)
	N=5,195 MDL=5 ppb	N=793 MDL=0.1 ppb	N=946 (95% CI) MDL=0.1 ppb	N=2,743 MDL=0.2 ppb (censor level)	N=1,190 MDL=1 ppb[7]
Non-Detects	~99%	~84.1%	~84.3%	~94.7%	~92.8%
MDL - 5 ppb	N/A[8]	~14.6%	~12.8%	~4.5%	~5.0%
5-20 ppb	~0.3%	~0.9%	~1.5%	~0.4%	~1.3%
> 20 ppb	~0.3%	~0.4%	~1.5%	~0.4%	~0.9%

[1]California Department of Health Services, April 22, 1999 (www.dhs.ca.gov/ps/ddwem/chemical-/MTBE/mtbe_summary.htm). Because the same source may be counted more than once (*e.g.*, as both "raw" and "treated", as with a reservoir), data from a single source have been consolidated for purposes of counting "sources."

[2]Although there have been detects below 5 ppb, such detections are not required to be reported.

[3]A.E. Smith, Analysis of MTBE data in public and private water sources sampled as part of the Maine MTBE Drinking Water Study -- Preliminary Report, October 13, 1998; Written Communication to U.S. EPA, May 20, 1999.

[4]Data are available for other sources (*e.g.*, springs and surface water).

[5]P.J. Squillace, D.A. Bender, J.S. Zogorski, Analysis of USGS data on MTBE in wells sampled as part of the National Water Quality Assessment Program, 1993-1998: Written Communication to U.S. EPA. May 20, 1999.

[6]S.J. Grady, Analysis of the Preliminary Findings of the 12-State MTBE/VOC Drinking Water Study, 1993-1998: Communication to U.S. EPA, May 20, 1999.

[7]Some samples with higher reporting levels have not been screened out.

Note: Some systems have multiple sources and the total number of sources is unknown. Systems with multiple detections are counted in the highest reported concentration range.

"MDL" = Minimum Detection Level.

MTBE was the second most commonly detected VOC in water from urban wells[6]. Due to the inadequacy of long-term monitoring data, the extent and trends of ground and surface water contamination in the nation are still not well known. As such, research is underway to obtain more contamination occurrence data for ground and surface waters. An American Water Works Association Research Foundation (AWWARF) study of the national occurrence of MTBE in sources of drinking water (i.e., rivers, reservoirs, ground water, etc.) began in May 1999 and will continue for two years. This type of data will document near-term impacts and provide important input for analysis to predict future contamination trends.

B. RFG/OXY Areas Versus Non-RFG/OXY Areas

Data from the joint USGS and U.S. Environmental Protection Agency (EPA) 12 Northeastern State study[7] and the USGS/NAWQA study (Table 1) were analyzed to evaluate the frequency of MTBE detections in drinking water in RFG/OXY versus non-RFG/OXY areas. Results from the USGS/EPA Northeastern State study indicate that MTBE is detected ten times more often in drinking water from community water systems in areas that use reformulated gasoline (RFG) or oxygenated fuels (OXY) than

[6] Paul Squillace, et al., "Occurrence of the Gasoline Additive MTBE in Shallow Ground Water in Urban and Agricultural Areas; Fact Sheet FS-114-95; U.S. Geological Survey: Rapid City, DS, 1995; Paul Squillace, et.al., Preliminary assessment of the occurrence and possible sources of MTBE in groundwater in the United States, 1993-1994. Environ. Sci. Tech. 30 (5) 1721-1730, 1996.

[7] U.S. Environmental Protection Agency and United States Geological Survey, *Preliminary Finding of the 12-State MTBE/VOC Drinking Water Retrospective*, 1999.

in non-RFG/OXY areas.[8] Likewise, data from USGS/NAWQA indicates a similar detection frequency in RFG/OXY areas (Table 2). The USGS/NAWQA study also indicates that higher levels of MTBE (>20 ppb) are 19 times more likely to be detected in RFG/OXY areas than in non-RFG/OXY areas.[9] MTBE detections are clearly elevated in RFG/OXY areas as compared to BTEX (benzene, toluene, ethylbenzene, and xylene) detections.

Table 2. MTBE and BTEX Detection, RFG/OXY vs. Non-RFG/OXY Areas[10]

	MTBE Detection (0.2 ppb)	BTEX Detection (0.2 ppb)
RFG/OXY Areas Using MTBE (480 Wells)	21%	4%
Non-RFG/OXY Areas in the United States (2,263)	2%	2%

After normalizing for factors that affect detection frequency (*i.e.*, gasoline stations, commercial and industrial land use, etc.), MTBE is four to six times more likely to be detected in RFG/OXY areas than non-RFG/OXY areas. In RFG/OXY areas, of the 50 million people dependent on ground water, 20 million use an aquifer containing at least one VOC, indicating potential vulnerability to MTBE.[11]

C. Co-Occurrence of MTBE and Other Gasoline Components

For co-occurring components in gasoline, preliminary data from both the USGS/EPA 12 Northeastern State study and the USGS/NAWQA study shows that MTBE is generally detected in groundwater samples that contain another VOC, but is not associated with BTEX detections. In USGS/EPA drinking water samples containing MTBE, BTEX co-occurrence were only 0.3 percent, even though approximately 44 percent of the samples contained one or more other VOCs.[12] Similar results are exhibited for USGS/NAWQA ground water samples containing MTBE, with only 13 percent of the samples with MTBE also detecting BTEX.[13]

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[8] Stephen Grady and Michael Osinski, "Preliminary Findings of the 12-State MTBE/VOC Drinking Water Retrospective," presentation at the April 1999 MTBE Blue Ribbon Panel meeting.

[9] Paul Squillace, "MTBE in the Nation's Ground Water, National Water-Quality Assessment (NAWQA) Program Results," presentation at the April 1999 MTBE Blue Ribbon Panel meeting.

[10] Paul Squillace, "MTBE in the Nation's Ground Water, National Water-Quality Assessment (NAWQA) Program Results," presentation at the April 1999 MTBE Blue Ribbon Panel meeting.

[11] Paul Squillace, "Volatile Organic Compound in Untreated Ambient Groundwater of the United States, 1985 - 1995," presentation at the April 1999 MTBE Blue Ribbon Panel meeting.

[12] Stephen Grady and Michael Osinski, "Preliminary Findings of the 12-State MTBE/VOC Drinking Water Retrospective" presentation at the April 1999 MTBE Blue Ribbon Panel meeting.

[13] Paul Squillace, "Volatile Organic Compound in Untreated Ambient Groundwater of the United States, 1985 - 1995," presentation at the April 1999 MTBE Blue Ribbon Panel meeting.

III. Sources

The most frequent sources of higher levels of ground water contamination (greater than 20 ppb)[14] appear to be releases from gasoline storage and distribution systems, although there have been reports (e.g., Maine) that would suggest other sources of contamination, such as small spills and improper disposal. In reservoirs and lakes, MTBE detections, which vary seasonally, appear to be from recreational watercraft, particularly those with older motors. More general contamination of ground and surface waters at lower levels (usually less than 5 ppb) are primarily from storm water runoff and to a lesser degree, air deposition, as well as from leaking tanks and accidental spills.

Specific examples of recent findings regarding the sources of ground water contamination include the following:

a. Santa Monica, California[15]

Ground water contamination from LUSTs has resulted in the contamination and closure of 9 high volume production drinking water wells (daily water demand at approximately 6.5 million gallons per day) at levels up to 610 ppb in the production wells, up to 17,000 ppb in regional monitoring wells, and up to 230,000 ppb in LUST source-site monitoring wells.

b. Maine[16]

An automobile gasoline leak contaminated a supply well 100 feet away to a level of 900 ppb.

c. University of California, Davis Donner Lake Study[17]

The use of motorized watercraft yielded concentration levels from 0.1 ppb to 12 ppb.

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[14] Office of Science and Technology Policy, National Science and Technology Council, *Interagency Assessment of Oxygenated Fuels*, June 1997.

[15] Komex H20 Science, *Draft Investigation Report of MTBE Contamination: City of Santa Monica, Charnock Well Field, Los Angeles, California*, March 21, 1997; Geomatrix Consultants, Inc., *Summary of MTBE Groundwater Monitoring Results, Fourth Quarter 1998, Charnock Well Field Regional Assessment, Los Angeles, California*, April 1, 1999.

[16] B. Hunter et al., "Impact of Small Gasoline Spills on Groundwater," preliminary report abstract presented at the Maine Water Conference Meeting, April 1999.

[17] J.E. Reuter et al., "Concentrations, Sources and Fate of the Gasoline Oxygenate Methyl Tert-Butyl Ether (MTBE) in a Multiple-Use Lake," *Environmental Science and Technology* 32, 3666-3672, 1998.

d. Metropolitan Water District of Southern California Monitoring Program[18]

A monthly monitoring program (January 1997 to present) at six surface water reservoirs resulted in concentrations as high as 29 ppb during summer boating months.

e. OSTP Report[19]

Storm water runoff exhibited concentrations of 0.2 - 8.7 ppb in 7 percent of samples tested in 16 cities from 1991 to 1995. Based on modeled air concentrations, concentrations in rainwater are predicted to range from less than 1 ppb to 3 ppb.

IV. Behavior

A. MTBE

In ground water, MTBE is more soluble, does not adsorb as readily to soil particles, biodegrades less rapidly, and thus moves more quickly than other components of gasoline (*i.e.*, BTEX).[20] In surface water, volatilization of MTBE at the air-water interface is a significant contributor to decreased concentrations of MTBE.[21]

Much of MTBE's behavior is dependent upon the nature of the release, whether the release source is point or non-point, its geologic settings, and environmental and microbial factors. In studies to date, *in situ* biodegradation of MTBE has been minimal or limited at best, which is significantly less (by at least one order of magnitude) when compared to benzene.

B. Ethanol

Ethanol is extremely soluble in water and, based on theory, should travel at about the same rate as MTBE. Ethanol is not expected, however, to persist in ground water due to ethanol's ability to biodegrade easily. In fact, laboratory research findings suggest that ethanol may inhibit the

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[18] Metropolitan Water District, *Methyl Tertiary Butyl Ether Monitoring Program at the Metropolitan Water District of Southern California*, monitoring program update, April 1999.

[19] Office of Science and Technology Policy, National Science and Technology Council, *Interagency Assessment of Oxygenated Fuels*, June 1997, pp. 2-33 – 2-35.

[20] A.M. Happel et al., *An Evaluation of MTBE Impacts to California Groundwater Resources*, Lawrence Livermore National Laboratory Report, UCRL-AR-130897, June 1998; A.M. Happel, B. Dooher, and E.H. Beckenbach, "Methyl Tertiary Butyl Ether (MTBE) Impacts to California Groundwater," presentation at the March 1999 MTBE Blue Ribbon Panel meeting; Salanitro, J.P., "Understanding the Limitations of Microbial Metabolism of Ethers Used as Fuel Octane Enhancers," Curr. Opin. Biotechnol. 6: 337-340, 1995.

[21] Paul Squillace et al., "Review of the Environmental Behavior and Fate of Methyl Tertiary-Butyl Ether," Environ. Tox. Chem, 1997; UC Davis Report, Transport and Fate Modeling of MTBE in Lakes and Reservoirs," Stephen A. McCord and Geoffrey S., Schladow.

biodegradation of BTEX because the microbes preferentially metabolize ethanol before BTEX.[22] Qualitative and quantitative characterizations of ethanol biodegradation under field conditions have not been done to date. In one hypothetical analysis presented to the Panel, the addition of ethanol to gasoline was estimated to extend BTEX plumes by 25 percent to 40 percent.[23] Additionally, a study in Brazil indicated that, high ethanol concentrations in ground water (greater than 2 percent) enhanced the solubilization and migration of BTEX.[24] No national monitoring of ethanol in ground water, surface water or drinking water has been completed at this time.[25]

V. Drinking Water Standards

A. Drinking Water Advisory

In certain situations, either the public's concern about potential contamination, or water supply officials' concerns about the taste and odor effects of MTBE contamination, or both, has affected the ability of local authorities to rely on their water supplies for drinking water. For example, South Lake Tahoe, California water officials recently closed 13 wells due to the proximity of MTBE plumes to its drinking water wells.

The U.S. Environmental Protection Agency's Office of Water has established a drinking water advisory[26] level of 20 to 40 ppb as a guidance for State and local authorities, based on taste and odor concerns. This guidance suggests control levels for taste and odor acceptability and also provides a large margin of safety against any potential adverse health effects. The advisory levels enable water suppliers to easily assess if their drinking water is likely to be acceptable to consumers. The advisory also recognizes that some members of the population may detect it below this range. However, as indicated in table 3, states have established different guidelines and standards based on differing interpretations of the data concerning the taste and odor thresholds and health effect studies for MTBE.

In addition, EPA has proposed a revised Unregulated Contaminant Monitoring Rule, which would require large water systems (serving more than 10,000 persons) and a representative sample of small- and medium-sized water systems (serving fewer than 10,000 persons) to monitor and report MTBE levels. This program is scheduled to take effect in January 2001. Under this regulation, the majority of public

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[22] H.X., Corseuil et al., "The Influence of the Gasoline Oxygenate Ethanol on Aerobic and Anaerobic BTX Biodegradation," *Wat. Res.*, 1998, 32, 2065-2072.; C.S. Hunt et al., "Effect of Ethanol on Aerobic BTX Degradation Papers from the Fourth International In Situ and On-Site Bioremediation Symposium," Battelle Press, April-May 1997, pp. 49-54.

[23] Michael Kavanaugh and Andrew Stocking, "Evaluation of the Fate and Transport of Ethanol in the Environment," November, 1998. Presentation at the May 1999 MTBE Blue Ribbon Panel. [Based on Malcome Pirnie, Inc. *Evaluation of the Fate and Transport of Ethanol in the Environment* (Oakland, CA, 1998.)]

[24] H.X. Corseuil and P.J.J. Alvarez, "Natural Bioremediation Perspective for BTX-Contaminated Groundwater in Brazil," *Wat. Sci. Tech.*, 1996, 35, 9-16.

[25] EPA analytical methods are limited for ethanol analysis providing only ppm range detection limits.

[26] U.S. Environmental Protection Agency, Office of Water, *Drinking Water Advisory: Consumer Acceptability Advice and Health Effects Analysis on Methyl Tertiary-Butyl Ether (MTBE)*, December 1997.

groundwater supply wells will still not be monitored for MTBE.[27] The availability of Consumer Confidence Reports will notify the public of what contaminants are found in drinking water. Increasing numbers of consumers may find the water unacceptable if they are aware of MTBE's presence.

Private wells are not subject to monitoring under the Safe Drinking Water Act, but are left to the discretion of the State. Therefore, private well owners rarely have routine monitoring for either bacterial or chemical contamination. Private wells are typically more vulnerable than public wells due to differences in wellhead construction. Specifically, these wells typically draw from shallow groundwater, which is more vulnerable to impacts from surface contamination.

B. State Guidelines and Action Levels

As Table 3 indicates, a number of States have established drinking water guidelines and action levels. Currently, four States have primary drinking water standards, three States have enforceable guidelines, and 12 States either have an MTBE guideline or action level in place. Figure A1, located in Appendix A, contains a map illustrating these various State standards.

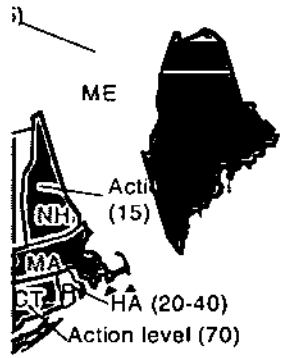
Table 3. State Drinking Water Standards, Guidelines, and Action Levels

States with Primary Drinking Water Standards (health-based)	• Maine (35 ppb) • New Jersey (70 ppb) • New York (50 ppb) • South Carolina (20-40 ppb)
State with a Secondary Standard (aesthetic)	• California (5 ppb); enforceable
States with Enforceable Guidelines	• Michigan (240 ppb); *health-based* • West Virginia (20-40 ppb); *EPA Advisory*
States with a Guideline or Action Level in Place	• Arizona (35 ppb); *health-based* • California (13 ppb); *health-based* • Connecticut (70 ppb); *health-based* • Illinois (70 ppb); *health-based* • Kansas (20-40 ppb); *EPA Advisory* • Maryland (10 ppb); *aesthetically-based* • Massachusetts (70 ppb); *health-based* • New Hampshire (15 ppb); *aesthetically based* • Pennsylvania (20-40 ppb); *EPA Advisory* • Rhode Island (20-40 ppb); *EPA Advisory* • Vermont (40 ppb); *EPA Advisory* • Wisconsin (60 ppb); *health-based*

Source: U.S. Environmental Protection Agency.

[27] Water suppliers are required to monitor for volatile organic compounds and MTBE can be analyzed by the same analytical methods and therefore could be included along with scheduled volatile organic compound sampling.

National Primary Drinking Water Standards, as defined by the Safe Drinking Water Act (SDWA), must be health-based. Although standards can be developed at the Federal level based on taste and odor, such standards are secondary and non-enforceable. Currently, the Drinking Water Advisory serves only as a national guidance level for aesthetic effects that EPA recommends for drinking water. Due to uncertainties in the health effects database, gaps in characterizing national occurrence, and significant variability among health study methodologies, EPA does not have sufficient information to establish an enforceable health-based standard at this time.



— Standard (70)

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B. Air Quality Benefits

I. Introduction

The Federal and California reformulated gasoline (RFG) programs have significantly improved air quality by reducing emissions of toxics and lowering the ozone forming potential through reductions in volatile organic compound (VOC) and oxides of nitrogen (NO_x). In general, these programs have resulted in greater emission reductions than statutorily required.

II. Federal RFG Program: Requirements and Benefits

A. Summary of RFG Requirements and Benefits

Ozone and air toxic levels in this nation have decreased substantially in recent years as a result of the Clean Air Act's implementation. There are over 30 areas, however, that are still in nonattainment with the current ozone standard. The results of emissions tests, tunnel studies, and remote sensing of tail pipe exhaust indicate that RFG usage can cause a decrease in both the exhaust and evaporative emissions from motor vehicles.[28] Based on separate cost effectiveness analyses conducted by both the U.S. Environmental Protection Agency (EPA) and the State of California, when compared to all available control options, RFG is a cost-effective approach to reducing ozone precursors such as VOCs and NO_x.[29] Although there is no National Ambient Air Quality Standard for toxics, a number of provisions of the Clean Air Act require reductions in toxics emissions, and Federal RFG has contributed to these reductions..

The RFG program, mandated under the 1990 Clean Air Act Amendments, requires changes in motor fuel formulation which result in decreased vehicle emissions for areas in the U.S. with significant low-level ozone pollution, otherwise known as smog. These areas represent about 30 percent of U.S. gasoline consumption. The program requires reductions relative to a 1990 fuel baseline in levels of NO_x, toxics, and VOC emissions and also requires a minimum level of oxygen and limits the maximum benzene level. The emissions performance of fuels relative to 1990 is evaluated using a linear regression model, referred to as the "complex model," which was developed using thousands of emissions tests relating fuel properties to emissions performance. To certify a fuel as RFG, a fuel manufacturer measures the eight relevant physical and chemical properties of the fuel, enters those results into the complex model, and the model determines the percent reduction in NO_x, VOC, and toxics, relative to 1990, for that fuel. Phase I of the program began in 1995. Phase II, scheduled to begin on January 1, 2000, will implement more stringent NO_x, VOC and toxics reduction standards.

The best available data indicate that the RFG program has substantially reduced emissions of ozone precursors and toxics (See Table 1). Analysis of fuel data reported by refiners for 1995 through 1998 indicates that emission reduction benefits exceeded the standards for VOCs, NO_x, and toxics.[30] Toxics

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[28] National Research Council (NRC), *Ozone-Forming Potential of Reformulated Gasoline*, May 1999.

[29] U.S. Environmental Protection Agency, Regulatory Impact Analysis, 59 FR 7716, Docket No. A-92-12, 1993.

[30] Refinery Reporting Data and RFG Survey Association Data. Data on gasoline properties contained in this *Issue Summary* are derived from two primary sources. The RFG reporting data represent data submitted by the universe of RFG producers or importers. The RFG survey data are derived from a carefully planned statistical

(continued...)

reductions in particular were substantially greater than the standard (an over 33 percent reduction versus a 17 percent requirement). (Refer to Figures B1 through B3 in this *Issue Summary's* Appendix).[31] In addition, ambient monitoring data also suggest that the RFG program is working. The EPA's 1995 Air Quality Trends report, which coincides with the first year of the RFG program, shows a median reduction of 38 percent in ambient benzene and significant decreases in other vehicle-related VOC concentrations in RFG areas.[32] No other control action could have accounted for such a substantial decrease in benzene levels.

In 1998, Northeast States for Coordinated Air Use Management (NESCAUM) conducted an assessment of the toxicity of conventional gasoline (CG) versus RFG sold in the Northeast. This study[33] focused on six toxic air pollutants [benzene, 1,3-butadiene, acetaldehyde, polycyclic organic matter (POM), formaldehyde, and MTBE]. A modified version of the complex model, incorporating MTBE emission rates, was used to compare differences in predicted emissions between composited average RFG and conventional fuel types sold in the Northeast. While emissions estimated by the complex model may not accurately represent actual emissions from the motor vehicle fleet, it does provide a means of establishing relative effects of fuel composition on emissions. Relative cancer potencies were assigned to the six compounds to compare carcinogenicity among fuel types. This study concluded that Phase I RFG (in 1996) "served to reduce cancer risk associated with gasoline vapors and automobile exhaust . . . by 12 percent. . . ," and that Phase II RFG would "reduce the public cancer risk . . . by 20 percent. . . ." This report also noted that "since the cancer potency of MTBE is significantly less than that of benzene, 1,3-butadiene and POM, its presence in RFG at 10 percent by volume tends to dilute other carcinogens. . . ." The National Research Council (NRC) report also stated that the most significant advantage of oxygenates in fuel appears to be displacement of some air toxics (*e.g.*, benzene from RFG). For additional information on typical fuels and standards, refer to Table B1 in Appendix B.

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[30] (...continued)
sampling of retail stations in various RFG cities. The survey plan is designed to estimate average gasoline properties for a given area over a specific time period with a high degree of statistical confidence.

The calculation of VOC, NOx, and toxics reductions is based upon measured properties from these two data sources and is calculated by the "complex model," a regression model based upon thousands of vehicle emissions tests. As with any model, some uncertainty exists regarding the calculated emissions reductions and their applicability for any given fleet in any given year.

[31] U.S. Environmental Protection Agency bar charts reflect survey data collected from 19,000 samples during 1998. Data from RFG Survey Association.

[32] U.S. Environmental Protection Agency, *National Air Quality and Emissions Trends Report*, 1995.

[33] NESCAUM, *Relative Cancer Risk of Reformulated Gasoline and Conventional Gasoline Sold in the Northeast*, August 1998.

Table B1. Typical Fuels and Standards

Fuel Parameter	Conventional Gasoline Pre-RFG	Federal RFG Phase I		Federal RFG Phase II		California RFG	
		Actual[1] (Summer)	Complex Avg. Std.	Actual	Averaging Standard	Actual	Averaging Standard
Reid Vapor Pressure (psi)	8.7/7.8	7.9/7.0	(8.0/7.1)[2]		(6.7)	6.8	(6.8)
Sulfur (ppm)	339	190	(285)		(150)	20	30
Oxygen (wt%)	<0.5	2.26	2.1 min		2.1 min	2.07	(2.0)
Aromatics (vol%)	32	26	(32)		(25)	23	22
Olefins (vol%)	13	10	(10)		(11)	4	4
E200 (%)	41	49	(45)		(49)	51	(49)
E300 (%)	83	83	(83)		(87)	89	(91)
Benzene (vol%)	1.5	0.68	0.95 max		.95 max	0.55	0.8
Phase II complex model performance (% reduction from 1990 baseline) of these fuels:							
VOC performance		26.1	22.1		29.8	29.9	29.6
NOx performance		5.3	1.4		6.8	14.6	14.7
Toxics performance		30.1	19.7		28.4	37.0	34.4

[1]"Actual" Phase I summer (VOC-controlled) RFG properties and performance estimated from 1998 RFG Compliance Surveys.
[2]Properties listed under the Federal RFG "standards" columns in parentheses are not standards *per se*, but indicate the average properties a summer fuel must have to meet the emissions performance standards. The "/" indicates "North/South" specific values. South (VOC Control Region 1) values were used in performance comparisons.

As shown in Table 1, Phase II RFG, which takes effect on January 1, 2000, requires additional emission reductions, beyond those required in Phase I. With the exception of air toxics and benzene, Phase II also requires reductions that are greater than the actual reductions achieved in Phase I. However, for both air toxics and benzene, the Phase II requirements, unless changed, would allow the formulation of RFG that does not maintain the current benefits (e.g. a 22 percent reduction in toxics versus a 33 percent actual Phase I reduction).

Table 1. Emission Reductions Required by the RFG Program

	VOCs	NOx	Toxics	Benzene	Oxygen
RFG Phase I (1995-1999)	• Northern States: 17% • Southern States: 37%	1.5%	17%	1%	2.0 wt%
Actual RFG[1] Phase I 1998	• Northern States: 21.2% Av[2], 20.3 - 25.0% Range • Southern States: 39.4% Av, 38.4 - 40.3% Range	(4.9% Average; 3.8% - 7.4% Range)	(33.2% Average; 23.7% -36.9% Range)	0.68 %	2.0 wt%
RFG Phase II (2000)	27%	6.8%	22%	1%	2.0 wt%
CaRFG Standards (approx.)	29.6%	14.7	34.4	0.8	0 - 2.0 wt%

[1]1998 RFG Compliance Survey Data (summer surveys), completed by the RFG Survey Association.
[2]"Av" = the average of the individual area results weighted by estimated gasoline volume in each area.

B. CaRFG Program

Also, as shown in Table 1, the California RFG program has in place more stringent standards for its Phase II than Federal RFG, in particular for NO_x, air toxics, and benzene. The second phase in the California RFG program (CaRFGII) is intended to ensure that benefits continue as the vehicle technology advances and fleets turn over. CaRFGII helps automakers meet the increasingly stringent emission standards for new vehicles. California's program requires automakers to certify their vehicles on CaRFGII, thus ensuring that new vehicles will be designed to meet emission standards on a fuel similar to what the vehicles will be operated with during daily use.

The CaRFG program is designed to ensure that different formulations of gasoline will meet the required emissions performance levels. This is accomplished through the predictive model, which allows one to compare the emissions performance of alternative fuel parameters against a standard set of parameters contained in the CaRFG regulation. If the alternative formulation provides emission benefits equal to or better than the standard formulation, emission benefits are preserved and the refiner (or fuel importer) is allowed to market the fuel. To ensure the predictive model reflects the most recent data on the relationship between fuel properties and emissions, the California Air Resources Board (CARB) is in the process of updating the model to reflect newer technology vehicles. This will provide extra assurance that the model will continue to be applicable as the vehicle fleet changes. In California, the predictive model has been used to produce and market fuels with no oxygenates while preserving the program's full air quality benefits.

C. EPA 1998 Area by Area Analysis

The EPA's Area by Area analysis of 1998 RFG Survey Data indicates that the complex model emissions performance of RFG in Chicago and Milwaukee, while easily exceeding all Phase I performance (*i.e.*, emission reduction) requirements, generally ranks low compared to other RFG areas. In order to investigate factors influencing the performance of Chicago and Milwaukee RFG relative to RFG in other areas, it is necessary to consider the composition of the fuels. Table B2 and an accompanying discussion, located in the Appendix, discuss estimates of average values of the fuel properties that are complex model inputs. The Chicago and Milwaukee properties are averages of the individual summer survey property averages. The National Average properties were estimated by calculating an average for each of the RFG areas surveyed during 1998, and then weighting these values by estimates of fuel volume for each area. The National Average Reid vapor pressure (RVP) value was for VOC Control Region 2 (North), which includes Chicago and Milwaukee. Other values include both regions. (California oxygen-only surveys were not included in the oxygenate computations.)

The higher sulfur levels in Chicago and Milwaukee RFG areas affected its relative complex model performance for all three pollutants (VOC, NO_x, toxics). This analysis indicates that sulfur was the primary factor influencing relative VOC and NO_x performance, and that sulfur may have some influence on toxics performance. The margin of air toxics overcompliance was not as great in Chicago and Milwaukee as in other areas primarily due to higher benzene content, but other factors such as increased acetaldehyde emissions and sulfur levels also contributed. Oxygenates had little impact on VOC or NO_x performance.

Table B2. Chicago and Milwaukee Data

	National Average	Chicago	Milwaukee
MTBE (wt% oxygen)	1.62	0.08	0.06
ETBE (wt% oxygen)	0	0	0
Ethanol (wt% oxygen)	0.51	3.38	3.39
TAME (wt% oxygen)	0.12	0	0
SULFUR (ppm)	190	255	261
RVP (psi) region 2	7.9	7.9	7.9
E200 (%)	49.4	50.7	50.9
E300 (%)	82.7	81.8	82.2
AROMATICS (vol%)	26.0	25.1	24.9
OLEFINS (vol%)	10.3	6.7	7.0
BENZENE (vol%)	0.68	0.90	0.99

III. The Impact on RFG if Oxygenates are Removed

A. Introduction

MTBE provides about 76 percent of the oxygenate used in all RFG, and ethanol provides about 19 percent. The remaining 5 percent is made up of other ethers, tertiary-amyl methyl ether (TAME) and ethyl tertiary butyl ether (ETBE).[34] MTBE and ethanol have been the primary oxygenates in RFG because of their availability, blendability, and ability to deliver air quality benefits while meeting American Society for Testing and Materials (ASTM) specifications. (Refer to Table D1 in *Issue Summary D*, Fuel Supply and Cost, for usage data and references.)

As shown in Table I above, Phase I RFG currently overcomplies with VOC, NOx, toxics, and benzene requirements. The *key* question is whether this current overcompliance with the Phase I RFG standards will be maintained in Phase II RFG if oxygenates are not required. Because the Phase II performance standards for VOCs and NO_x are above the current actual performance of Phase I RFG, all fuels will be required to maintain or exceed the current VOC and NOx benefits, whether or not they contain oxygenates. However, since the Phase II performance standard for air toxics (22 percent reduction) is below the current Phase I actual reductions (average 33 percent reduction), there is no guarantee that the current (Phase I) level of air toxics benefits will be maintained in all cases

The impact of removing oxygenates such as MTBE is not likely to be identical for CaRFG and Federal RFG. Federal RFG is subject to fewer caps on specific properties (e.g. aromatics) than CaRFG and therefore is more likely to show emissions impacts from the removal of oxygenates. Specific fuel parameters (e.g. the CaRFG cap on aromatics) may provide extra assurance that certain pollution reductions occur. Alternatively, performance standards (such as the current mass-based requirements for toxics and VOCs) assure that pollution reductions will occur, but allow the refiner more flexibility in determining how to achieve those reductions.

[34] Estimate from 1997 RFG Survey Data.

B. Air Toxics

Current RFG over complies with both the Phase I and planned Phase II toxics standards. With the data available the panel could not determine with precision all of the factors which produce this overcompliance. However, as is explained below, when blending gasoline, it is reasonable to conclude that the use of octane-rich oxygenates is one of the factors that affects a refiner's decision to use high-octane aromatics, a major contributor to the formation of toxic emissions.[35]

Decisions about refinery blending are complex and vary greatly over the range of U.S. refineries. Despite the variability in fuels likely to result from this complex system, however, certain trends can be identified that may help explain the larger-than-expected air toxics benefits.

- First, it would be expected that each refiner would incorporate a measurable degree of overcompliance in order to ensure that their fuel never falls below the standard.

- Second, no matter how refiners blend fuel to meet the air quality standards, fuels will also be blended to maintain at least the minimum octane required for current automobiles. Thus, one would expect that with increased use of oxygenates (a high octane component) in RFG, one would see, *on average*, reduced need for, and use of, other high-octane components such as aromatics. Conversely, one would expect that with reduced use of oxygenates, this octane need would be met, in part, with increased use of aromatics and, in the longer term once capacity is expanded, alkylates.[36]

- Third, although it is difficult to determine the precise role that oxygenates play in overcompliance, and some fuels would likely be blended by some refiners with lower oxygen yet

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[35] Air toxics emissions reductions result primarily from reductions in RFG of aromatics and benzene (itself an aromatic) when compared to pre-RFG gasoline.

[36] The production of octane quality is the primary performance property considered by refiners in the production of gasoline. All refining/blending decisions are based, in part, on the need for a certain minimum level of octane quality in order that vehicles using the fuel operate properly. There are a limited number of octane rich components that refiners can choose to produce needed octane. Aromatics, alkylates, and oxygenates are three of the most available sources of octane quality for U.S. refiners. The most important (and for most refiners, the most economical) gasoline upgrading process in U.S. refineries is catalytic reforming which produces aromatics and increases the octane quality of the gasoline. (See, for example, Anderson, Robert O., Fundamentals of the Petroleum Industry, University of Oklahoma Press, 1984, p. 221.) Reforming changes the shape of straight-chain carbon molecules to high-octane ring-shaped molecules. These ring-shaped molecules are referred to as aromatics and include benzene and benzene-like molecules. Since oxygenates are also primarily used for octane enhancement when producing gasoline, for a refiner using these two octane sources, there exists a gasoline balance situation between the use of aromatics and the use of oxygenates. Although the increased use of alkylates would also be expected as oxygenates are reduced, U.S. reforming capacity to produce aromatics is far greater than is the capacity to produce alkylates.

Under the federal RFG program, the oxygenate requirement results in a high level of octane quality and, for the reasons mentioned above, would be expected to push the use of aromatics and benzene from reforming in a downward direction. (Addition of oxygenate volumes would result in more than a 10 percent decrease in aromatics and benzene from dilution alone, even if the octane quality properties are ignored.) Refiners would not be expected to utilize refinery capacity to produce aromatics that are not needed for octane. Since aromatics (including benzene) are the strongest contributors to the formation of toxics in the complex model, it is reasonable to conclude that the use of oxygenates and the resulting downward movement in aromatics and benzene is likely responsible for a substantial amount of the overcompliance in toxic emission reductions.

high air toxics benefits, on average one would expect the presence of higher levels of oxygenate in the fuel to lead to reduced levels of aromatics, and thus greater air toxics benefits.

Although reasonable to assume that oxygenates thus contribute to toxics overcompliance, it is difficult to quantify this effect. The ideal data set would be able to compare fuels blended to meet current RFG requirements with a full range of oxygen levels (i.e. 0%, .5%, 1.0%, 2%, etc.), and such a data set does not exist. There is limited data from the State of Maine which recently implemented its own fuel program, albeit with less stringent requirements than RFG, to substantially reduce the use of MTBE: fuel properties reported by Maine's gasoline suppliers and distributors show a decrease in MTBE use by 50% and a corresponding increase in aromatics of 20% over the levels of aromatics present in RFG sold in Maine in 1997[37]. There is also data from Northern California (where 2.0% oxygen is not required) that CaRFG sold in the San Francisco area contained over 8% by volume MTBE in 1997 in part to meet the more stringent CARB requirements for CaRFG, although such data must be interpreted carefully since both the RFG requirements and the market situation in California are unique[38].

The only other available data set is data on actual RFG fuel properties collected as part of the implementation of the program. At the Panel's request, EPA analyzed available data on actual RFG properties in the marketplace and the relationship in that data between MTBE use, air toxics and aromatics content. The EPA's regulations allow producers of RFG to meet the oxygen content requirement on an averaged basis and to employ oxygen credits to meet the averaged standard of 2.1 percent by weight. Consequently, the oxygen content in any given sample of RFG may vary to a limited degree from the statutory 2.0 percent by weight per gallon requirement. In 1998 RFG fuel quality surveys, the oxygen content of samples that did not contain ethanol but were oxygenated wholly or in part with MTBE, varied between about 1.5 and 3.0 percent by weight. Even though the availability of this data provides an opportunity to explore how aromatics content changes as oxygen levels vary, most of the data points clustered around the 2.1 percent average standard and the data set contains no data for oxygen levels below the regulatory minimum of 1.5 percent. Therefore, although the analyses performed for the Panel showed a weak positive correlation between oxygen levels and both toxics performance and aromatics content, and more recent analyses by the Colorado School of Mines of the same data found some stronger correlations,[39] the Panel concluded that this data is extremely limited and can not be used for the purpose of coming to any specific quantitative statistical conclusions.

In the absence of certainty on the effects of removing oxygenates, the primary concern is that if the oxygen mandate is removed and a significant amount of RFG does not contain oxygenates, use of aromatics might rise at least in some portion of the RFG fuel blends. Such a rise would likely decrease the overcompliance now seen for toxics in Federal RFG. In California, where CaRFG both requires much lower sulfur levels and places a limit on the level of aromatics allowed in the fuel, such overcompliance is more likely to continue. In the absence of certainty around this issue, the only way to ensure that there is no loss of current air quality benefits is for EPA to seek mechanisms for both the RFG Phase II and Conventional Gasoline programs to define and maintain in RFG II the real world performance observed in RFG Phase I while preventing deterioration of the current air quality performance of conventional gasoline.

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[37] NESCAUM, RFG/MTBE Findings and Recommendations, Boston, MA, August, 1999.

[38] University of California, Health and Environmental Assessment of MTBE, Volume I. Summary and Recommendations, P.16, November 1998.

[39] NESCAUM, RFG/MTBE Findings and Recommendations, Boston, MA, August, 1999.

There are several possible mechanisms to accomplish this. One obvious way is to enhance the mass-based performance requirements currently used in the program. At the same time, the panel recognizes that the different exhaust components pose differential risks to public health due in large degree to their variable potency. EPA should explore and implement mechanisms to achieve equivalent or improved public health results that focus on reducing those compounds that pose the greatest risk.

C. Carbon Monoxide Benefits

Although there is no carbon monoxide (CO) standard for RFG, oxygenates affect CO emissions so that current RFG actually produces significant CO benefits. Estimates show that about one-fourth of the CO benefits associated with oxygenated RFG will disappear if oxygenates are on used.[40] Thus, if RFG contains no oxygenates, the CO reductions associated with RFG will be reduced by approximately 25 percent. This will be less critical in future years due to stricter tailpipe CO emission standards. As the vehicle fleet turns over, the oxygenate impact on CO emissions diminishes (see Table 3). It is important to note that there are now relatively few CO nonattainment areas (see discussion of Wintertime Oxyfuel Program in Section V. below).

D. Particulate Matter Benefits

There are limited data available on the effect of oxygenates on emissions of particulate matter (PM). The Colorado Department of Public Health and Environment conducted a study to evaluate the effects of oxygenated fuels on motor vehicle emissions at low ambient temperatures.[41] The study, which analyzed winter oxygenated fuels rather than RFG, concluded that there were statistically significant PM emissions reductions associated with the use of an ethanol oxygenated fuel.[42] Additional research is necessary including use of ethanol-oxygenated RFG and non-oxygenated RFG fuels in a variety of climates, to better understand how different formulations of gasoline affect PM.

IV. Other Air Quality Considerations for Oxygenates

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[40] EPA estimate based on complex and MOBILE model calculations.

[41] Colorado Department of Public Health and Environment (Ken Nelson and Ron Ragazzi), *The Impact of a 10 percent Ethanol Blended Fuel on the Exhaust Emissions of Tier 0 & Tier 1 Light Duty Gasoline Vehicles at 35 F*, March 26, 1999.

[42] This study involved testing light duty vehicles (LDVs) and trucks (LDTs) at 35 °F. Twelve Tier 0 and 12 Tier 1 vehicles (8 LDVs, 4 LDTs), six high emitters, and one low emission vehicle (LEV), were tested under three driving cycles [Federal Test Procedure (FTP), Unified, and REPO5]. The FTP is based on typical urban driving patterns. The Unified Cycle has higher speeds and accelerations than the FTP, and the REPO5 is a very aggressive driving cycle. In this program, the FTP was conducted from a cold start while the other cycles were conducted from a hot running start. The vehicles were tested with a non-oxygenated fuel and a 10 percent ethanol oxygenated fuel. The program measured emissions of hydrocarbons (HC), CO, NOx, carbon dioxide (CO_2) and fine particulate (PM10 and smaller).

The study reported that FTP particulate emissions were reduced with the oxygenated fuel. For the FTP, a mean absolute reduction of 3.31 milligrams per mile (mg/mi) or 36.0 percent was achieved for the main group of 24 Tier 0 plus Tier 1 vehicles. The reduction for the Tier 0 vehicles was 5.24 mg/mile, or 39.7 percent, and the reduction for the Tier 1 vehicles was 1.38 mg/mi, or 26.6 percent. These absolute reductions were statistically significant at the 95 percent confidence level. The numbers indicate that older vehicles receive greater PM benefits from the use of oxygenated fuels than newer technology vehicles. No statistically significant differences were detected for other driving cycles. There were no statistically significant changes in particulate emissions for the high emitters. Because only one LEV was tested, statistical significance cannot be determined.

A. Ozone Reactivity of Alternatives (CO Reduction)

One key question that has been raised about the air quality effects of RFG has been whether the ozone reactivity of fuels with different oxygenates could be a better measure of ozone forming potential than the correct mass-based measurement of VOCs.

A recently released report from the National Research Council (NRC), *Ozone-Forming Potential of Reformulated Gasoline*, concluded that there is no compelling scientific basis at this time to recommend that ozone forming potential or reactivity replace mass of emissions in the RFG program. A change from the mass of emissions approach to a reactivity approach would not impact the choice of one fuel over another from the standpoint of air quality benefits.

The NRC report found that fuel oxygen content appears to have only a small effect on the ozone forming emissions of RFG with reductions in CO emissions and in exhaust emissions of VOCs but with some evidence of increases in NO_x emissions. The NRC did not examine the contribution of oxygenates to the emissions of air toxics.

The NRC report found that the contribution of CO to ozone formation should be recognized in assessments of the effects of RFG. The NRC committee found that CO emissions account for 15 percent to 25 percent of the reactivity of exhaust emissions from light duty vehicles and should be included in reactivity assessments because despite its low reactivity adjustment factor, the large mass of CO emissions contributes to ozone formation.

B. Ethanol Blend Commingling with MTBE and Hydrocarbon Blends

An RVP[43] increase of approximately one pound per square inch (psi) is caused by the addition of ethanol to a hydrocarbon base fuel.[44] As a result, all ethanol blended RFG is now blended with base gasoline that has had certain high RVP components, such as pentanes and butanes, reduced in order to ensure that ethanol blended RFG meets RVP requirements.[45]

Traditional thinking would conclude that when an ethanol blend is commingled with a non-ethanol blend in a consumers tank, one would see a resulting RVP greater than would be expected from a simple volume-weighted linear combination of the two blends' RVPs, at least if a sufficient amount of the ethanol blend were to be present. Thus, in a 50-50 commingled blend, where 10 percent ethanol gasoline with an RVP of 8.0 psi is added to an all-hydrocarbon gasoline with the same 8.0 psi RVP, the resulting blend has an RVP of about 8.5 psi and not 8.0 psi as would be expected when non-ethanol blends are commingled.

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[43] Reid vapor pressure is a measure of the gas pressure a liquid/gas system will apply to a closed system when heated to 100 degrees Fahrenheit. As such, RVP is a measure of a liquid's volatility (*i.e.*, its tendency to evaporate).

[44] The size of increase in RVP is clearly affected by other factors, including the hydrocarbon makeup and original volatility characteristics of the blend into which the ethanol is added.

[45] EPA has promulgated a program controlling the RVP of conventional gasoline on a nationwide basis. (See 40 CFR 80.27.) This program allows for a 1.0 psi exemption for 10 percent ethanol blends. Thus, if this program requires that RVP not exceed 9.0 psi for a given area, 10 percent ethanol blends are allowed at RVPs of up to 10 psi. This exemption for ethanol blends <u>does not</u> apply to the RFG program.

Commingling these two blends is equivalent to first combining the hydrocarbon portion of both blends and then adding the ethanol from the first blend to the combined hydrocarbon components. The hydrocarbon gasoline by definition has an RVP of 8.0 psi. The hydrocarbon portion of the ethanol gasoline had to have an RVP of 7.0 psi (since the subsequent addition of the ethanol produced an ethanol gasoline with an RVP of 8.0 psi). The hydrocarbon components combine linearly producing a new hydrocarbon component having an RVP of about 7.5 psi (half way between 7.0 and 8.0 psi).[46] Then, adding in the ethanol component, which would now be about 5 percent of the final blend, increases the RVP of the final blend to about 8.5 psi. It is important to note that although the new 50-50 commingled blend would have an ethanol level of around 5 percent, not 10 percent as in the original ethanol blend, the full 1.0 psi RVP increase due to ethanol addition would still occur even at this lower ethanol level.[47]

Although this scenario does accurately describe the basic principles involved in volatility changes when these types of gasolines are blended, the reality is somewhat more complicated. The presence of less polar oxygenates like MTBE can decrease the volatility bump to some degree when more polar oxygenates like ethanol (*e.g.*, as an ethanol blend) are added. This mechanism is called cosolvency.[48] One recent study on the impact of ethanol blend commingling concluded in part that an RVP bump of slightly greater than one psi occurs when ethanol is added at a two volume percent level in an all-hydrocarbon blend, but that a bump of 0.7 psi occurs when ethanol is added to an MTBE blend at the same original RVP level.[49]

In addition to the expected RVP increase, many other factors are extremely important in determining the effect of commingling. These include ethanol blend market share, station/brand loyalty, and the distribution of fuel tank levels before and after a refueling event. Caffrey and Machiele attempted to take these variables into account in modeling the effect of ethanol blend commingling in a mixed fuel marketplace. Their conclusions include the following:

> (1) Brand loyalty and ethanol market share are much more important variables than the distribution of fuel tank levels before and after a refueling event.
>
> (2) Commingling effects can cause a significant increase in fuel RVP.
>
> (3) Commingling effects are clearly more dramatic in a market in which a significant portion of the gasoline is all-hydrocarbon (*i.e.*, non-oxygenated). Depending on the combination of variables chosen (*i.e.*, especially ethanol market share), the RVP increase over the entire gasoline pool can range from around 0.1 to 0.3 psi in a reformulated gasoline market (*i.e.*, ethanol blends commingled only with MTBE blends). Analogous increases for a non-reformulated market (*i.e.*,

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[46] The final RVP resulting from the combination of these two hydrocarbon components would actually be slightly higher than 7.5 psi since the volume of the hydrocarbon portion of the ethanol gasoline is less than the volume of the hydrocarbon gasoline by an amount equal to the volume of the ethanol component.

[47] These are approximations in order to demonstrate basic blending patterns. The volatility of blends resulting from commingling are not necessarily exact linear interpolations of the volatilities of the commingled blends.

[48] Peter Caffrey and Paul Machiele, "In-Use Volatility Impact of Commingling Ethanol and Non-Ethanol Fuels," SAE Technical Paper #94065, February 29, 1994. See also, "The Octamix Waiver," 53 FR 3636, February 8, 1988.

[49] Peter Caffrey and Paul Machiele, "In-Use Volatility Impact of Commingling Ethanol and Non-Ethanol Fuels," SAE Technical Paper #94065, February 29, 1994.

ethanol blends commingled only with all-hydrocarbon blends) range from under 0.1 psi to over 0.4 psi.

(4) The effects of the increase in RVP commingling approaches a maximum when the ethanol market share becomes 30 to 50 percent, and declines thereafter as ethanol takes a larger market share.

C. Fuel Quality in Conventional Gasoline

Conventional gasoline is controlled under EPA's Anti-Dumping Program. When the reformulated gasoline (RFG) regulations were introduced, an anti-dumping program was also introduced. Refiners (and importers) were required to provide information on CG to show that its properties become no worse than they were in 1990. This program was meant to prevent refiners from simply removing "bad" blendstocks from RFG and dumping these into CG. In order to show that properties of CG would not deteriorate, refiners established individual 1990 baselines for CG, which were independently audited and submitted to the EPA. Refiners who could not establish a baseline because of insufficient available information were required to adopt the Clean Air Act baseline included in the statute. (Most parties believe that the Clean Air Act baseline is actually more stringent than a typical individual refinery baseline.)

However, there is no assurance that CG air toxics benefits gained since 1990 will be protected. The EPA's 1997 refinery survey data indicates that 1997 CG sold in the Northeast was 12.8 percent less toxic than 1990 levels. The data also indicate an additional 3.5 percent VOC reduction in the Northeast over the 1990 levels.[50]

Under the complex model, refiners must not exceed their 1990 baselines for exhaust toxics and NO_x. Although EPA does collect information on the quality of CG, the first data on complex model CG (from 1998) were not required to be submitted to EPA until May 31, 1999. The analysis of that data will take at least several months. Thus, at this time the EPA does not have current data on whether complex model CG toxics is in overcompliance. The Agency has indicated, however, that this analysis would be a critical element of guaranteeing that future increase in emissions potential will not occur in CG. Once the analysis is completed, EPA should review any regulatory or administrative authorities available to prevent deterioration of the current air quality performance of conventional gasoline.

If MTBE use was phased out, the antidumping program would prevent any increase in CG from 1990 NO_x and toxics levels only. However, should MTBE be eliminated and ethanol use increase in CG, Department of Energy (DOE) modeling shows a 6 to 7 percent VOC increase in conventional gasoline due to the one pound waiver for ethanol use outside RFG areas. Regarding MTBE use in CG, the Energy Information Administration (EIA) data show that very little MTBE is actually used in conventional gasoline;[51] estimates range, however, from 4,000 to 25,000 barrels per day. It should be noted that the anti-dumping program would not prevent increases in MTBE use in CG.

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[50] NESCAUM, *Relative Cancer Risk of Reformulated Gasoline and Conventional Gasoline Sold in the Northeast*, August 1998.

[51] U.S. Energy Information Administration (Aileen Bohn and Tancred Lidderdale), *Demand and Price Outlook for Phase 2 Reformulated Gasoline, 2000*, April 1999. Data indicate that 5 thousand barrels per day oxygenate demand for conventional gasoline.

EPA is also pursuing other initiatives that are related to the quality of CG. EPA has proposed a gasoline sulfur program and, if any form of sulfur control program were adopted nationally, NO_x levels in CG would clearly be better than current levels.[32] The Agency is also in the process of evaluating mobile source air toxics and is expected to issue a proposal in early 2000, at which time the Agency will further address the issue of toxic emissions.

V. Wintertime Oxyfuel Program

A. Introduction

In addition to the RFG program, the CAAA of 1990 required the establishment of a Wintertime Oxyfuel program. Under this program gasoline must contain 2.7 percent oxygen by weight during the wintertime in areas that are not in attainment for the National Ambient Air Quality Standards for CO.

In 1992, when the oxygenated fuels program began, there were 36 areas implementing the program. The 1998-99 oxygenated fuels season had 17 areas implementing the program. Nineteen areas were able to redesignate to CO attainment due to the implementation of the oxygenated fuels program along with other control measures. Of the remaining 17 areas, eight have data to redesignate and are either working on or have submitted redesignation requests to EPA, or they have chosen to continue to implement the program as a CO control measure even though they have attained the standard. Six areas are classified as "serious" CO nonattainment areas, and the remaining three areas are classified as "moderate" CO nonattainment areas; all of these areas continue to implement the program in an effort to attain the CO standard.

Most of the winter oxygenated fuel areas use ethanol. The only two areas using MTBE for the winter oxygenate program are Los Angeles and the New York City metropolitan area. It is a possibility that New York City, which includes metropolitan Connecticut, New Jersey, and New York, will leave the program before the next winter season because they will demonstrate attainment with the CO standard. Los Angeles will need to phase-out MTBE use under the Governor's recent directive. Therefore, MTBE use for winter oxygenated areas is not likely to be common in the future.

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[32] The Panel is aware of the current proposal for further changes to the sulfur levels of gasoline and recognizes that implementation of any change resulting from the Panel's recommendations will, of necessity, need to be coordinated with implementation of these other changes. However, a majority of the Panel considered the maintenance of current RFG air quality benefits as separate from any additional benefits that might accrue from the sulfur changes currently under consideration.

B. Air Quality Benefits

The most comprehensive study regarding oxygenated fuels was completed in June 1997 by the Office of Science and Technology Policy (OSTP).[53] The report concluded that "analyses of ambient CO measurements in some cities with winter oxygenated fuels programs find a reduction in ambient CO concentrations of about 10 percent."[54] The report also suggested "the need for a thorough, statistically defensible analysis of ambient CO data." In response to that suggestion, EPA initiated a study[55] that analyzed ambient CO data from about 300 monitoring sites. The study indicated a downward shift in ambient CO ranging from 6 percent to 13 percent for the six month winter season in areas implementing an oxyfuel program in 1992. This EPA study was further refined by Systems Applications International (SAI).[56] The SAI study analyzed summer (June and July) and winter (December and January) bimonthly means or maximum daily 8-hour CO concentrations from 1986 to 1995. The report concluded that there was a substantial (14 percent reduction) and statistically significant association (± 4 percent with 95 percent confidence) between the use of oxyfuels and monitored CO concentrations.

On this point, the OSTP report concluded:

> Older technology vehicles (carbureted and oxidation catalysts) benefit more from the use of oxygenated fuel. The amount of pollutant emissions is smaller in newer technology vehicles (fuel injected and adaptive learning, closed loop three-way catalyst systems). Additionally, the percentage reductions in CO and hydrocarbon emissions from the use of fuel oxygenates are found to be smaller in the newer technology vehicles compared to older technology and higher emitting vehicles.[57]

Analysis by the EPA (MOBIL6 Model) also indicates that even with fleet turnover, a significant contribution to CO reduction from the winter oxygenated program is expected until at least 2005 (Table 3).

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[53] Office of Science and Technology Policy, National Science and Technology Council, *Interagency Assessment of Oxygenated Fuels*, June 1997.

[54] Office of Science and Technology Policy, National Science and Technology Council, *Interagency Assessment of Oxygenated Fuels*, June 1997, p. iv.

[55] U.S. Environmental Protection Agency, Office of Mobile Sources, (R. Cook), *Impact of the Oxyfuel Program on Ambient CO Levels*, 1996.

[56] Systems Application International, *Regression Modeling of Oxyfuel Effects On Ambient CO Concentrations*, January 1997.

[57] Office of Science and Technology Policy, National Science and Technology Council, *Interagency Assessment of Oxygenated Fuels*, June 1997, p. iv.

Table 3. Percent Reduction in CO Emissions Resulting from 3.5 Percent Oxygen, As Predicted by the MOBILE Model[58]

Year	MOBILE6
1997	10% to 20%
2000	5% to 15%
2005	0% to 10%
2010	0% to 2%

Source: U.S. Environmental Protection Agency

Most winter oxygenated areas use ethanol, which is typically blended at 3.5 percent by weight. Therefore the chart reflects actual benefits rather than the benefits that may result from the regulatory requirement of 2.7 percent oxygen by weight. If a lower oxygen level is used, one would expect there to be a linear downward trend in benefits.

The U.S. Environmental Protection Agency's Area by Area analysis of 1998 RFG Survey Data indicates that the complex model emissions performance of RFG in Chicago and Milwaukee, while easily exceeding all Phase I performance (*i.e.*, emission reduction) requirements, generally ranks low compared to other RFG areas. In order to investigate factors influencing the performance of Chicago and Milwaukee RFG relative to RFG in other areas, it is necessary to consider the composition of the fuels. The Chicago and Milwaukee property values were similar, and there were notable differences from the National Average properties. The sulfur and benzene levels for Chicago and Milwaukee were substantially higher. These two areas had the highest and second highest levels of all areas for these parameters. Oxygenate type and oxygen content differed from the National Average. Ethanol was the primary oxygenate used in these areas. Therefore, the total oxygen content and the ethanol contribution to total oxygen were highest for these areas. Olefin content was lower than the National Average RFG, and the olefin content for these two areas was the lowest of all areas surveyed.

The higher sulfur levels in the Chicago and Milwaukee RFG affected its relative complex model performance for all three pollutants. This analysis indicates that sulfur was the primary factor influencing relative VOC and NOx performance, and that it may have some influence on toxics performance. Although 1998 RFG Survey Data indicates that the complex model emissions performance of RFG in Chicago and Milwaukee, easily exceeded all Phase I performance (*i.e.*, emission reduction) requirements. The margin of air toxics overcompliance was not as great there as in other areas primarily due to higher benzene content, but other factors such as increased acetaldehyde emissions and sulfur levels also contributed. Oxygenates had little impact on VOC or NO_x performance.

[58] MOBILE6 effects are draft only. Only after MOBILE6 is finalized will actual and more accurate estimates be available. These projected MOBILE6 Oxy-on-CO effects are based on MOBIL Report #M6.FUL.002, which is posted on the MOBILE6 web site (http://www.epa.gov/OMS/M6.htm.)

It is important to realize that this analysis was intended to identify factors which caused Chicago and Milwaukee to rank lower than most other RFG areas in complex model emissions performance. The approach was to vary one property at a time and look at its effect on emissions performance. In reality, fuel properties are not independent, and this "one at a time" analysis was not intended to answer more complex questions such as "What would happen to fuel properties and emissions performance if Chicago and Milwaukee RFG suppliers switched from ethanol to MTBE?"

Appendix B

Figure B1. RFG Survey Data, Summer 1998: Phase I VOC Reduction

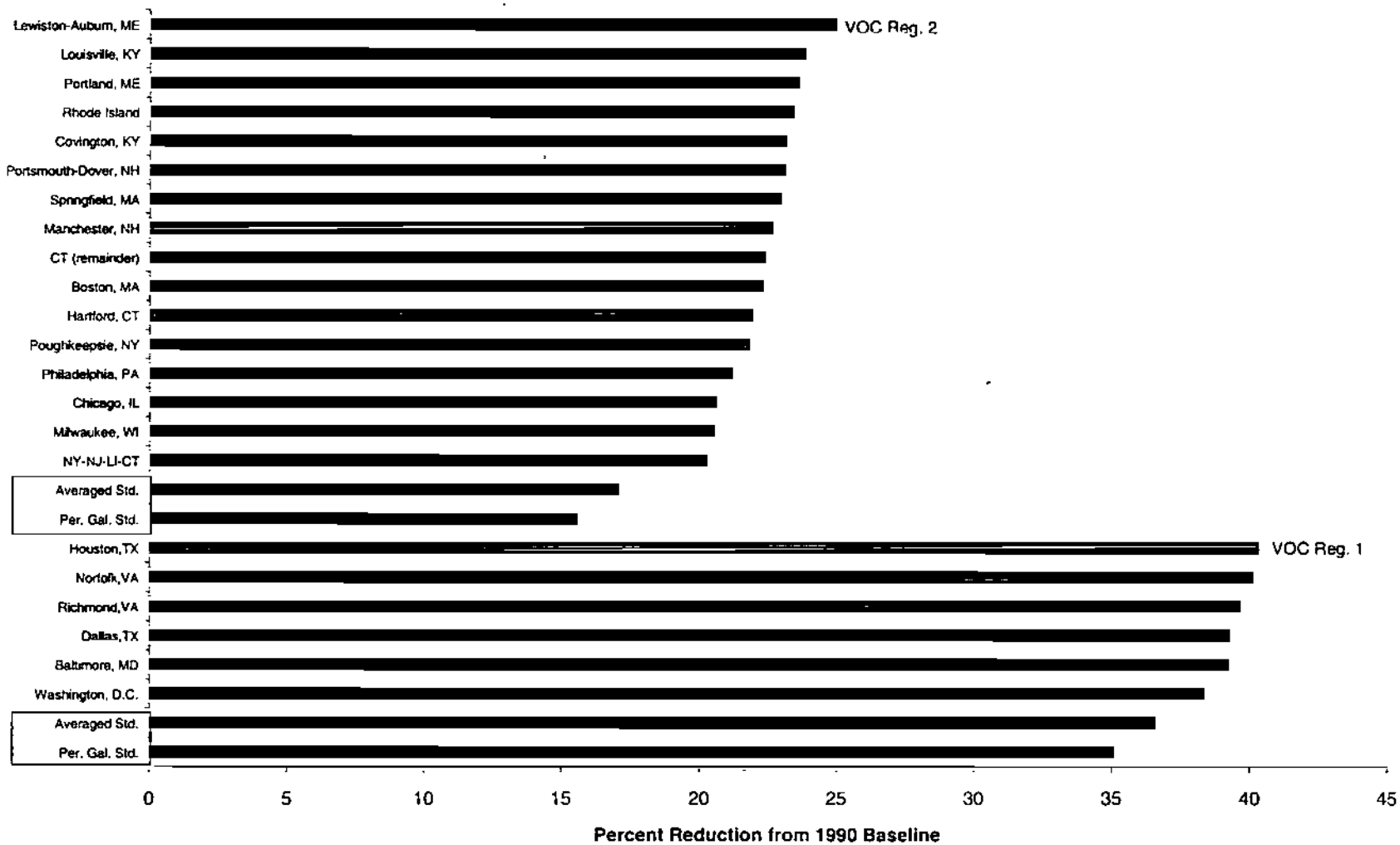


Figure B2. RFG Survey Data, Summer 1998: Phase I Toxics Reduction

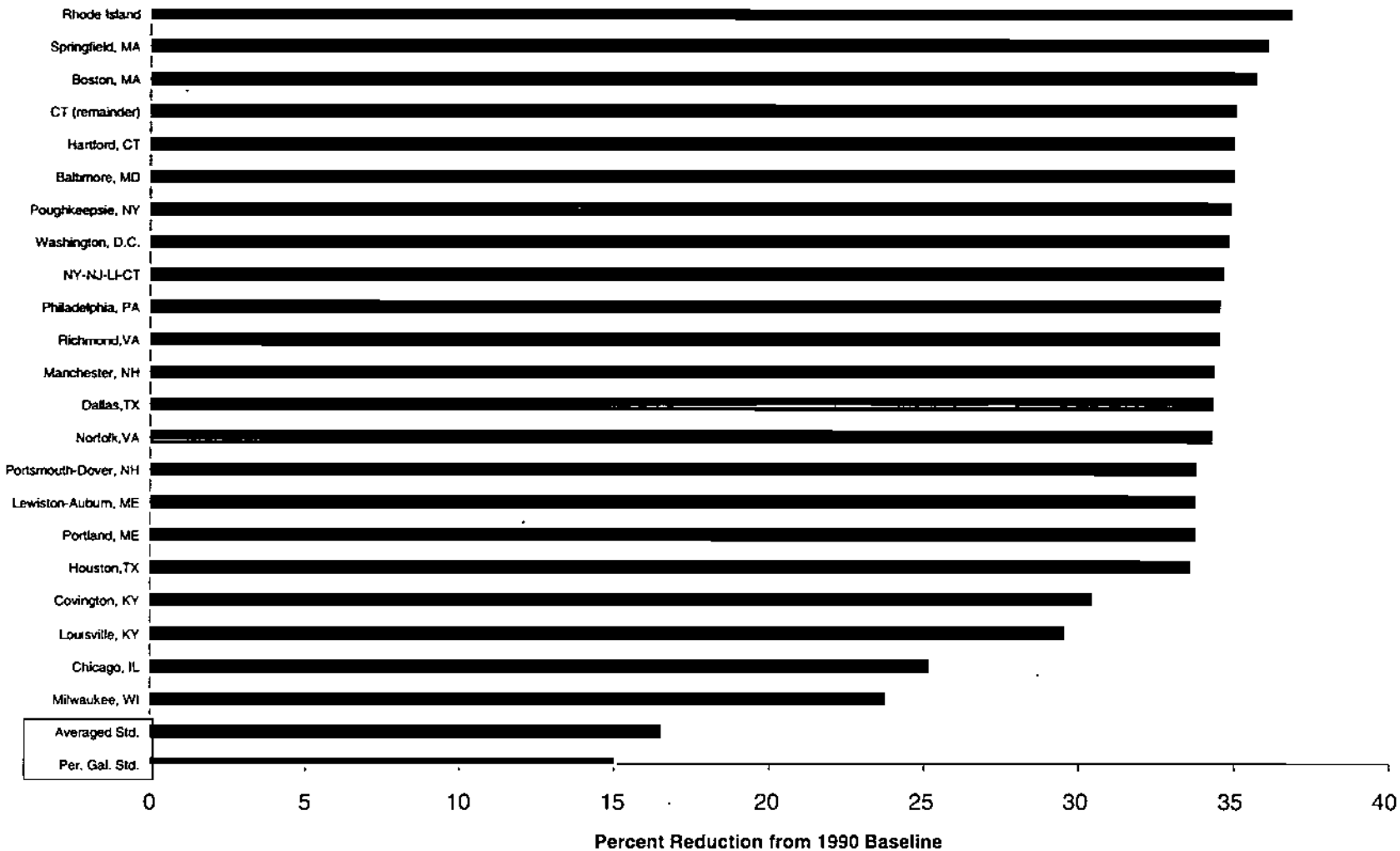
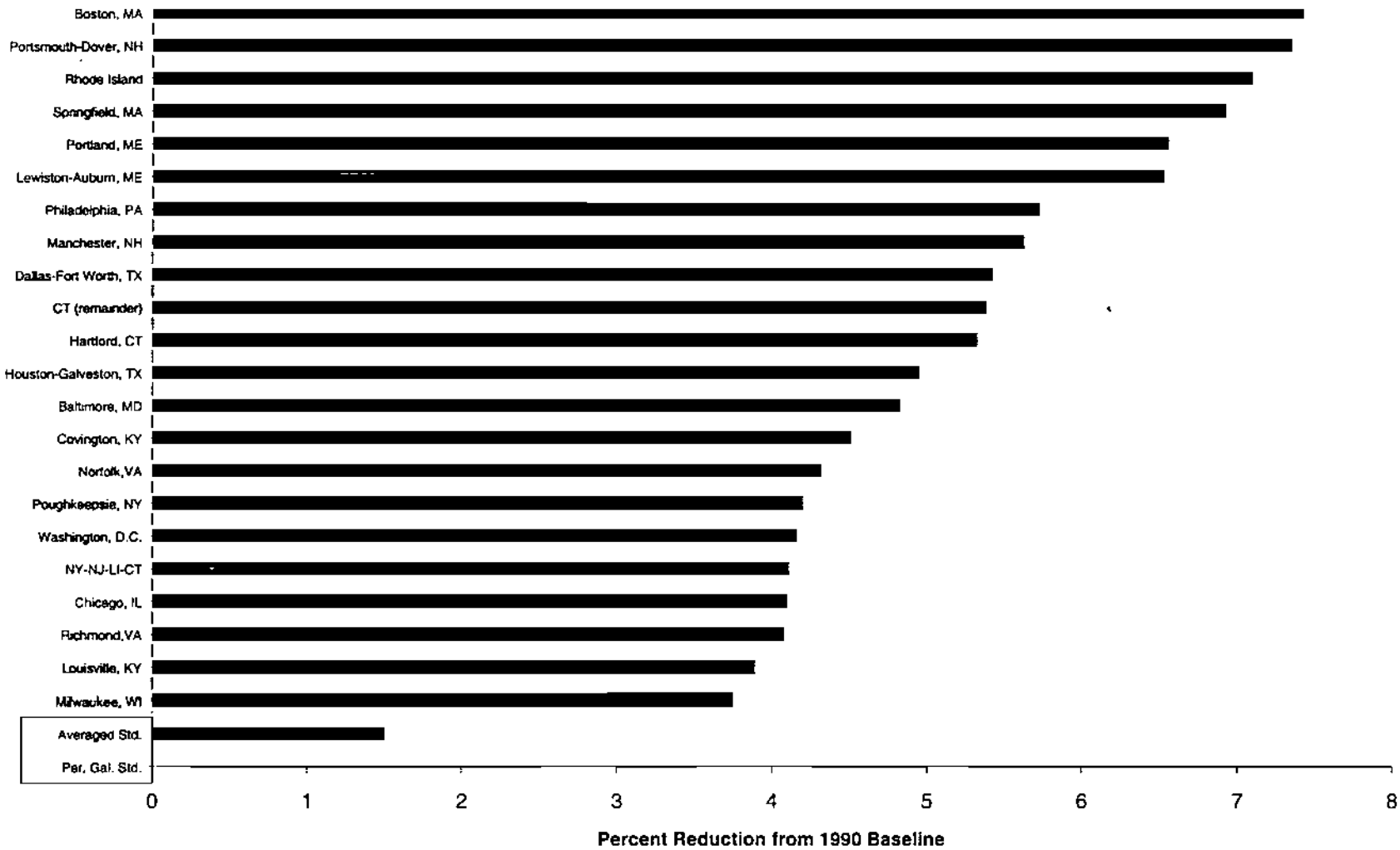


Figure B3. RFG Survey Data, Summer 1998: Phase I NOx Reduction



C. Prevention, Treatment, and Remediation

I. Introduction

This *Issue Summary* reviews the technical and regulatory approaches to reducing the sources of oxygenate impacts on water resources; release prevention and detection; storage tank-related issues; Federal and State approaches to protecting drinking water sources; the treatment of impacted drinking water; the remediation of oxygenate-impacted ground water; and funding sources. Because of recent detections of methyl tertiary butyl ether (MTBE) in drinking water supplies, MTBE is emphasized throughout this section. The body of information available to evaluate impacts of other gasoline oxygenates on water resources is significantly more limited.

The water resources described in this section are generally divided into two categories: surface water (streams, lakes, reservoirs, and stormwater); and ground water (water table and confined aquifers). Drinking water refers to those water resources currently used for public and private water supply systems. Although a variety of sources of MTBE impacts to water quality have been identified, this section focuses primarily on releases from underground storage tank (UST) systems, as this population comprises the vast majority of the known potential point sources and has been studied in much greater detail than other potential sources of MTBE impact.

II. Sources and Trends of Water Quality Impacts

As described in *Issue Summary A* (Water Contamination), surface water and ground water resources are impacted by both gasoline oxygenates and a variety of other natural and anthropomorphic sources of contaminants. There are a number of primary sources that appear to be responsible for most identified MTBE impacts:

- Underground storage tanks, other gasoline storage and distribution facilities, such as bulk storage terminals, small household/farm gasoline tanks, and aboveground storage tanks;
- Interstate and intrastate petroleum pipelines;
- Small releases (*e.g.*, gasoline tank ruptures during car accidents or consumer disposal of gasoline in backyards) appear to have been the source of private well contamination in Maine.[59] These types of releases are also expected to be a source of contamination to private wells in other States;
- Engine exhaust and related releases (*e.g.*, spillage) into lakes and reservoirs from two-stroke watercraft and older four-stroke watercraft;
- Stormwater runoff.

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[59] State of Maine Bureau of Health, Department of Human Services, Bureau of Waste Management & Remediation, Department of Environmental Protection, Maine Geological Survey, and Department of Conservation, *Maine MTBE Drinking Water Study, The Presence of MTBE and other Gasoline Compounds in Maine's Drinking Water--Preliminary Report*, 1998.

A. Assessing Impacts and Trends

There are no comprehensive quality assessments of our nation's water resources that can provide clear indications of the trend of MTBE impacts on water supplies. Further, it is unknown how frequently gasoline compounds are released from the current population of UST systems or the quantity of gasoline that is released. As such, it is unknown whether releases of gasoline and related impacts to water resources are continuing to grow, whether increasing awareness of this issue has stabilized or reduced the frequency of such releases, or whether they are on the decline. Not all States require monitoring for MTBE at LUFT sites and in drinking water quality sampling, further preventing a full characterization of MTBE's current or potential future impacts.

New Federal and State UST regulations promulgated in the 1980's have spurred comprehensive assessments and corrective action programs at facilities with USTs. As of December 1998, many currently regulated UST facilities can be expected to have had some type of site assessment conducted as part of compliance activities and property transfer information requirements in order to determine whether there have been any releases. The number of identified UST releases has grown steadily during the last decade, averaging about 20,000 new known releases annually.[60] Most releases have been discovered with tank removal during the tank upgrading process, rather than being detected as part of a continuous monitoring program. Thus, it is not possible to know when the release actually occurred (*e.g.*, many releases reported in 1998 occurred in previous years, but were only discovered in 1998). The rate at which new release sites are discovered is expected to decrease in coming years, as most UST facilities being evaluated for contamination were in the process of meeting the December 1998 upgrading deadline. Because of limitations inherent in current leak detection technologies, it is expected that releases reported in future years from the current population of upgraded facilities will not provide a more accurate characterization of the occurrence of new releases.

Limited information is available regarding releases from other gasoline storage/distribution facilities, and very little data exist to characterize the extent to which other types of gasoline releases occur.

B. Underground and Aboveground Storage Tanks

Underground storage tanks represent the largest population of potential point sources of gasoline releases to ground water.[61] Gasoline storage and distribution facilities are of particular importance as potential sources of ground water contamination from MTBE and other oxygenates, because these facilities can release relatively large volumes of gasoline (*e.g.*, hundreds of gallons to thousands of gallons), which can result in localized subsurface impacts with aqueous concentrations in excess of 100,000 parts per billion (ppb) adjacent to the release source, as well as extensive dissolved plumes at lower concentrations. In California, MTBE (associated with gasoline releases throughout the State) is a frequent and widespread contaminant in shallow groundwater. Detections of MTBE are reported at 75 percent of sites where fuel hydrocarbons have impacted ground water. The minimum number of MTBE point sources from leaking underground storage tank (LUST) sites in California is estimated at greater than 10,000. Maximum concentrations at these sites ranged from several ppb to concentrations greater than 100,000 ppb, indicating a wide range in the magnitude of MTBE impacts at these sites (Table 1).

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[60] U.S. Environmental Protection Agency, Office of Underground Storage Tanks, "Corrective Action Measures Archive," http://www.epa.gov/swerust1/cat/camarchv.htm.

[61] U.S. Environmental Protection Agency, Office of Water, *National Water Quality Inventory: 1996 Report to Congress*, 1996.

Table 1. Comparison of Maximum MTBE Ground Water Concentrations Collected by the California Regional Boards, January 1999

MTBE Concentration (Parts Per Billion)	Sites Exhibiting Concentration Level (Percent)
<5	23%
5-50	12%
50-200	11%
200-1,000	17%
1,000-5,000	14%
5,000-20,000	13%
20,000-100,000	7%
>100,000	3%

Note: Data represent collections from 4,300 sites.

Source: Happel, Dooher, and Beckenbach, "Methyl Tertiary Butyl Ether Impacts to California Groundwater," presentation at the March 1999 MTBE Blue Ribbon Panel meeting.

There are currently an estimated 825,000 regulated USTs at approximately 400,000 facilities.[62] Of the nation's approximately 182,000 retail gasoline outlets, the "major" oil companies own about 20 percent, or about 36,000 facilities.[63] On average, each of the nation's retail outlets have about 3 storage tanks, thus containing a total of approximately 550,000 USTs, 66 percent of the national total. The remainder of the regulated UST population consists of state or federally owned facilities and nonretail fueling facilities (*e.g.*, on-site fueling for taxis, rental cars, delivery trucks, etc.). Over the past 10 years, approximately 1.3 million Federally regulated USTs have been closed, *i.e.*, removed or properly emptied, cleaned, and buried in place.[64]

There are approximately 3 million underground fuel storage tanks exempt from Federal regulations (*e.g.*, certain farm and residential gasoline tanks and home heating oil tanks).[65] Large aboveground storage tanks (ASTs) at refineries and distribution terminals, however, are regulated under both State and Federal laws, including the Spill Control and Countermeasures (SPCC) regulations of the Oil Pollution Act (OPA) of 1990. There are currently over 10,000 facilities with this type of bulk storage of gasoline. As compared with USTs, there is no comparable Federal regulatory program for ASTs, and thus current release statistics for ASTs are not available. A 1994 American Petroleum Institute (API) survey

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[62] U.S. Environmental Protection Agency, Office of Underground Storage Tanks, based upon *FY 1999 Semi-Annual Activity Report – First Half* (unpublished).

[63] National Petroleum News, *Market Facts 1998* (Arlington Heights, IL: Adams Business Media, 1998), p. 124.

[64] There is no database that identifies the specific locations of these federally regulated facilities or their proximity to drinking water supply sources. See U.S. Environmental Protection Agency, Office of Underground Storage Tanks, "Corrective Action Measures Archive," http://www.epa.gov/swerust1/cat/camarchv.htm.

[65] U.S. Environmental Protection Agency, *Underground Heating Oil And Motor Fuel Tanks Exempt From Regulation Under Subtitle I Of The Resource Conservation And Recovery Act* (May 1990).

estimated that ground water contamination had been identified at approximately 68 percent of marketing terminals with ASTs, 85 percent of refinery tank fields with ASTs, and 10 percent of transportation facilities with ASTs. Of these facilities, over 95 percent were engaged in corrective action under the guidance of a State or Federal authority.[66]

C. Pipelines

Excluding intrastate pipelines and small gathering lines associated with crude oil production fields, there are approximately 160,000 miles of liquids pipelines in the United States.[67] These pipelines transport approximately 12.5 billion barrels of crude oil and refined products annually. Over a recent six-year period (1993 to 1998), an average of 197 spills occurred annually, with an average volume from all spills totaling 140,000 barrels per year. Of the volume spilled during this period, crude oil accounted for 44 percent, whereas refined petroleum products (*e.g.*, gasoline, home heating oil, jet fuel) accounted for 31 percent. Although the specific volume of gasoline spilled cannot be readily identified, gasoline represents the largest volume of refined products transported. Additionally, there are little or no data on the extent of MTBE releases from pipelines.

In California, pipeline release data are currently being compiled by the Office of the State Fire Marshal, which regulates approximately 8,500 miles of pipelines. Since 1981, there have been approximately 300 pipeline releases within the State Fire Marshal's Jurisdiction.

The pipeline industry is working with pipeline regulators and environmental trustee agencies to develop a definition of areas that may be unusually sensitive to environmental damage from pipeline leaks to be used in conducting future risk assessments along pipeline rights-of-way. Included under the draft definition are areas with drinking water resources, which are based on EPA's standards for defining both surface and subsurface drinking water supplies. Once work is completed both on drinking water and biological resources that may be unusually sensitive to environmental damage, OPS will make information available for pipeline operators to use in conducting risk assessments along pipeline rights-of-way. The Office of Pipeline Safety may also require increased pipeline integrity standards to prevent releases in unusually sensitive areas.[68]

In California, the locations of fuel pipelines and drinking water wells are being integrated into a geographic information system (GIS), which is discussed in greater detail in Section V of this *Issue Summary*. The State Fire Marshal Office is required at least once every two years to determine the identity of each pipeline or pipeline segment that transports petroleum products within 1,000 feet of a public drinking water well. Furthermore, these pipelines' operators must be notified to prepare a pipeline wellhead protection plan for the State Fire Marshal's approval.

D. Small Releases

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[66] American Petroleum Institute, *A Survey of API Members' Aboveground Storage Tank Facilities*, July 1994.

[67] The U.S. Department of Transportation (DOT)'s Office of Pipeline Safety (OPS) oversees the safety and environmental regulation of interstate petroleum pipelines. Petroleum pipelines are also subject to economic regulation by the Federal Energy Regulatory Commission (FERC).

[68] Development of the definition and its subsequent application are subject to notice and comment requirements under Federal rulemaking procedures.

Small releases from automobile accidents, consumer disposal of "old" gasoline, or other backyard spills during fueling operations have been identified by officials in Maine as sources of contamination of private drinking water wells. For example, in a 1998 study of over 900 private household drinking water wells in Maine, approximately 16 percent had detectable MTBE concentrations, and about 1 percent contained concentrations exceeding the State of Maine's 35 ppb drinking water standard.[69] In one incident in Maine, about 7 to 12 gallons of gasoline spilled during a car accident contaminating 24 nearby private wells installed in a bedrock aquifer. Eleven of the wells had MTBE concentrations in excess of 35 ppb. Following the excavation of the contaminated soil, well monitoring at this site has indicated that MTBE levels are decreasing rapidly in all wells. Similarly, home heating oil storage tanks have also been identified as potential sources of MTBE contamination, as MTBE might be present from mixing the heating oil with small volumes of gasoline in the bulk fuel distribution or tank truck delivery systems.[70]

E. Watercraft

Gasoline-powered watercraft have contributed to the contamination of lakes and reservoirs with MTBE. These impacts are primarily attributed to exhaust discharges from two-stroke engines, which are the most commonly used engine type in such watercraft. The two-stroke engines discharge in their exhaust up to 30 percent of each gallon of gasoline as unburned hydrocarbons. In two recent studies examining MTBE contamination at lakes at which reformulated gasoline (RFG) with MTBE was used, concentrations of MTBE in substantial portions of the lakes' volume ranged from 10 ppb to 30 ppb after peak periods of recreational watercraft usage.[71] After the boating season ended, these concentrations decreased fairly rapidly (half-life of approximately 14 days) to low background levels (approximately 1 ppb to 2 ppb or less). Volatilization is considered the dominant mechanism for this removal process.[72]

F. Stormwater Runoff

Stormwater runoff is considered a nonpoint source of MTBE contamination. Runoff becomes contaminated with MTBE from both the dissolution of residual MTBE from parking lots (*e.g.*, service

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[69] State of Maine Bureau of Health, Department of Human Services, Bureau of Waste Management & Remediation, Department of Environmental Protection, Maine Geological Survey, and Department of Conservation. *Maine MTBE Drinking Water Study, The Presence of MTBE and Other Gasoline Compounds in Maine's Drinking Water--Preliminary Report*, 1998.

[70] G.A. Robbins et al., "Evidence for MTBE in Heating Oil," *Ground Water and Remediation*, Spring 1999, pp. 65-68.

[71] M.S. Dale et al., "MTBE -- Occurrence and Fate in Source-Water Supplies," in American Chemical Society Division of Environmental Chemistry preprints of papers, 213th, San Francisco, CA: American Chemical Society, v. 37, no. 1, 1997, pp. 376-377; J.E. Reuter et al., "Concentrations, Sources, and Fate of the Gasoline Oxygenate Methyl Tert-Butyl Ether (MTBE) in a Multiple-Use Lake," *Environmental Science & Technology*, 1998, v. 32, no. 23, pp. 3666-3672.

[72] J.E. Reuter et al., "Concentrations, Sources, and Fate of the Gasoline Oxygenate Methyl Tert-Butyl Ether (MTBE) in a Multiple-Use Lake," *Environmental Science & Technology*, 1998, v. 32, no. 23, pp. 3666-3672.

stations and retail businesses) and roadways and from "atmospheric washout."[73] MTBE contamination from atmospheric washout is thought to be small compared to that from paved surfaces.[74] The United States Geological Survey (USGS) has characterized MTBE concentrations in runoff in many areas and has typically found such contamination to be lower than 2 ppb. Stormwater is discharged both to surface water and to ground water, and thus serves as a source of very low-level MTBE contamination of these potential drinking water sources.

III. Release Prevention and Detection

A. Prevention

Since the passage of Federal UST legislation in 1984, improved release prevention practices (*e.g.*, corrosion protection, and compatibility between the tank's construction materials and its contents) has been required for all new USTs. Following a 10-year phase-in period from the promulgation of EPA regulations in 1988, as of December 1998, all regulated USTs are required to be protected from corrosion, small spills, and overfills, and must also have release detection equipment and procedures in place. Many States have additional and more stringent standards. These regulations are intended to prevent releases, and should a release occur, to detect it promptly in order to minimize ground water impacts. Presently, it is not possible to demonstrate the effectiveness of individual States' UST upgrade programs or the Federal upgrade program in preventing releases of gasoline from dispensing/storage facilities.

Even after tank systems (tanks and piping) are in full compliance with the 1998 regulations, however, some releases are expected to occur as a result of improper installation or upgrading, improper operation and maintenance, and accidents. Many of these releases may not be detected as intended due to the inherent limitations of release detection technologies.

Anecdotal reports from California, Maine, and Delaware indicate that upgraded USTs continue to have releases. Efforts are underway by the EPA and in California to evaluate new and upgraded UST systems to determine which factors may contribute to such releases. In California, for example, the Santa Clara Valley Water District has completed a study evaluating release prevention and detection performance at approximately 30 upgraded facilities.[75] The California Environmental Protection Agency (CalEPA) is planning to begin a similar study in 1999. Further studies will likely be required in order to investigate a representative sampling of the UST population.

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[73] G.C. Delzer et al., *Occurrence of the Gasoline Oxygenate MTBE and BTEX Compounds in Urban Stormwater in the United States, 1991-95*, U.S. Geological Survey Water Resources Investigation Report WRIR 96-4145,1996.

[74] A.L. Baehr, P.E. Stackelberg, and R.J. Baker, "Evaluation of the Atmosphere as a Source of Volatile Organic Compounds in Shallow Ground Water," *Water Resources Research*, Jan. 1999, v. 35, no. 1, pp. 127-136; T.J. Lopes and D.A. Bender, "Nonpoint Sources of Volatile Organic Compounds in Urban Areas -- Relative Importance of Urban Land Surfaces and Air," *Environmental Pollution*, 1998, v. 101, pp. 221-230.

[75] Santa Clara Valley Water District Groundwater Vulnerability Pilot Study, "Investigation of MTBE Occurrence Associated with Operating UST Systems," July 22, 1999. http://www.scvwd.dst.ca.us/wtrqual/factmtbe.htm.

Based on reports received to date from the States, EPA estimates that approximately 80 percent of the regulated universe of UST systems currently meet the December 1998 requirements.[76] By the end of 2000, EPA expects at least 90 percent of the regulated tanks will be in compliance, leaving approximately 80,000 tanks that have not been upgraded. States' UST programs are primarily responsible for implementing and enforcing UST regulations. In augmenting and assisting States' activities, EPA provides outreach, helps States train UST inspectors, and fosters the exchange of information among States regarding effective means of securing compliance. Upon a State's request, or acting independently when necessary, EPA will also take direct action to enforce the regulations.

Approximately 20 States now prohibit deliveries to UST systems that are not fully compliant with the December 1998 regulations, and several major gasoline suppliers have stopped fuel delivery to non-compliant tanks. These actions, along with the traditional enforcement actions taken by EPA and States, have contributed to higher compliance rates.[77]

The U.S. Environmental Protection Agency and the States also require that USTs that do not meet the technical standards are properly closed with thorough site assessments for potential releases. Through December 29, 1999, non-compliant USTs can be temporarily closed, but must be permanently closed, and any releases identified and remediated, thereafter if not brought into compliance.

Currently, there is an apparent trend toward using small ASTs (*i.e.*, fewer than 20,000 gallons) to replace regulated USTs.[78] These ASTs are generally not subject to the same release prevention and detection requirements as USTs. Releases from ASTs may also result in MTBE contamination, and so it may be necessary to evaluate the performance of such systems.

B. Detection

Existing regulations require the use of release detection techniques that meet specific performance criteria. Internal (*e.g.*, automatic tank gauges) or external (*e.g.*, ground water monitoring) approaches may be used in meeting these criteria. Although these regulations do not allow any detected releases to go unreported, the regulations do permit several options of varying degrees of sensitivity in the detection of a release, which can result in smaller releases going undetected for an extended period of time.[79] The regulations, promulgated in 1988, were considered adequate and "best available technology" for typical gasoline (and other fuels) formulations at the time because hydrocarbon plumes are generally self-limiting (primarily due to intrinsic bioremediation) and thus small releases or slow chronic releases that

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[76] U.S. Environmental Protection Agency, Office of Underground Storage Tanks, estimate based upon data submitted by States on February 28, 1999 and April 30, 1999 (unpublished).

[77] Ellen Frye, "When Push Comes to Shove," *LUSTLine*, September 1998.

[78] Juan Sexton, Kansas State Department of Health & Environment, paper presented at the 10th Annual UST/LUST National Conference (Long Beach, CA, March 30, 1999); Wayne Geyer, "Above the Ground but not the Law: ASTs on the Rise, Regulators in Hot Pursuit," Petroleum Equipment and Technology, July 1999.

[79] For example, under one option, a 0.2 gallon per hour release could go undetected in up to 5 percent of all cases (*i.e.*, it is detected in 95 of 100 instances) and unreported by compliant systems (in a worst case scenario). The same technology should not have greater than a 5 percent occurrence of false alarms. Other types of leak detection may have lower or higher thresholds and still meet the EPA guidelines. A 0.2 gallon/hour release would result in a release of 1,752 gallons if undetected for one year, and could go undetected for several years.

remain undetected have typically not resulted in drinking water impacts. The regulations did not address the use of oxygenates although they were used as octane enhancers at this time, albeit at generally lower levels than in RFG and oxyfuel.[80]

Changing existing UST release detection regulations to address the use of oxygenates in gasoline will require EPA to analyze the risks, costs, and benefits of any regulatory changes. In the past, changing such a regulation has taken three to five years. The U.S. Environmental Protection Agency has initiated a field verification study of UST release detection performance and expects initial results in early 2000.[81]

IV. Underground Storage Tanks

A. Materials Compatibility

The use of oxygenates in gasoline in the conventional gasoline supply was well established in the mid-1980's when EPA began formulating the current Federal UST regulations (1998), which formally identified and addressed compatibility issues. The regulations noted that standard specifications for steel and fiberglass tank system materials had been established to provide for compatibility with gasoline/oxygenate mixtures containing up to 15 percent by volume MTBE, 10 percent by volume ethanol, and 5 percent by volume methanol. Industry standards for materials compatibility have been in place since 1986.

A recent evaluation concluded that there are no known studies indicating that any significant deterioration will occur in metal or fiberglass UST systems as a result of concentrations of MTBE or other oxygenates in gasoline.[82] The same study indicated, however, that given the lack of existing "real world" characterizations of the long-term performance of typical UST system materials, further independent quantitative evaluation may be warranted, particularly with regard to potential metallic corrosion, fiberglass permeability, and the elastomer integrity of gaskets and seals. Because tank and piping materials may be in contact both with gasoline vapors and water containing high concentrations of dissolved gasoline components, compatibility with the vapor or aqueous phase of oxygenated gasolines may also merit study, especially if there is potential for the substantial enrichment of oxygenates in either phase.

B. Training, Education, and Certification

It has long been recognized that UST releases can be caused by the failure to adequately perform certain standard installation and daily operational and maintenance practices. Despite existing regulations that address many of these practices, owners, contractors, and employees may not routinely exercise appropriate care in performing these activities. The most frequently identified problem areas include

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[80] The use of oxygenates in gasoline was well established by the mid-1980's.

[81] Thomas M. Young and the U.S. Environmental Protection Agency, *Field Evaluation of Leak Detection Performance*, National Leak Detection Performance Study, 1999.

[82] Kevin Couch and Thomas M. Young, "Leaking Underground Storage Tanks (USTs) as Point Sources of MTBE to Groundwater and Related MTBE-UST Compatibility Issues," in University of California and UC Toxic Substances Research & Teaching Program, *Health and Environmental Assessment of MTBE, Volume IV*, 1998.

installation, fuel delivery and procedures, and routine maintenance of dispensers and release detection equipment.[83]

Federal UST law contains neither any requirement nor any authority for the certification of owners, operators, inspectors, or contractors. In practice, most Federal, State, and local inspectors are well trained, and many UST owners require training for their employees. There is often considerable turnover of facility employees in State and local programs, however, and constant training is required. A few States have third party inspection programs requiring that facility owners hire a certified inspector to document a facility's state of compliance, although there is anecdotal evidence that these programs are not followed.

States have taken the impetus in certification and similar programs. For example, half of the States have programs for licensing or certifying contractors who install, repair, and remove USTs. A smaller percentage of States (perhaps 25 percent) require certification or licensing of tank testers -- primarily for those who perform release detection tests. Finally, even a smaller percentage of States, probably around 20 percent, have registration or certification programs for remediation contractors. As these estimates indicate, further progress could be made in establishing such programs in additional States.

V. Protection of Drinking Water Sources and Water Quality Management

A. Federal Efforts

Section 1453 of the 1996 Safe Drinking Water Act (SDWA), as amended in 1996, requires all States to complete assessments of their public drinking water supplies. By 2003, each State and participating Tribe must delineate the boundaries of areas in the State (or on Tribal lands) that supply water for each public drinking water system; identify significant potential sources of contamination; and determine each system's susceptibility to sources of contamination. The assessments will synthesize existing information about the sources of drinking water supplies in order to provide a national baseline of the potential contaminant threats and to guide future watershed restoration and protection.

The assessment of drinking water sources is only one part of protecting underground drinking water sources.[84] The Wellhead Protection Program, which was established under the 1986 SDWA amendments, goes beyond assessment to add additional requirements for prevention within wellhead protection areas, and to establish contingency plans in the case of a release. Wellhead protection programs are currently in place in 49 States and territories. Over 125,000 public drinking water systems have community-level wellhead protection measures in place or under development.

To further identify those areas that may be impacted by MTBE and other contaminants associated with gasoline, EPA is reviewing all State assessment program submittals to ensure that each program inventories gasoline service stations, marinas, USTs, and gasoline pipelines in drinking water source

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[83] California State Water Resources Control Board, "Are Leak Detection Methods Effective In Finding Leaks In Underground Storage Tank Systems? (Leaking Site Survey Report)" January 1998. Http://www.swrcb.ca.gov/~cwphome/ust/leak_reports/index.htm.

[84] U.S. Environmental Protection Agency, Office of Water, *State Source Water Assessment and Protection Programs Guidance*, EPA 816-F-97-004, August 1997, www.epa.gov/OGWDW/swp/fs-swpg.html.

protection areas. This will provide an opportunity to collect locational data for water sources and contaminant sites as part of the State Source Water Assessment Programs. Here, the challenge will be threefold: (1) to collect information useful to multiple stakeholders; (2) to maintain, update, and improve the data over time; and (3) most importantly, to make this information easily accessible among agencies

The U.S. Environmental Protection Agency is also revising its current Unregulated Contaminant Monitoring Rule. The revised rule, scheduled to take effect in January 2001, will require large water systems (serving more than 10,000 persons) and a representative sampling of small and medium-sized water systems (serving fewer than 10,000 persons) to monitor and report MTBE detections, a procedure that should not add substantially to monitoring costs due to the inclusion of MTBE analysis within analytical tests used for monitoring of other VOCs. Although this will substantially increase the monitoring for MTBE, under this regulation, the majority of public groundwater supply wells will still not be monitored for MTBE. For example, if this regulation were to be enacted today, in California, MTBE monitoring and reporting would be required for all 3,094 active wells (within water systems serving more than 10,000 persons) and a representative sample of the other 7,160 active wells (within water systems serving fewer than 10,000 persons), resulting in fewer than half of the total number of active wells being monitored.

B. State Efforts

Under California legislation enacted in 1997, the State Water Resources Control Board (SWRCB) is required to implement a statewide GIS to manage the risk of MTBE contamination to public ground water supplies. In the short-term (by July 1999), this project seeks (1) to identify all underground storage tanks and all known releases of motor vehicle fuel from underground storage tanks that are within 1,000 feet of a drinking water well; and (2) to identify public wells within 1,000 feet of a petroleum product pipeline.[85]

This GIS displays and reports detailed information for both tank release sites and drinking water sources. Most importantly, the system streamlines the integration of data from multiple agencies, *i.e.*, the system integrates data for both contaminant sites and drinking water sources. This GIS will be used by a variety of State agencies to better protect public drinking water wells and aquifers reasonably expected to be used as drinking water from both motor vehicle fuel sources, including underground storage tanks (operating sites and closed sites with existing contamination), and petroleum pipelines. Public access via the Internet will serve to overcome current limitations on obtaining and sharing data among multiple regulatory agencies, water purveyors, the petroleum industry, and other stakeholders. Furthermore, the system gives all stakeholders access to on-line data analysis tools that can be used to estimate vulnerability.

Other States are also developing and implementing GIS capabilities, although not as comprehensively as California's program.

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[85] The GeoTracker report was a pilot study that addressed the Santa Clara Valley and Santa Monica water districts - not the entire state. However, the GeoTracker approach is expected to be used to get information for the rest of the state compiled. For more information about this GIS, refer to http://geotracker.lbl.gov/.

VI. Treatment of Impacted Drinking Water[86]

When drinking water supplies become contaminated with MTBE, water suppliers must take steps to treat the water so as to restore it to potable condition. The MTBE Research Partnership, which includes the Association of California Water Agencies, the Western States Petroleum Association (WSPA), and the Oxygenated Fuels Association (OFA), recently published *Treatment Technologies For Removal of MTBE From Drinking Water*, a report reviewing and analyzing the costs of three water treatment technologies: air stripping; activated carbon; and advanced oxidation.

- Treatment of extracted air and water effluents is typically accomplished using air stripping, a process in which contaminated water flows down a column filled with packing material while upward-flowing air volatilizes the contaminant from the water. Although highly effective for benzene, it is less effective and somewhat more costly for MTBE (*e.g.*, 95 percent and higher removal efficiency for benzene vs. 90 percent and higher for MTBE). Commonly, air stripped effluent is "polished" to lower contaminant levels by subsequent treatment with activated carbon.

- Activated carbon, or carbon adsorption, is also widely employed to remove low levels of organic compounds from water by pumping it through a bed of activated carbon. Additionally, many individual homeowners use small carbon canisters to remove a variety of contaminants, including MTBE, from impacted private wells. Again, this process is highly effective for benzene, but much less so for MTBE, which requires greater volumes of carbon per unit mass of MTBE removed, and thus is significantly more expensive and less effective than benzene removal.

- Advanced oxidation technologies use appropriate combinations of ultraviolet light, chemical oxidants, and catalysts to transform contaminants. Oxidation technologies have been demonstrated to oxidize a wide range of organic chemicals, including MTBE. These same technologies, especially air stripping and granular activated carbon (GAC), have been employed successfully for use at individual homes with impacted drinking water wells.[87]

The costs associated with these types of treatment for drinking water are summarized in Figure 1.

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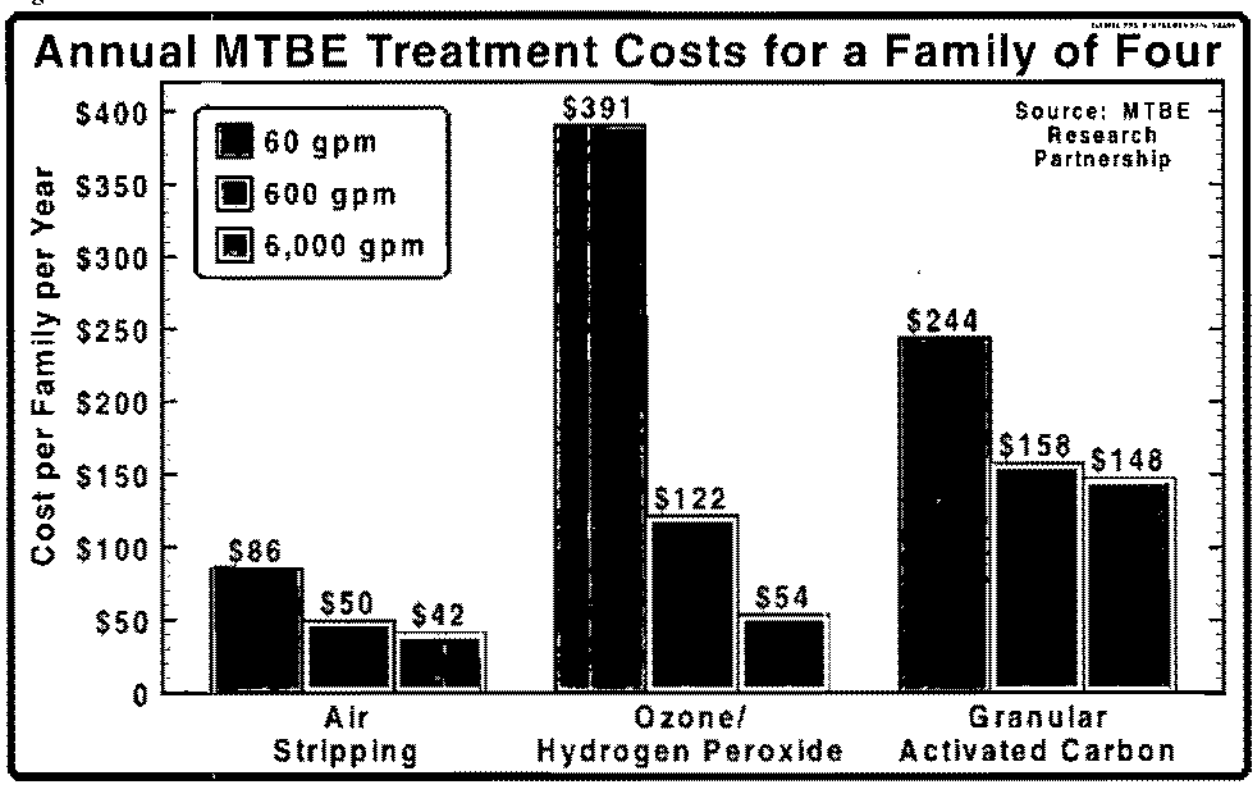
[86] This discussion refers specifically to the *treatment* of ground waters or surface waters intended for distribution to consumers or to private well owners; *remediation* of ground water associated with contaminant sites is addressed in the following section.

[87] J.P. Malley, Jr., P.A. Eliason, and J.L. Wagler, "Point-of-Entry Treatment of Petroleum Contaminated Water Supplies," *Water Environment Research*, 1993, v. 65, no. 2, pp. 119-128.

Figure 1



Source: MTBE Research Partnership (Western States Petroleum Association, Association of California Water Agencies, and Oxygenated Fuels Association), *Treatment Technologies for Removal of Methyl Tertiary Butyl Ether (MTBE) from Drinking Water -- Air Stripping, Advanced Oxidation Process (AOP), and Granular Activated Carbon (GAC), Executive Summary*, Sacramento, CA, December 1998.

Tertiary butyl alcohol (TBA) is another oxygenate that has been found at oxygenated gasoline release sites. Because TBA is a byproduct of some MTBE production processes, TBA is found in some fuel-grade MTBE.[68] TBA is also a metabolite of the biodegradation of MTBE.[69] Because TBA is infinitely soluble in water, use of air stripping and activated carbon treatment methods are even more limited than for treatment of MTBE. TBA's treatment by advanced oxidation may generate compounds potentially of health and environmental concern. The presence of TBA will further limit the usefulness of the above described technologies and increase treatment costs.

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[68] National Toxicology Program, *Summary of Data For Chemical Selection: Methyl Tert-Butyl Ether*, http://ntp-db.niehs.nih.gov/NTP_Reports/NTP_Chem_H&S/NTP_MSDS/HS_1634-04-4.txt

[69] J.P. Salanitro et al., "Perspectives on MTBE Biodegradation and the Potential for in situ Aquifer Bioremediation," proceedings of the National Ground Water Association's *Southwest Focused Ground Water Conference: Discussing the Issue of MTBE and Perchlorate in Ground Water* (Anaheim, CA, June 3-4, 1998), pp. 40-54.

VII. Remediation

A. MTBE

1. *Risk Based Corrective Action*

The following discussion focuses on the remediation of UST releases, as they are the predominant source of higher levels of MTBE contamination and potential drinking water supply impacts. Releases from other point sources of gasoline (*e.g.*, ASTs and pipelines), however, would be managed in a similar fashion.

Regulatory policies have evolved during the last decade toward the increasing use of risk-based corrective action (RBCA) programs. These programs serve as a means through which the management of petroleum releases is prioritized so that time and resources can be directed to those sites most likely to impact public or environmental health and safety. These changes in policies and practices are the result of conclusive demonstrations of existing and innovative technologies' limits in achieving complete remediation of impacted ground water systems.[90] The complex properties and interactions of gasoline and hydrogeologic systems have been found to be substantial barriers to the effective removal of motor fuel hydrocarbon masses released to ground water. The ascendancy of RBCA programs paralleled and was assisted by an increased understanding of the role of natural attenuation and intrinsic bioremediation in limiting the migration of dissolved hydrocarbon plumes. As a result, corrective action for many sites now focuses first on removing any readily mobile hydrocarbon mass at the source, and then on managing the dissolved plume using intrinsic bioremediation. Because MTBE is generally recalcitrant, the presence of MTBE is expected to limit the utilization of intrinsic bioremediation as a remediation option. Although other natural attenuation processes may be used as deemed appropriate.

The American Society for Testing and Material's (ASTM) E 1739-95 *Standard Guide for Risk Based Corrective Action*, developed during the early 1990's, forms the basis for most State risk-based programs. This RBCA guidance focuses on setting remedial goals based on health risks. MTBE also presents aesthetic (*i.e.*, taste and odor) problems at relatively low levels, which is currently not addressed by ASTM RBCA. Alternative RBCA guidance would need to be developed to adequately address aesthetic concerns.

Methyl tertiary butyl ether is included in this guide as a compound of concern when evaluating impacts from gasoline releases. The use of a risk-based framework places the emphasis on decisions that balance cost, resource value, and risk to human health and the environment. Risk-based approaches seek to implement management strategies that shift the focus of cleanup away from broadly defined cleanup goals, which have been demonstrated to be technologically infeasible, and instead focus on a more site-specific elimination or reduction of risk. It should be noted, however, that RBCA focuses on health risks, and because MTBE has also been shown to present aesthetic (*i.e.*, taste and odor) problems at relatively low levels, alternative RBCA guidance may need to be developed to adequately address those types of environmental concerns.

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[90] U.S. Environmental Protection Agency, Office of Research and Development, *Pump-and-Treat Ground-Water Remediation: A Guide for Decision Makers and Practitioners*, EPA/625/R-95/005, 1996.

During the last several years, it has become an accepted practice at UST release sites to carefully evaluate the potential for intrinsic remediation (*i.e.*, bioremediation of the contaminant primarily by the microbial population naturally present in the subsurface), and then to determine whether there is a need for active remediation. The presence of MTBE can complicate the utilization of intrinsic remediation, as although the BTEX[91] plume may be shown to be contained satisfactorily, adequately demonstrating stability and/or containment of an MTBE plume may be much more difficult. Methyl tertiary butyl ether is generally recalcitrant, and therefore intrinsic remediation will typically not be a feasible option.

Source control (*i.e.*, removal of contaminant mass near the source of the release) is frequently employed to reduce long-term impacts to ground water and drinking water in situations where intrinsic remediation is not viable. After a release, non-aqueous phase liquid (NAPL) is likely to be present in the vadose zone, capillary fringe, and ground water. The NAPL (*e.g.*, gasoline) will act as a long-term source of dissolved contaminants. Where practical, delineation and removal of NAPL are critical for complete restoration of an impacted aquifer.[92] In areas with shallow ground water, excavation of the NAPL-contaminated source area (down to and below the water table) can be an effective remediation approach. This technique is less effective at sites with extensive areal contamination, subsurface structures, or deeper water tables. The excavation and disposal of large volumes of contaminated soil or aquifer sediments have also been discouraged at many sites, in part because of limited solid waste treatment and disposal facilities.

2. *Conventional and Innovative Technologies*

Although the conventional and innovative technologies used for ground water remediation of nonoxygenated gasoline releases are also applicable for MTBE remediation, their relative effectiveness and costs may vary depending on site-specific conditions.[93] A remediation system typically employs air- or water-based approaches for removing contaminants from the subsurface, and one or more treatment technologies for removing the contaminant from those aqueous or vapor phase effluents. Alternatively, *in-situ* techniques can be used to treat or destroy contaminants without bringing them above the surface. The applications of these technologies for MTBE and benzene are briefly compared below.

- Pump and treat is a mature, well-understood technology that pumps ground water to the surface for subsequent treatment and discharge. Because of the relatively low solubility of benzene, this technique is more effective as a benzene plume migration control technology than for mass removal. MTBE's high solubility and low soil sorption should enable MTBE to be more readily extracted from an aquifer than benzene. As with all pump and treat, the effluent will have to be treated with technologies such as air stripping, advanced oxidation, GAC, or bioreactor.

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[91] The compounds benzene, toluene, ethyl benzene, and xylene are commonly known as "BTEX."

[92] U.S. Environmental Protection Agency, Office of Research and Development and Office of Solid Waste & Emergency Response, *Light Nonaqueous Phase Liquids*, EPA Ground Water Issue Paper # EPA/540/S-95/500, 1995.

[93] Daniel N. Creek and J. Davidson, "The Performance and Cost of MTBE Remediation," National Ground Water Association, 1998 Petroleum Hydrocarbons and Organic Chemicals in Ground Water, pp. 560-569;
Tom Peagrin, "Empirical Study of MTBE Benzene and Xylene Groundwater Remediation Rates," National Ground Water Association, 1998 Petroleum Hydrocarbons and Organic Chemicals in Ground Water, pp.551-559.

- Soil vapor extraction (SVE) pulls air through the soil to volatilize contaminants. Because MTBE does not adsorb strongly to soils and has a higher vapor pressure than benzene, MTBE will readily volatilize from gasoline in soils. When MTBE is dissolved in soil moisture, however, SVE will not remove MTBE, which is highly soluble.

- Air sparging injects air below the water table to volatilize contaminants from ground water. Compared with BTEX, a much larger flow of air is required to volatilize a similar mass of MTBE. This addition of air/oxygen also enhances biodegradation of contaminants that are aerobically degraded by native microorganisms. Although air sparging will readily enhance the biodegradation of benzene, studies to date have shown MTBE to be relatively recalcitrant to biodegradation by native populations of microbes in the subsurface. Therefore, although air sparging is known to be an effective technology for remediating benzene (increases volatilization and biodegradation), it is expected to be less effective and more costly for MTBE remediation (*i.e.*, dissolved phase does not volatilize and may be relatively recalcitrant to native biodegradation). Air sparging is frequently teamed with SVE to capture the volatilized compounds.

- Dual phase extraction involves vapor extraction and ground water extraction in the same well. This technique is likely to be most effective in situations in which the water table can be lowered, allowing for a larger area of influence for the vapor extraction system. As discussed above, when MTBE is dissolved in soil moisture, vapor extraction will not effectively remove MTBE, which is highly soluble. Therefore, this technique is most effective for volatilizing MTBE from gasoline.

- Bioremediation of MTBE contamination is an increasingly active area of research. The biodegradability of MTBE is considered to be much slower relative to the abundant natural bioremediation of other gasoline constituents in the subsurface (*e.g.*, benzene), and MTBE generally has been recalcitrant or limited relative to benzene biodegradation in field samples, although there is some field evidence to the contrary.[94] Recent lab and field studies have

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[94] R.C. Borden et al., "Intrinsic Biodegradation of MTBE and BTEX in a Gasoline-Contaminated Aquifer," *Water Resources Research*, 1997, v. 33, no. 5, pp. 1105-1115; A.M. Happel, B. Dooher, and E.H. Beckenbach, "Methyl Tertiary Butyl Ether (MTBE) Impacts to California Groundwater," presentation at MTBE Blue Ribbon Panel meeting (March 1999); A.M. Happel et al., Lawrence Livermore National Laboratory, *An Evaluation of MTBE Impacts to California Groundwater Resources*, UCRL-AR-130897, p.68 (June 1998); J.E. Landmeyer et al., "Fate of MTBE Relative to Benzene in a Gasoline-Contaminated Aquifer (1993-98)," *Ground Water Monitoring & Remediation*, Fall 1998, pp.93-102; Mario Schirmer and J.F. Barker, "A Study of Long-Term MTBE Attenuation in the Borden Aquifer, Ontario, Canada," *Ground Water Monitoring & Remediation*, Spring 1998, pp. 113-122; Reid, J.B., et al., "A Comparative Assessment of the Long-Term Behavior of MTBE and Benzene Plumes in Florida," pp. 97-102 *Natural Attenuation of Chlorinated Solvents, Petroleum Hydrocarbon and Other Organic Compounds* (1999); Hurt, K.L., et. al., "Anaerobic Biodegradation of MTBE in a Contaminated Aquifer..." pp. 103-108, *Natural Attenuation of Chlorinated Solvents, Petroleum Hydrocarbon and Other Organic Compounds* (1999); Bradley, P.M., et.al., Aerobic Mineralization of MTBE and tert-Butyl Alcohol by Stream-bed Sediment Microorganisms:

(continued...)

indicated that biodegradation processes can be accelerated by augmenting the subsurface environment or microbial population (*e.g.*, by the addition of oxygen, microbes, nutrients, or hydrocarbons that stimulate MTBE cometabolism).

- In-situ oxidation relies on the capacity of certain chemical mixtures (*e.g.*, hydrogen peroxide combined with iron) to rapidly oxidize organic molecules such as MTBE in water. Because MTBE oxidizes rapidly, it will be removed during the course of routine water treatment by this technique. Although current use of this technology is limited, when subsurface conditions and contaminant distribution are favorable, it has been demonstrated to effectively remove both MTBE and conventional gasoline components.

3. *Treatment of Remediation Effluent*

Treatment of the air and water effluents extracted from the above processes is typically accomplished using the same processes described previously for drinking water treatment (air stripping, activated carbon, and oxidation). Again, these processes are highly effective for benzene, but less so for MTBE. The costs associated with the treatment of effluents with MTBE are thus likely to be somewhat higher than for BTEX.[95] Catalytic or thermal oxidation technologies are also commonly used for air phase effluents, and MTBE again poses a more difficult and costly problem than benzene. Fluidized bioreactors are less commonly employed, as they require somewhat more complex operation and maintenance. They typically use activated carbon to support microbial growth so that contaminants are adsorbed onto the carbon and destroyed by resident microbes as the contaminants pass through the unit. This technology is somewhat more elaborate than air stripping and carbon adsorption, but may grow in acceptability if reliable MTBE treatment can be documented. In general, MTBE-BTEX effluents will be more costly to treat and discharge than BTEX alone. Synthetic Resin Adsorbents, which exhibit a much higher adsorbent capacity for MTBE relative to activated carbon, are currently available. With additional research, they may become a viable cost effective treatment.

4. *Incremental Costs for MTBE Remediation*

A certain level of remediation activity/corrective action is required for almost every release of gasoline, with or without oxygenates. Evaluation of the incremental remediation costs of MTBE contamination is a difficult task because of the numerous site-specific variables to address. Four key variables include (1) the cleanup target established for the site; (2) allowable MTBE discharge levels in the water and vapor effluents generated during the remediation process;[96] (3) the size of the dissolved plume; and (4) the potential for using natural attenuation as the treatment technology.

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[94] (...continued)
Envtl. Sci. Tech., v. 33 no. 11, pp. 1877-1897 (1999).

[95] Depending on the precise circumstances, these costs can range from moderately higher than BTEX-related costs to significantly higher.

[96] These levels are addressed in the permits issued by the appropriate regulatory authorities for these discharges.

Clearly, it will be more expensive to reach an MTBE ground water cleanup goal of 15 ppb than a goal of 40 ppb or higher. Similarly, the related effluent treatment costs will be much higher if permitted water discharge levels are 35 ppb as opposed to 500 ppb, and daily volatile organic compounds (VOC) discharges to the atmosphere are limited to 2 pounds compared with 50 pounds. As there are no national standards for MTBE, it is not possible to estimate these incremental costs.

The U.S. Environmental Protection Agency has surveyed UST program managers to obtain some initial estimate of increases in remediation cost.[97] Although the survey data have a high degree of uncertainty and should be viewed as preliminary, the EPA survey estimated that perhaps 75 percent of MTBE-impacted UST sites would have remediation costs less than 150 percent of the cost of typical BTEX sites, and that many MTBE sites might have no additional cost. The Leaking Underground Storage Tank (LUST) program managers estimated that the remaining 25 percent of sites would cost greater than 150 percent of representative BTEX sites, with perhaps 5 percent costing in excess of 200 percent more than typical BTEX sites. The UC study, Health and Environmental Assessment of MTBE, evaluated costs of remediation of MTBE sites in California based on industry, regulatory data and studies of MTBE impacts to groundwater in California. Overall, this study concluded that on average MTBE contaminated sites may be 140 percent of the cost of remediating conventional gasoline sites.[98]

Remediating MTBE plumes can be roughly comparable to the cost of conventional BTEX treatment for equivalent plume sizes, assuming the permitted MTBE effluent treatment and discharge levels allow standard air stripping and carbon adsorption approaches to be used. However, because an MTBE plume is more likely to become larger than typical benzene plumes when release detection is delayed, if dissolved MTBE source zone concentrations are much higher than BTEX (as they might be from a release of an RFG), or if stringent MTBE effluent discharge levels are applied, remediation costs are expected to increase proportionately. Absent active remediation or sufficient intrinsic bioremediation to prevent further migration, MTBE plumes are expected to extend further, perhaps by a large extent, than the companion benzene plumes.

This potential difference between benzene and MTBE plume lengths may influence remediation costs in another way. Monitored natural attenuation (MNA) is a widely accepted, cost effective approach to managing benzene plumes.[99] If MTBE plumes are expected to migrate further because of higher source area dissolved concentrations and exhibit limited biodegradation as compared to benzene, then fewer sites may be able to use MNA as an acceptable remediation option (*i.e.*, active remediation would be required, thus increasing cleanup costs). Only a limited number of field studies have been conducted to

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[97] Robert Hitzig, Paul Kostecki, and Denise Leonard, "Study Reports LUST Programs are Feeling Effects of MTBE Releases," *Soil & Groundwater Cleanup*, August-September 1998, pp. 15-19.

[98] The UC Study, *Health and Environmental Assessment of MTBE*, evaluated costs of remediation of MTBE sites in California based on industry, regulatory data and studies of MTBE impacts to groundwater in California. Overall, this study concluded that on average MTBE contaminated sites may be 1.4 times more costly to remediate than conventional gasoline sites.

[99] U.S. Environmental Protection Agency, Draft Memorandum from Timothy Fields, Jr., Acting Assistant Administrator, Office of Solid Waste and Emergency Response, "Use of Monitored Natural Attenuation at Superfund, RCRA Corrective Action, and Underground Storage Tank Sites," June 9, 1997.

evaluate MTBE natural attenuation;[100] thus, it is difficult to assess fully the potential future costs. A recent study estimated that while over 80 percent of non-MTBE conventional gasoline sites might utilize MNA, few MTBE sites would be able to, resulting in substantially higher cleanup costs for MTBE sites.[101]

B. Ethanol

The above discussions are focused on remediation issues identified for MTBE. It is difficult to make a comparative assessment of MTBE versus ethanol gasoline releases, as there is relatively little field data characterizing the behavior of ethanol gasoline releases.[102] Monitoring for ethanol is not required at UST sites, even in Midwestern States that use large volumes of ethanol. Additionally, standard EPA methods used to analyze fuel hydrocarbon compounds are not technically appropriate for detection and quantification of ethanol below the 1 part per million (ppm) to 10 ppm range. Ethanol is known to be much more biodegradable than benzene. Although ethanol is likely to biodegrade rapidly in ground water, because ethanol is infinitely soluble in water, much more ethanol will be dissolved into water than MTBE. It is not known how long it may take to biodegrade large amounts of dissolved ethanol. Laboratory research suggests that microorganisms prefer to biodegrade ethanol over other fuel components, so that ethanol biodegradation consumes all available oxygen and depletes other electron acceptors needed for biodegradation, thus delaying the onset, and potentially slowing the rate, of BTEX biodegradation. Although the magnitude of this effect is presently unknown, it is expected to result in somewhat longer BTEX plumes at gasoline release sites.[103] Because ethanol is most commonly blended at distribution terminals, releases of neat (pure) ethanol may occur at those facilities, requiring remediation. The extent of any current possible problem and cost associated with such clean up is unknown.

C. Funding

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[100] R.C. Borden et al., "Intrinsic Biodegradation of MTBE and BTEX in a Gasoline-Contaminated Aquifer," *Water Resources Research*, 1997, v. 33, no. 5, pp. 1105-1115; J.E. Landmeyer et al., "Fate of MTBE Relative to Benzene in a Gasoline-Contaminated Aquifer (1993-98)," *Ground Water Monitoring & Remediation*, Fall 1998, pp.93-102; Mario Schirmer and J.F. Barker, "A Study of Long-Term MTBE Attenuation in the Borden Aquifer, Ontario, Canada," *Ground Water Monitoring & Remediation*, Spring 1998, pp. 113-122.

[101] Arturo Keller, Ph.D., et.al., Executive Summary, Recommendations, Summary, "*Health and Environmental Assessment of MTBE*," 1999.

[102] Malcome Pirnie, Inc., *Evaluation of the Fate and Transport of Ethanol in the Environment*, (Oakland, CA: Malcome Pirnie, Inc.), 1998; H.X., Corseuil et al., "The Influence of the Gasoline Oxygenate Ethanol on Aerobic and Anaerobic BTX Biodegradation," *Wat. Res.*, 1998, 32, 2065-2072.; C.S. Hunt et al., "Effect of Ethanol on Aerobic BTX Degradation Papers from the Fourth International In Situ and On-Site Bioremediation Symposium," Battelle Press, April-May 1997, pp. 49-54.

[103] Michael Kavanaugh and Andrew Stocking, "Fate and Transport of Ethanol in the Environment," presentation at the May 1999 MTBE Blue Ribbon Panel meeting. [Based on Malcome Pirnie, Inc. *Evaluation of the Fate and Transport of Ethanol in the Environment* (Oakland, CA, 1998.)]

1. *State and Federal Sources*[104]

The primary sources of funding for UST remediation are State UST cleanup funds.[105] State cleanup funds raise and expend about $1 billion annually, by far the largest source of funding available to pay for remediation of MTBE-contaminated soil and ground water. The second largest source of funding is private insurance. Most owners and operators have the required financial assurance coverage provided by State funds. Owners and operators in States without State funds, or in those States in which State funds are transitioning and not providing coverage for new releases, must meet their UST financial responsibility requirements by other mechanisms, most commonly UST insurance provided by private insurers. According to the insurance industry, roughly 10 percent to 15 percent of USTs are currently covered by private insurance. This percentage is likely to increase as more States transition out of their UST cleanup funds.

The Federal LUST Trust Fund is supported through a 0.1 cent per gallon Federal tax on motor fuels that expires after March 30, 2005. At the end of fiscal year (FY) 1998, the Trust Fund had a balance of approximately $1.2 billion. In FY 1998, the Fund received approximately $203 million in new monies – $136 million from the Federal tax and $67 million in interest on the Fund's balance. In FY 1999, new receipts are expected to increase to $278 million ($212 million from the tax and $66 million in interest), raising the Fund's balance to approximately $1.4 billion (after FY 1999 appropriations).[106] Monies in this fund are subject to appropriation, and Congress has been appropriating approximately $70 million annually in recent years.[107] Approximately 85 percent of the appropriated funds are given to the States to administer and enforce their LUST programs and to pay for remediation of eligible releases. The States use approximately two-thirds of the funds to support staff who oversee and enforce cleanups by responsible parties. Approximately one-third of the funds are used to pay for cleanups in which the owner and operator are unknown, unwilling, or financially unable to undertake and to complete cleanup

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[104] See EPA OUST's *Publication on Sources of Financial Assistance for Underground Storage Tank Work*. The document entitled "Financing Underground Storage Tank Work: Federal and State Assistance Programs" lists Federal and State programs that provide money to assist in upgrading or replacing underground storage tanks, conducting investigations, and performing remediation. This document provides information on financial assistance available to municipalities, State or local governments, non-profits, private UST owners or operators, and for tanks on Native American or tribal lands. The assistance is available in the form of direct loans, loan guarantees, grants, or interest subsidies. The publication also describes some of the available State financial assistance programs. Eighteen States have active financial assistance programs for UST upgrades and replacement; some of these programs also offer assistance cleaning up UST releases. Also, see the ASTSWMO Report, "State Leaking Underground Storage Tank Financial Assurance Funds Annual Survey Summary," June 1998. Http://www.astswmo.org/Publications/pdf/98visum.pdf.

[105] U.S. Environmental Protection Agency, *State Assurance Funds: State Funds in Transition Models for Underground Storage Tank Assurance Funds*, 1997, EPA 510-B-97-002, www.epa.gov/swerust1/states/fundinfo.htm.

[106] Executive Office of the President of the United States, *Budget of the United States Government, Fiscal Year 2000 – Appendix*, 1999, p. 937.

[107] Fiscal year 1998 (actual) and 1999 (estimated) appropriations from the LUST Trust Fund were $65 million and $73 million, respectively. (See Executive Office of the President of the United States, *Budget of the United States Government, Fiscal Year 2000 – Appendix*, 1999, p. 937.)

of a contaminated site.[108] The law establishing the LUST Trust Fund places clear responsibility for remediation on owners and operators and places significant eligibility requirements on the use of LUST Funds for actual cleanup of contaminated sites.

2. *Recovery of Funds from Potentially Responsible Parties*

Water suppliers can face substantial expenditures for either replacement water supplies or treatment of contaminated waters. For example, the City of Santa Monica lost 50 percent of its existing water supply in 1996 as the result of MTBE impacts. The annual costs of the required volume of replacement water (more than 6 million gallons per day) are estimated at approximately $4 million. Although these costs are the full responsibility of the party shown to be liable for the contamination, establishing such liability may take months or years. It has been suggested that a funding mechanism should exist for covering these unexpected costs.

3. *State Water Supply Revolving Funds*

Other potential funding sources for addressing MTBE contamination are the Clean Water State Revolving Fund (CWSRF) and Drinking Water State Revolving Fund (DWSRF) programs. These programs were established to provide States with a continuing source of funding to address (1) wastewater treatment, nonpoint source, and estuary activities (CWSRF); and (2) drinking water treatment, source water protection, and water system management activities (DWSRF). Funding decisions for projects and activities are made by each State, pursuant to eligibility guidelines provided by EPA.

The CWSRF can be used for site mitigation efforts to address MTBE releases to the extent that such activities are included in an EPA-approved State nonpoint source management program. To date, three States (Delaware, Nebraska, and Wyoming) have provided a total of approximately $48 million in CWSRF loans to about 1,200 sites for removing underground tanks and purchasing release detection systems. In these three States, the CWSRF program works in partnership with the State's Leaking Underground Storage Loan Program to provide technical assistance and funding support to potential loan recipients. Funds available to address problems related to MTBE may increase as States expand use of their CWSRF programs to address nonpoint source problems.

Although the DWSRF cannot be used to fund remediation efforts, States can loan DWSRF monies to public water systems for the installation of treatment equipment to address contaminated source water entering the treatment plant. In addition to providing loan assistance to public water systems for eligible projects, the DWSRF also allows each State to reserve up to 31 percent of its grant to fund programs and activities that enhance source water protection and water systems management. Several of the activities eligible under the reserves could address protection and management issues associated with MTBE.

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[108] If the owner or operator is financially able, but otherwise unwilling to cleanup the site, the implementing agency is responsible for recovering the costs of remediating the site.

4. *Alternative Water Supply Funding Mechanism*

The above discussion has reviewed a variety of existing potential sources of funds available to replace or treat public and private water systems. Should these sources not meet existing needs adequately, an alternative funding approach may be required. To simultaneously provide a source of funding for emergency alternative supplies and treatment of impacted public water systems, and to act as a gradual disincentive for use of MTBE, a tax/surcharge could be levied on MTBE production for use in gasoline. These levied monies could then be made readily accessible by public and private water suppliers to reimburse incurred expenses associated with addressing MTBE contamination incidents. The economic viability and amount of this surcharge would need to be determined, but would likely range from 5 percent to 50 percent of the price of each gallon of MTBE sold. For example, a 10 percent surcharge with an MTBE price of $0.70 per gallon and RFG with 11 percent by volume MTBE would add about 1 cent to the per gallon-price of RFG and would accumulate about $300 million annually with current MTBE usage. This surtax could also be structured to increase over time to further discourage MTBE use.

D. Fuel Supply and Cost

I. Introduction

The current U.S. fuel supply system is a finely balanced network that depends on crude oil supply, refinery production, unimpeded pipeline and marine movements, and strategically sited commercial stocks to protect against market volatility. Recent accident- and weather-related refinery and pipeline outages (*e.g.*, incidents in California and Washington State) demonstrate the system's delicate nature.

As such, changes in fuel regulatory requirements, with their attendant capital investment needs and infrastructure changes, must be implemented without introducing unnecessary volatility. Disruptions to the nation's fuel supply system result in price volatility and increased costs to consumers. Therefore, any proposed changes to U.S. fuel requirements should consider the following:

- The time required to implement capital investments in both refineries and infrastructure, which entails raising capital, obtaining permits, and constructing units and infrastructure.[109]

- The need for regulatory certainty to provide industry with sufficient lead time to make all necessary changes. Regulatory uncertainty increases investment risks and forces industry to postpone investments to the last minute.

- The need for regulatory flexibility in achieving targeted goals. The petroleum industry is diverse, and what is optimal for one sector may not be optimal for another.

- The need for fungibility in the system. At present, the U.S. fuel supply system works well, as most requirements tend to be national (*e.g.*, low sulfur on-road diesel) or regional (*e.g.*, reformulated gasoline or California reformulated gasoline). Once small areas begin requiring unique fuels, however, the system operates at sub-optimal efficiency, costs to consumers increase, and fuel supplies are more vulnerable to volatility.

This combination of sufficient time, regulatory certainty and flexibility, and fungibility will facilitate a smooth transition, thus avoiding excessive cost increases driven by unnecessary stress to the system.

An important consideration in this discussion is the regulatory status of methyl tertiary butyl ether (MTBE). If the use of MTBE (and other ethers) is reduced substantially or phased out, but the oxygenate requirement is maintained, ethanol (and possibly other alcohols) will remain as the only alternatives. At present, however, ethanol is produced primarily in the Midwest and is not manufactured in sufficient volume to meet national demand. Although new ethanol production capacity can be brought on-line in two years, the permitting and construction of necessary infrastructure will be a critical determinant of ethanol's availability and cost.

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[109] Moreover, if all refineries and terminals require capital upgrades, the construction industry may become strained.

II. Industry Overview

A. Consumption

1. *Consumption of Gasoline and Oxygenates*

Current consumption of gasoline in the United States is approximately 8.3 million barrels per day (b/d), or approximately 126.5 billion gallons annually.[110] Based on Federal fuel supply data, total U.S. oxygenate demand was approximately 370,000 b/d in 1997 (refer to Table D1 in this section's Appendix).[111] Excluding the volume of oxygenate used only for octane purposes, the average 1997 demand for oxygenates in reformulated gasoline (RFG) and oxygenated gasoline in environmental control areas was approximately 265,000 b/d, 41,000 b/d, and 17,000 b/d per day for MTBE, ethanol, and other ethers, respectively. Thus, although making up less than 5 percent of total national gasoline consumption, MTBE and other ethers met approximately 87 percent of the oxygenate volume requirement in 1997.

2. *Meeting California's Ethanol Demand*

A recent study funded by the Renewable Fuels Association (RFA), *The Use of Ethanol in California Clean Burning Gasoline*, estimates that if MTBE was banned, California would demand 41,000 b/d of ethanol in order to meet the oxygenate volume in the mandated areas plus 30 percent penetration into the non-mandated areas. A study by the California Energy Commission (CEC), however estimates 75,000 b/d in demand for similar requirements.[112] According to the RFA report, California's demand could be met from currently underutilized production, which equates to 29,000 b/d with 100 percent utilization, and new plant start-ups. The balance would be made up by ethanol redirected from the octane enhancement markets and increased imports.[113]

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[110] U.S. Energy Information Administration, *Petroleum Supply Annual 1998, Volume 1*, Table S4, p. 17, June 1999.

[111] U.S. Energy Information Administration (T. Litterdale and A. Bohn), *Demand and Price Outlook for Phase 2 Reformulated Gasoline, 2000*, April 1999, pp. 7-8.

[112] California Energy Commission, *Supply and Cost Alternatives to MTBE in Gasoline*, October 1998.

[113] Downstream Alternatives, *Ethanol Supply, Demand, and Logistics: California and Other RFG Markets*, May 1999.

B. Ethanol Production

Current U.S. ethanol production capacity is estimated at 120,000 b/d[114], which is equivalent in oxygen content to approximately 230,000 b/d of MTBE. In order for ethanol alone to fulfill the nationwide oxygen requirement in all RFG and oxygenated fuels areas, the U.S. Environmental Protection Agency (EPA) estimates that approximately 187,000 b/d of ethanol would be needed, assuming that no ethanol is used for economic octane blending.[115] Thus, in a scenario of complete MTBE removal, an estimated additional 67,000 b/d of ethanol would be needed to fulfill the required oxygenate volume nationwide. Ethanol supply could be fulfilled by a combination of imports and additional production capacity created by removing bottlenecks at existing plants and by building new facilities. The ethanol industry estimates that the current expansion of existing ethanol-from-corn production facilities may increase production capacity by as much as 40,000 b/d. Additionally, new ethanol production facilities currently being planned could provide another 25,000 b/d (new ethanol plants may take two or more years to build).[116] The U.S. Department of Agriculture (USDA) estimates that 5 percent of the total corn utilized in 1997-98 was for fuel ethanol production.[117]

Ethanol production from biomass processing is currently about 60 million gallons per year (equivalent to approximately 4,000 b/d). Estimates from the USDA indicate that assuming favorable economics, the resource base for ethanol from biomass could reach approximately 10 billion gallons annually (approximately 650,000 b/d) after 2025.[118] Recently, on August 12, 1999, President Clinton issued an executive order to initiate a government effort to develop a biomass research program. The goal of the program is to triple the use of bioenergy and bioproducts by 2010, which includes the production of clean fuels such as ethanol and other products.

Based on total gasoline regulated properties, ethanol used at 5.7 percent by volume to meet the 2.0 percent by weight (wt.%) oxygen requirement in RFG will not be able to replace all of the 11 percent by volume of MTBE in RFG. In California, some refiners have stated that they must remove some volume of butanes/pentanes from California Phase 2 RFG in order to accommodate the increase in gasoline's Reid vapor pressure (RVP) with the addition of ethanol, and thus must significantly expand their crude

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[114] Roger Conway, "Ethanol and Its Implications for Fuel Supply," presentation at the April 1999 MTBE Blue Ribbon Panel meeting; Downstream Alternatives, *Ethanol Supply, Demand, and Logistics: California and Other RFG Markets*, May 1999.

[115] This figure is the result of the following calculations: (1) Calculate the total ether supply for RFG and oxygenated fuels in 1997: 265,000 b/d + 17,000 b/d = 282,000 b/d; (2) Multiply 282,000 b/d by 0.52 to adjust for the oxygen equivalency of ethanol = 146,640 b/d; and (3) Add 41,000 b/d to include the current volume of ethanol utilized for RFG and oxygenated fuels, thus reaching a total of 187,640 b/d (refer to Table D1 in the Appendix).

[116] Jack Huggins. Submitted written comments on behalf of the Renewable Fuels Association at the April 1999 MTBE Blue Ribbon Panel meeting.

[117] Roger Conway, "Ethanol and Its Implications for Fuel Supply," presentation at the April 1999 MTBE Blue Ribbon Panel meeting; Downstream Alternatives, *Ethanol Supply, Demand, and Logistics: California and Other RFG Markets*, May 1999.

[118] Stephen Gatto, presentation on BC International Corporation at the April 1999 Blue Ribbon Panel meeting; Roger Conway, "Ethanol and Its Implications for Fuel Supply," presentation at the April 1999 MTBE Blue Ribbon Panel meeting.

oil-based RFG production capacity by the full 11 percent by volume lost by removing MTBE.[119] Although this Panel did not investigate the effect that the loss of MTBE would have on refineries outside of California, there are some similarities and a number of differences in refinery processes that, on balance, result in similar volume shortfalls in blending component capacities during the summer seasons.

A similar analysis by the U.S. Department of Energy (DOE) also concluded that additional supply would be necessary under an ether ban in the Northeast, requiring increased domestic supply or foreign imports.[120]

C. Ethanol Infrastructure/Transportation

Because ethanol is soluble in water, which is commonly found in pipelines and storage tanks associated with the gasoline distribution system, and will separate from gasoline, ethanol is usually blended at the distribution terminal.[121] Therefore, because most of the nation's ethanol is produced in the Midwest, the ethanol would have to be transported to terminals for blending through a dedicated (ethanol-only) pipeline, by rail, by marine shipping, or by some combination of these methods. Transportation from the Midwest to the Northeast and the West is challenging and will likely be costly and transportation-facility intensive.

A study[122] estimates that approximately 1,982 rail cars (30,000-gallons[123] each) would be necessary to supply the California market with ethanol for RFG purposes, assuming only rail transport. Given the range in ethanol demand projected by the CEC study (35,000 b/d to 92,000 b/d), this rail car estimate could actually be more than double. The existing fleet of 30,000-gallon rail cars is between 8,000 and 10,000, nearly all of which are currently unavailable for ethanol transport due to prior leasing commitments. With existing manufacturing capability, it is estimated that approximately 1,000 additional (30,000-gallon) rail cars could be built per year.[124]

In California, marine transport has been found to cost approximately the same as rail transport, although in certain instances marine shipping can be slightly cheaper. Surveys of terminal operators in California have indicated that a large portion of product (most likely at least 50 percent) would be shipped as waterborne cargo. Some California operators have stated that the large size of marine cargoes makes it preferable to spotting, inspecting, and unloading numerous rail cars. Moreover, in the Northeast, nearly

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[119] Al Jessel, Chevron Products Company, "Fuels Regulations and Emissions Technology," presentation at the March 1999 MTBE Blue Ribbon Panel meeting. See also, Duane Bordvick, Tosco Corporation, "Perspectives on Gasoline Blending for Clean Air," presentation at the March 1999 MTBE Blue Ribbon Panel meeting.

[120] U.S. Department of Energy, *Estimating the Refining Impacts of Revised Oxygenate Requirements for Gasoline: Summary Findings*, May 1999.

[121] Al Jessel, Chevron Products Company, "Fuels Regulations and Emissions Technology," presentation at the March 1999 MTBE Blue Ribbon Panel meeting.

[122] Downstream Alternatives, *Ethanol Supply, Demand, and Logistics: California and Other RFG Markets*, May 1999.

[123] 42 gallons = 1 barrel

[124] Based on API confidential communications with rail car lessors, 1999.

every terminal location is accessible by water, whereas only a few can be accessed by rail. As such, some estimate that 60 percent of the Northeast's total demand would be met through ship and ocean-going barge transport.[125]

These will also be cited to develop the necessary blending and distribution infrastructure to deliver ethanol-based RFG to retail outlets. Ethanol requires blending much further down the distribution channel (at the truck-loading point) than does MTBE (at the refinery terminal). The infrastructure to support such blending on a wide scale does not currently exist.[126]

D. Producing Non-Oxygenate Alternatives

In the event of an MTBE phase down with oxygenate flexibility, refiners have a number of blending options to meet RFG performance standards, including increased use of alkylates, aromatics, and perhaps other fuel blending streams derived from petroleum.[127] Each refinery has a uniquely optimal mode of operation, facility selection, and size, all of which are currently balanced for MTBE use. Without MTBE, refiners would have to determine their most economic mode of operation and also determine which new facilities and technologies would provide the economic return on investment that shareholders require for continued investment. The strategy of total alkylate replacement is expensive (possibly exceeding $1 billion), may not fully meet octane needs, and demands other operational trade-offs in the refinery and/or additional supply of isobutane and olefin feedstocks. Although aromatics can also be produced in greater volume and will provide higher octane, higher aromatics use will also increase toxics emissions so that aromatics cannot likely fulfill all non-oxygenate needs. Nevertheless, oxygenate flexibility is an important component of the solution to removing MTBE from the system in a timely manner since it increases refiner flexibility in meeting RFG performance standards. The Panel could not conduct a comprehensive evaluation of the technologies, facilities, and strategies necessary to achieve a new, economically optimal fuels refining industry without MTBE, and with or without the current oxygenate requirements, but rather chose to rely on analyses by others to estimate likely effects on supply and cost, as discussed in Section III below.

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[125] Letter to Daniel Greenbaum from Robert E. Reynolds, President, Downstream Alternatives, Inc., June 24, 1999. See also, Downstream Alternatives, *Ethanol Supply, Demand, and Logistics: California and Other RFG Markets*, May 1999.

[126] Oil and Gas Journal, *California refiners anticipate broad effects of possible state MTBE ban*, January 18, 1999.

[127] Dexter Miller, "Alkyates, Key Components in Clean-Burning Gasoline," presentation at the May 1999 MTBE Blue Ribbon Panel Meeting.

III. Impact of Fuel Requirement Changes on Supply

A. Overview

The impact of a change in fuel requirements (*e.g.*, reduction in the use of oxygenates or of a particular oxygenate) on fuel availability and cost will depend primarily on the following factors:

- The **time** available for a transition and the availability of adequate and sustained supplies of any new component, and the time required for permitting and achieving compliance with applicable regulations;
- Regulatory **certainty** and flexibility regarding fuel specifications;
- The degree to which fuel changes are national, regional, or state-by-state in scope, *i.e.*, **fungibility**;
- Additional capital costs (*e.g.*, new refinery facilities) and/or operating costs (*e.g.*, transportation and distribution costs); and
- The cost of replacing octane while continuing compliance with environmental standards.

B. Time

Government agencies and fuel refiners/marketers have stated that without adequate lead time, rapid reductions in the volume of MTBE allowed in the gasoline supply stream will have an immediate and negative effect on regional markets as well as the nation's ability to meet gasoline demand.[128]

In general, refineries must undergo a stepwise process to implement major changes in fuel processing, such as desulfurization or oxygenate reduction. A summary of Sunoco's recent analysis of the process time required to comply with future sulfur limits is show in Table 1 as a general guide to such capital projects.[129] (Actual time requirements will vary from refinery to refinery.)

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[128] U.S. Department of Energy, *Estimating the Refining Impacts of Revised Oxygenate Requirements for Gasoline: Summary Findings*, March 1999; California Energy Commission, *Supply and Cost Alternatives to MTBE in Gasoline*, October 1998; Robert Cunningham, "Costs of Potential Ban of MTBE in Gasolines," presentation at the March 1999 MTBE Blue Ribbon Panel meeting.

[129] Sunoco, *Time Required to Complete Desulfurization*, personal communication.

Table 1. Sample Process Timetable for Complying with Future Sulfur Limits in the Refining Industry

I. Conceptual/Process Feasibility • Identify purpose, scope, and permits required • Produce cost estimates • Management approval	7 months
II. Process/Project Scope Definition • Develop scope, equipment requirements, project milestones, and construction strategies • Produce more accurate budget estimates • Management approval	8 months
III. Preliminary Engineering • Select engineering contractor • Submit permit applications • Conduct design review • Issue master schedule • Submit costs for approval	12 months
IV. Detailed Project Execution • Procure materials • Receive all permits • Award contracts • Construction • Testing • Training • Start-up	21 months
Total	**48 months**

Source: Sunoco

Should ethers, particularly MTBE, be phased out in California, the CEC estimates that in three years California refineries would require as much as 75,000 b/d of ethanol and up to 142,000 b/d of additional gasoline imports to meet demand.[130]

The U.S. Department of Energy estimates that if regulation changes are finalized, four years would be needed to allow for new construction of refineries and for ethanol production, transportation, loading and unloading capacities to increase. Under this assumption, a scenario of an ether phase-out should not

[130] California Energy Commission, *Supply and Cost Alternatives to MTBE in Gasoline*, October 1998. This study did not analyze the likely fuel supply impacts to areas outside of California if MTBE use were to be phased out in California.

cause supply problems in Petroleum Administration for Defense District (PADD) I, the East Coast.[131] This analysis did not consider effects on regional supplies in the event of a national MTBE ban or other changes in fuel properties (*i.e.*, sulfur reductions).

Relative to California refiners, the transition to a non-ether RFG would be more difficult and require more time for non-California refiners. Implementation of the proposed sulfur rules (TIER 2) will have less impact on California refiners, as all California RFG (CaRFG) is already at a sulfur level of 30 parts per million (ppm) or lower. Other refiners will need additional time to build adequate desulfurization units, as well as other facilities needed to generate the octane lost through desulfurization. The State of California believes that with a repeal of the Federal oxygen mandate, MTBE should be phased out in three and one-half years.[132]

C. Certainty

Refiners/marketers have stated that regulatory certainty is necessary to insure low-risk capital investment in alternatives to our current fuel supply system. For example, whether the current oxygenate mandate will remain or be removed will be a critical factor in future refinery, product transportation, and marketing terminal construction decision making. Refiners/marketers believe that the removal of the oxygenate mandate would provide maximum flexibility for the individual decisions necessary for each refiner to meet all Federal and State RFG performance standards.

D. Fungibility

Refiners/marketers have indicated that to meet consumer fuel demand and to minimize supply shortages, the scope of any future fuel changes should be national or regional. Permitting state-specific fuel changes (*e.g.*, low RVP, low sulfur) may lead to greater uncertainty in fuel supply and may cause periodic shortages unless there is a mechanism to ensure consistency across state boundaries.

Although ethanol blended gasoline can be blended to maintain low vapor pressure, reformulated gasoline made with ethanol will likely increase evaporative emissions when commingled with other fuels in markets where ethanol occupies 30 percent to 50 percent of the market.[133] (Refer to *Issue Summary B*, "Air Quality Benefits"). In order to minimize commingling, refiners in these markets will need to develop and use infrastructure (storage, trucks, etc.) dedicated to fuels containing ethanol. In areas of the country (*e.g.*, the Midwest) where ethanol has been the predominant fuel additive, this will not be a problem. However, areas of the country that have not traditionally used ethanol fuels, but would likely do so for a part of their supply in the future, will need to make infrastructure investments to avoid losses in air quality as a result of commingling. Even then, some commingling of fuels will likely occur when consumers mix ethanol blended gasoline with non-ethanol blended gasoline in their vehicles' tanks (see discussion in Air Quality Section B.).

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[131] U.S. Department of Energy, *Estimating the Refining Impacts of Revised Oxygenate Requirements for Gasoline: Summary Findings*, March 1999; Downstream Alternatives, *Ethanol Supply, Demand, and Logistics: California and Other RFG* Markets, May 1999.

[132] California Energy Commission, *Supply and Cost Alternatives to MTBE in Gasoline*, October 1998.

[133] Office of Science and Technology Policy, National Science and Technology Council, *Interagency Assessment of Oxygenated Fuels*, June 1997.

IV. Cost Impacts of Changing Fuel Reformulations

A. Cost Impacts

The cost of gasoline is influenced by a wide range of factors, including crude oil prices, refining costs, the grade and type of the gasoline, taxes, available supplies (inventory), seasonal and regional market demand, weather, transportation costs, and specific areas' relative costs of living. Each additional cent per gallon increase in average gasoline price is equivalent to annual costs of between $1 billion to $1.3 billion, borne ultimately by consumers.

Both ethanol and oil receive some subsidy from the government. All fuel ethanol receives a $0.54 per gallon subsidy, while approximately 6-7 percent of gasoline receives a cost benefit from the crude oil depletion allowance. In both cases these government subsidies are supported by Congress because it is seen to expand domestic industry; increase commerce and employment; improve the nation's balance of trade (*i.e.*, reduce imports and increase exports); and generate additional personal and corporate incomes and the taxes accruing from these incomes. Analysis has suggested that the real cost to the government is a net benefit. For example, replacing the 282,000 b/d of ethers used in RFG in 1997 would require approximately 146,000 b/d of ethanol on an oxygen equivalent basis. The U.S. Environmental Protection Agency estimates that the incremental annual cost to the Federal government (*i.e.*, to taxpayers) for new fuel ethanol production of 146,000 b/d (approximately 2.2 billion gallons per year) would be approximately $1.2 billion.[134] The State of Nebraska Ethanol Board estimates that the ethanol subsidy resulted in $3.5 billion in net savings for the Federal government in 1997.[135]

Table 2 shows recent information from the U.S. Energy Information Administration (EIA) regarding the price differences among CaRFG, Federal RFG, conventional gasoline, and the national average price for gasoline. These prices reflect the various factors that influence the cost of gasoline. For example, after reaching their lowest point in 25 years (adjusted for inflation) at the end of 1998, world crude oil prices began recovering during the spring of 1999. In addition, April represents the beginning of the summer driving season, which leads to higher gasoline demand; California is regionally influenced by the summer driving demand before much of the rest of the nation. Finally, California prices have been influenced in 1999 by fires and shutdowns at several major refineries. Thus, due to regional and seasonal demand variation, the volatility of world crude oil prices and unforeseen supply shortages, consumers may see swings in gasoline prices of as much as $.50 per gallon.

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[134] This figure is the result of the following calculations: (1) Calculate the total ether supply for RFG and oxygenated fuels in 1997: 265,000 b/d + 17,000 b/d = 282,000 b/d; (2) Multiply 282,000 b/d by 0.52 to adjust for the oxygen equivalency of ethanol = 146,640 b/d, or 2.2 billion gallons annually; (3) Multiply by the $0.54 per gallon subsidy = $1.2 billion per year (refer to Table D1 in the Appendix for total ether volumes).

[135] State of Nebraska Ethanol Board, "Economic Impacts of Ethanol Production in the United States," April, 1998.

Table 2. Gasoline Prices, February 1999 and April 1999
(per gallon, including State and Federal taxes)

	February 1999	April 1999
California RFG	$1.101	$1.568
Federal RFG	$0.987	$1.229
Conventional	$0.901	$1.088
Average	$0.927	$1.131

Source: U.S. Energy Information Administration

Nevertheless, the real cost of gasoline, although quite variable, increases with higher refining costs, which are associated with environmental quality restrictions and local or regional differences in gasoline specifications. Fuel refiners/marketers have commented that with (1) adequate lead time to make refinery investments and modifications; (2) regulatory certainty regarding specific fuel requirements; and (3) fuel fungibility on a regional or national scope, increases in fuel prices due to regulatory changes may not cause substantial and unnecessary volatility in prices beyond the normal seasonal fluctuations.

Economic impacts will not be shared equally among petroleum refiners/marketers. Refineries each process different types of crude, supply different mixes of products (*e.g.*, some refineries do not manufacture any RFG), and use widely varying technologies. For example, the State of California currently requires low levels of sulfur in CaRFG. As such, the economic impact of lowering sulfur levels would not be as great for some California refineries that manufacture mostly CaRFG as it might be for some other refiners, and in other markets where refineries would require capital investments for desulfurization facilities. Similarly, areas of the country that rely heavily on oxygenates such as MTBE will experience a more pronounced economic effect in the event of a oxygenate replacement or removal (*e.g.*, Texas, California, and Northeast RFG markets use MTBE, whereas the Chicago and Milwaukee RFG markets use ethanol).

B. Modeling

Modeling fuel price increases is a relatively effective technique with which to examine the direction of the impacts of regional fuel formulation choices on gasoline costs. Such predictions are instructive in assessing the relative impacts of different options assuming constant assumptions. Models should not be used, however, to predict exact outcomes. With the exception of precipitous transition times and a major increase in ethanol use, which would require significant new infrastructure, all other modeled scenarios add cost to gasoline of a magnitude similar to the typical variability of gasoline prices. The results of three such models are summarized below (also refer to Table D2 in the Appendix):

- The California Energy Commission estimated that the intermediate-term (three years) change in the price of California RFG could range from a decrease of 0.2 cents per gallon to an increase of 8.8 cents per gallon depending on the type of oxygenate used (if oxygenates are used at all), the lead time to implement the changes, and flexibility

regarding the type and amount of oxygenate allowed.[136] This study did not analyze the likely economic impacts to areas outside of California if MTBE use were to be phased out in California or nationally (*i.e.*, increased market volatility from dependence on imported blendstocks to replace MTBE, with or without ethanol use).

- A Chevron/Tosco analysis estimates that if refiners were given flexibility in oxygenate use, a California ban on MTBE would increase the cost of CaRFG 2.7 cents per gallon within a three year-period. Without oxygenate flexibility, the price would increase 6.1 cents per gallon.[137]

- An analysis by Pace Consultants found that it would cost an additional 0.7 to 24 cents per gallon to make reformulated gasoline blendstock that is suitable for use with ethanol (rather than MTBE) in the summer during the RFG Phase II program. For refiners already using ethanol in RFG (less than 10 percent of the RFG market), the Pace study indicated that the additional cost of using ethanol in Phase II RFG would be less than one cent per gallon. In general, the cost of RVP reduction differs among refiners and depends on refinery process configuration, product and raw material slates, and ability to dispose of streams displaced in RVP reduction.[138]

- A recent DOE analysis shows that under the scenario of an ether ban, assuming at least four years for refinery investment, and with a continuation of the oxygenate requirement for RFG, the increased cost for RFG per gallon in PADD I ranges from 2.4 cents to 3.9 cents, with the cost most sensitive to the price of ethanol.[139] This analysis, however, was not national in scope.

C. Conclusions

Assuming that changes in oxygenate requirements occur, the limited modeling analyses to date have shown that for California and PADD I:

- Once regulations are finalized, a range of three to six years is necessary to develop the infrastructure necessary to substantially alter the regional, possibly national, fuel formulation and supply infrastructure without serious market volatility.

- The estimated costs of implementing these changes will range from a slight savings under a scenario of oxygenate-use flexibility and continued MTBE use, to a cost of about 8.8 cents per gallon under a scenario of no oxygenate use (no mandate). (See Table D2 in the Appendix).

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[136] California Energy Commission, *Supply and Cost Alternatives to MTBE in Gasoline*, October 1998.

[137] MathPro, *Potential Economic Benefits of the Feinstein-Bilbray Bill*, March 18, 1999.

[138] PACE Consultants, Inc., *Analysis and Refinery Implications of Ethanol-Based RFG Blends Under the Complex Model Phase II*, November 1998.

[139] U.S. Department of Energy, *Estimating the Refining Impacts of Revised Oxygenate Requirements for Gasoline: Follow-up Findings*, May 1999.

- Because no studies have been national in scope, the predictions of cost impacts are uncertain. In addition, most studies were conducted on the assumption of meeting only the current regulatory minimum emission reductions.

- The likely oxygenate replacement for MTBE is ethanol. Current and near future ethanol production (*i.e.*, on-line in less than two years), however, is not adequate to meet the volume of oxygenate required nationally. Transporting ethanol from the Midwest, where it is primarily produced, to Northeast and California markets will require significant efforts to upgrade and build new pipeline (or use segregated shipments through existing pipelines), rail, marine, and truck transportation infrastructure.

Appendix D

Table D1. Oxygenate Demand in Reformulated and Oxygenated Gasoline Control Areas, 1997

(thousands of barrels per day)

Region	Estimated 1997 Gasoline Demand in Control Areas	Estimated Oxygenate Volume in Control Area Gasoline		
		MTBE	ETBE or TAME	Ethanol
Reformulated Gasoline				
PADD 1 (East Coast)	1,054	128.2	9.1	1.0
PADD 2 (Midwest)	270	4.0	0.0	21.8
PADD 3 (Gulf Coast)	282	27.4	3.2	0.0
PADD 4 (Rocky Mountain)	0	0.0	0.0	0.0
PADD 5 (West Coast)	934	100.9	3.4	2.0
Subtotal	**2,674**	**259.5**	**15.7**	**24.7**
Oxygenated Gasoline				
PADD 1 (East Coast)	0	0.0	0.0	0.0
PADD 2 (Midwest)	79	0.0	0.0	6.7
PADD 3 (Gulf Coast)	16	0.0	0.0	1.4
PADD 4 (Rocky Mountain)	36	0.3	1.1	2.7
PADD 5 (West Coast)	73	0.1	0.0	4.7
Subtotal	**204**	**0.5**	**1.1**	**15.5**
Oxygenated-Reformulated Gasoline				
PADD 1 (East Coast)	137	4.8	0.0	0.4
PADD 5 (West Coast)	10	0.1	0.0	0.7
Subtotal	**147**	**4.9**	**0.0**	**1.1**
Average 1997 Oxygenate Demand for RFG and Oxygenated Gasoline Blending		**265**	**17**	**41**
Imputed Oxygenate Demand for Conventional Gasoline (*e.g.*, octane and gasohol)		**4***	**–**	**41**
Total 1997 Oxygenate Supply		**269**	**17**	**82**

*Other sources have estimated this number to be as high as 25,000 b/d (Sunoco) and 28,000 b/d (DeWitt) for ethers in the conventional pool, with a slightly lower volume in the RFG pool.

Source: U.S. Energy Information Administration, (T. Litterdale and A. Bohn), *Demand and Price Outlook for Phase 2 Reformulated Gasoline, 2000*. April 1999, pp. 7-8.

Note: "–" signifies "Not Applicable."

Table D2. Summary of Modeling Results
(cents per gallon)

Report	Scenario	Results (cents per gallon)	
		Intermediate Term (3 years)	Long Term (6 Years)
CEC Analysis: California Only	• MTBE allowed - no oxygenate requirement	-0.2 to -0.8	-0.3 to -1.5
	• No oxygenates allowed - no oxygen requirement	4.3 to 8.8	0.9 to 3.7
	• Ethanol only - oxygen requirement maintained	6.1 to 6.7	1.9 to 2.5
Chevron/Tosco Analysis: California Only	• No ethers - no oxygen requirement	2.7	1.2
	• Ethanol only - oxygen requirement maintained	6.1	1.9
		Near Term (less than 2 years, no investment)	Long Term (at least 4 years, investment allowed)
DOE Analysis: PADD I Only	• MTBE allowed - no oxygenate requirement	-0.3	Not Investigated
	• No ethers - no oxygen requirement	Not Investigated	1.9
	• Ethanol only - oxygen requirement maintained	6.0	2.4 to 3.9

Source: U.S. Environmental Protection Agency

E. Comparing the Fuel Additives

I. Introduction

In comparing various alternatives to the current use of automotive fuel additives (primarily oxygenates), the relative impact of these alternative compounds on the environment as a whole must be considered. More specifically, one must assess how changes to fuels or fuel additives impact:[1]

- Air quality and fuel blending characteristics;
- Fuel or fuel additive behavior and fate under various water and soil conditions; and
- Potential health effects resulting from exposure to the additives or their combustion products.

Health effects research is currently underway by industry[2] and EPA[3] to understand more fully the comparative risks associated with exposure to fuels both with and without oxygenates, including methyl tertiary butyl ether (MTBE), ethanol, ethyl tertiary butyl ether (ETBE), tertiary-amyl methyl ether (TAME), and tertiary butyl alcohol (TBA).[4] Although the majority of this research is focused on inhalation-related health effects, the results should help in our understanding of the human health risks associated with exposure to fuels from any route of exposure. Currently, there is not enough information to fully characterize potential health risks of all the oxygenates or their alternatives.

II. MTBE

A. Air Quality and Fuel

Blending serves as a cost-effective oxygenate for blending in reformulated gasoline (RFG), enabling fuels to meet both California and Federal RFG air quality requirements while preserving octane enhancement, low VOC emissions, and driveability. Analyses have shown that even without an oxygen

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[1] Refer to *Issue Summaries A* and *B*, "Water Contamination" and "Air Quality Benefits" respectively, for detailed discussions of these topics.

[2] U.S. Environmental Protection Agency, Federal Register Vol. 63, No. 236, December 9, 1998, p. 67877. Final Notification of Health Effects Testing Requirements for Baseline Gasoline and Oxygenated Nonbaseline Gasoline and Approval of an Alternative Emissions Generator.

[3] Jim Prah of the U.S. Environmental Protection Agency is currently conducting studies on pharmacokinetics of MTBE.

[4] Refer to Table E1 in this section's Appendix for detailed data on the chemical properties of these and related compounds.

mandate, MTBE use is economically suited to meet air quality and gasoline performance goals.[5] However, it should be noted that emissions of formaldehyde (a probable carcinogen), resulting from the incomplete combustion of fuels, increase by about 13 (± 6) percent with the use of 2.0 percent by weight (wt%) MTBE oxygenated gasoline.[6]

B. Behavior in Water

MTBE, an ether, is more soluble in water than other gasoline components and appears recalcitrant to biodegradation relative to other components of concern in gasoline, such as benzene, toluene, ethylbenzene, and xylenes (collectively referred to as "BTEX").[7] In general, compared to the slow migration of BTEX compounds in subsurface soil and ground water, MTBE moves at nearly the same velocity as the ground water itself. This is due to MTBE's high water solubility and low soil sorption. Given sufficient time and distance, MTBE would be expected to be at the leading edge of a gasoline contamination plume or could become completely separated from the rest of the plume if the original source of oxygenate were eliminated.[8]

Tert-butyl alcohol (TBA) is the primary metabolite of MTBE resulting from biodegradation, but is also a common byproduct in the production of MTBE and often present with MTBE in the fuel supply. Thus, detection of TBA in ground water is not necessarily evidence of MTBE biodegradation. By itself, TBA, like ethanol, is infinitely (miscible) soluble in water and is reported to be recalcitrant to biodegradation.[9]

C. Health Effects

In terms of neurotoxicity and reproductive effects, inhalation toxicity testing to date generally has not shown MTBE to be any more toxic than other components of gasoline. At high doses, MTBE has caused tumors in two species of rat and one species of mouse at a variety of sites; it is uncertain, however, whether these effects can be extrapolated to humans. The International Agency for Research on Cancer

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[5] U.S. Department of Energy, *Estimating the Refining Impacts of Revised Oxygenate Requirements for Gasoline: Summary Findings*, March 1999; California Energy Commission, *Supply and Cost Alternatives to MTBE in Gasoline*, October 1999; Robert Cunningham, "Costs of Potential Ban of MTBE in Gasolines," presentation at the March 1999 MTBE Blue Ribbon Panel meeting.

[6] T.W. Kirchstetter, et. al., "Impact of Oxygenated Gasoline Use on California Light-Duty Vehicle Emissions," *Environ. Sci. And Tech.*, 1996.

[7] U.S. Environmental Protection Agency, Office of Research and Development, *Oxygenates in Water: Critical Information and Research Needs*, December 1998.

[8] A.M. Happel et al., *An Evaluation of MTBE Impacts to California Groundwater Resources*, Lawrence Livermore National Laboratory Report, UCRL-AR-130897, June 1998.

[9] Office of Science and Technology Policy, National Science and Technology Council. *Interagency Assessment of Oxygenated Fuels*, June 1997; Steffan, R.J., et. al., *Biodegradation of the Gasoline Oxygenates Methyl tert-Butyl Ether (MTBE), Ethyl tert-Butyl Ether (ETBE), and tert-Amyl Methyl Ether (TAME) by Propane Oxidizing Bacteria*, Appl. Environ. Microbiol. 63(11):4216-4222).

(IARC) and the National Institute of Environmental Health Sciences (NIEHS) have indicated that at this time there are not adequate data to consider MTBE a probable or known human carcinogen.[10]

There are limited data on human populations that may be sensitive to MTBE. Although there is some evidence that fuels containing MTBE could irritate the eyes, as well as cause headaches and rashes, effects attributed to MTBE alone have yet to be proven. Limited epidemiological data suggest greater attention should be given to the potential for increased symptom reporting among highly exposed workers.[11]

There have been no human or animal health effects studies performed for MTBE in drinking water. However, human and animal studies are currently underway at the U.S. Environmental Protection Agency (EPA), Health Effects Institute (HEI) and the Chemical Industry Institute of Toxicology (CIIT) to address some of these research needs.[12] Animal ingestion studies using "bolus" (all at once) dosing of MTBE in olive oil have shown carcinogenic effects at high levels of exposure (250,000 micrograms per kilogram animal body weight and higher).[13] [14]

Drinking water containing MTBE at or below the taste and odor levels identified in the EPA's Drinking Water Advisory (20 to 40 micrograms per liter) is not expected to cause adverse health concerns for the majority of the population.[15] The turpentine-like taste and odor of MTBE, however, can make such drinking water unacceptable to consumers.

TBA is a major metabolite of MTBE, regardless of the route of exposure. Animal testing of TBA in drinking water produced carcinogenic effects at high levels of exposure (1,250,000 micrograms per liter and higher).[16] Additionally, formaldehyde, also a metabolite of MTBE, is a respiratory irritant at high

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[10] Office of Science and Technology Policy, National Science and Technology Council, *Interagency Assessment of Oxygenated Fuels*, June 1997.

[11] Office of Science and Technology Policy, National Science and Technology Council, *Interagency Assessment of Oxygenated Fuels*, June 1997.

[12] Correspondence with the Health Effects Institute, Chemical Industry Institute of Toxicology, and EPA verify currently on-going studies on animal and human health effects from MTBE exposure.

[13] U.S. Environmental Protection Agency, Office of Water, *Drinking Water Advisory: Consumer Acceptability Advice and Health Effects Analysis on Methyl Tertiary-Butyl Ether (MTBE)*, December 1997.

[14] It should be noted that the National Research Council has cautioned against the use of this study until a thorough review has been accomplished, including an objective third-party review of the pathology. (Toxicological and Performance Aspects of Oxygenated Motor Vehicle Fuels, National Research Council, Washington, D.C. 1996, page 115.)

[15] U.S. Environmental Protection Agency, Office of Water, *Drinking Water Advisory: Consumer Acceptability Advice and Health Effects Analysis on Methyl Tertiary-Butyl Ether (MTBE)*, December 1997.

[16] U.S. Environmental Protection Agency, Office of Water, *Drinking Water Advisory: Consumer Acceptability Advice and Health Effects Analysis on Methyl Tertiary-Butyl Ether (MTBE)*, December 1997.

levels of human exposure and is currently considered by EPA to be a probable human carcinogen by the inhalation route, with less certainty via ingestion.[17]

III. Ethanol

A. Air Quality and Fuel Blending

Ethanol is commonly used as an octane enhancer in conventional gasoline, as well as serving as an oxygenate for blending in Federal RFG and oxygenated gasoline in a number of locations (primarily in the Midwest).[18] Because of its unique physical and chemical properties, ethanol raises the volatility of gasoline with which it is blended, thus additional refinery processing of blendstocks is performed prior to ethanol blending in order to meet the air quality performance standards in reformulated fuels.[19] Ethanol is soluble in the water commonly found in pipelines and storage tanks associated with the gasoline distribution system, and once mixed with water will separate from the gasoline. Due to this potential phase separation, which can occur when ethanol and gasoline blends are transported through pipelines, ethanol is usually blended at the terminal, rather than the refinery.

A National Research Council study[20] did not support using ozone forming potential or reactivity (as opposed to mass emission reductions) to assess the relative effectiveness of MTBE or ethanol in the RFG program. However, the report did find that the contribution of the reduction of carbon monoxide (CO) and its effect on ozone formation should be recognized in assessments of the effects of ethanol in RFG. (Refer to *Issue Summary B*, "Air Quality Benefits.")

In markets where ethanol blended fuels make up 30 percent to 50 percent of the market, the possibility of commingling of ethanol fuels with non-ethanol fuels in the fuel supply system will require separation of ethanol fuel infrastructure, and commingling in the gas tank can result in an increase in both vapor pressure and evaporative emissions.[21] (Refer to *Issue Summary B*, "Air Quality Benefits.")

Vehicle exhaust emissions data have shown that acetaldehyde (principle metabolite of ethanol) emissions can increase by as much as 100 percent with the use of 2.0 wt% ethanol oxygenated gasoline, part of which undergoes photochemical reactions in the atmosphere to make peroxyacetyl nitrate (PAN).[22]

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[17] Office of Science and Technology Policy, National Science and Technology Council, *Interagency Assessment of Oxygenated Fuels*, June 1997.

[18] Refer to *Issue Summary D*, "Fuel Supply and Cost," for a more detailed discussion of this topic.

[19] California Energy Commission, *Supply and Cost Alternatives to MTBE in Gasoline*, October 1999.

[20] Office of Science and Technology Policy, National Science and Technology Council, *Interagency Assessment of Oxygenated Fuels*, June 1997.

[21] Office of Science and Technology Policy, National Science and Technology Council, *Interagency Assessment of Oxygenated Fuels*, June 1997.

[22] J. Froines et. al., *Health and Environmental Assessment of MTBE, Vol. II*, November, 1998; A.P. Altshuller, "PANs in the Atmosphere," *J. Air Waste Manag. Assoc.*, 1993, 43(9), 1221-1230; L. Milgrom, "Clean Car Fuels Run Into Trouble," *New Scientist*, 1989, 122 (1656), 30.

B. Behavior in Water

"Neat" (pure) ethanol is infinitely soluble in water. Laboratory data and hypothetical modeling indicate that based on physical, chemical, and biological properties, ethanol will likely preferentially biodegrade in ground water compared with other gasoline components with the potential to extend BTEX plumes further than they would be without ethanol present.[23]

Although ethanol has been shown to retard BTEX biodegradation under certain laboratory conditions, evidence of ethanol's effect on the migration of BTEX plumes under various conditions, *i.e.*, hydrogeology; field concentrations; nature of release scenario (for example, large sudden release versus slow continuous release) has not been collected and compiled.[24] A more comprehensive review is still needed to investigate and determine the nature and extent of field experiences regarding ethanol's effect (including behavior and fate properties) on BTEX plume migration, aquifer remediation, and drinking water treatment.

C. Health Effects

The health effects of ingested ethanol have been extensively investigated. Given that ethanol is formed naturally in the body at low levels, inhalation exposure to ethanol at the low levels that humans are likely to be exposed are generally not expected to result in adverse health effects.[25] Health effects questions have been raised, however, about potentially sensitive subpopulations. In addition, increased use of ethanol may result in increases of certain atmospheric transformation products, such as PAN and acetaldehyde, although the extent of such increase is unknown.[26] PAN, which has been shown to be mutagenic in cellular research, is a known toxin to plant life and a respiratory irritant to humans.[27] Combustion byproducts of ethanol may also cause adverse health effects. Acetaldehyde is a respiratory irritant at high levels of human exposure and is currently classified by EPA as a probable human carcinogen.

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[23] Michael Kavanaugh and Andrew Stocking, "Fate and Transport of Ethanol in the Environment," presentation at the May 1999 MTBE Blue Ribbon Panel meeting. [Based on Malcome Pirnie, Inc. *Evaluation of the Fate and Transport of Ethanol in the Environment* (Oakland, CA, 1998.)]

[24] Michael Kavanaugh and Andrew Stocking, "Fate and Transport of Ethanol in the Environment," presentation at the May 1999 MTBE Blue Ribbon Panel meeting. [Based on Malcome Pirnie, Inc. *Evaluation of the Fate and Transport of Ethanol in the Environment* (Oakland, CA, 1998.)]

[25] Health Effects Institute, *The Potential Health Effects of Oxygenates Added to Gasoline*, April 1996.

[26] Health Effects Institute, *The Potential Health Effects of Oxygenates Added to Gasoline*, April 1996.

[27] L. Milgrom, "Clean Car Fuels Run Into Trouble," *New Scientist*, 1989, 122 (1656), 30.

IV. Other Ethers[28]

A. Air Quality and Fuel Blending

Other ethers have been shown to provide the same emissions benefits as MTBE or ethanol. Alternative ethers (except tertiary-amyl methyl ether - TAME) have found only limited use, however, because they are economically less competitive to manufacture.

B. Behavior in Water

Other ethers are likely to be similar, although not identical to, MTBE, i.e. highly soluble in ground water, poorly sorbed to soil, and degraded more slowly than BTEX chemicals. Behavior in ground water is a function of solubility, soil sorption, and the ability to biodegrade. All oxygenates are significantly more soluble than benzene and evidence to date demonstrates that in situ biodegradation of these compounds is limited as compared to benzene. Differences may exist between solubility and degradability of ethers. Accelerated studies are necessary in order to make this determination.

C. Health Effects

Although toxicity testing of these substances is underway, there is less current knowledge regarding the inhalation or ingestion health effects associated with these compounds than for ethanol and MTBE.

V. Other Alternatives

A. Air Quality and Fuel Blending

In addition to ethanol, the most likely alternatives to replace the current volume of MTBE and other ethers in RFG are increased use of refinery streams such as alkylates, reformates, aromatics, and other streams resulting from the fluid catalytic cracking (FCC) processes.

Alkylates are a mix of high octane, low vapor pressure branched chain paraffinic hydrocarbons that can be made from crude oil through well established refinery processes, using the output from an FCC unit. Because of these desirable properties, alkylates are highly favored as streams for blending into gasoline.[29] In general, an increase in the amount of alkylates used in fuels will have no adverse effect on overall vehicle performance.[30] Aromatics are hydrocarbons characterized by unsaturated ring structures of carbon atoms (i.e. benzene, toluene, and xylene), and increased use of aromatics would be likely to

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[28] Ethers are organic compounds consisting of carbon, hydrogen, and oxygen. Often used as gasoline blendstocks and as oxygenates, ethers include: MTBE; ETBE; TAME; and diisopropyl ether (DIPE).

[29] Dexter Miller, "Alkylates, Key Components in Clean-Burning Gasoline," presentation at the May 1999 MTBE Blue Ribbon Panel meeting.

[30] Duane Bordvick, Tosco Corporation, "Perspectives on Gasoline Blending for Clean Air," presentation at the March 1999 MTBE Blue Ribbon Panel meeting; Al Jessel, Chevron Products Company, "Removing MTBE From Gasoline," presentation at the March 1999 MTBE Blue Ribbon Panel meeting.

increase toxic emissions when used in high quantities. Refiners in California have produced non-oxygenated fuels using lower sulfur, alkylates and aromatics, that meet or exceed all California RFG air quality requirements.[31]

B. Behavior in Water

Alkylates are nonpolar and have a much lower (over 100 times less) solubility in water than aromatics such as BTEX compounds. Based on alkylates' physical, chemical, and biological properties, dissolution from the gasoline source area, biodegradation, and movement in ground water, are all expected to be significantly slower than BTEX compounds.

Water-related environmental fate research should include studies in the following areas:

- Water solubility, dissolution behavior, and sorption tendency to soil and aquifer material;
- Effects of biodegradation on the gasoline contaminated plume's overall movement;
- Transformation studies to determine if the compound breaks down in soil or surface/ground water; and
- Whether intermediates and/or final products pose either a greater or lesser risk.

C. Health Effects

Alkylates have long been a common ingredient in fuels, and thus a modest increase in alkylate content would not be expected to cause additional human health risks above those already associated with human exposure to fuels. However, the human and aquatic toxicity risk data associated with exposure to alkylates are limited. Aromatics have also long been used in fuel, and contain compounds (e.g. benzene and toluene) which are known to have a range of potential health effects; any substantial increase in their use should be carefully evaluated. At a minimum, testing for non oxygenated fuel alternatives should include sufficient data to develop an adequate risk assessment. These tests should seek inhalation and ingestion data through animal toxicity and human microenvironmental exposure studies using both the additives themselves, and the gasoline mixtures of which they are a part.

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[31] MathPro, *Potential Economic Benefits of the Feinstein-Bilbray Bill*, March 18, 1999.

Appendix E

Table E1. Chemical Properties of Selected Compounds[a]

	Benzene[2]	MTBE[2]	Ethanol[3]	ETBE[1]	TAME[1]	TBA[3]	Alkylates (Isooctane)
Molecular Weight (g/mol)	78.11	88.2	46.1	102.2	102.2	74.1	114.2
Boiling Point (°C)	80.1	55.2	78.5	72.2	86.3	82.4	99.2
Vapor Pressure (mm Hg at 20 °C)	73	240	44	130	75	41	72
Density (g/L)	0.88	0.74	0.79	0.74	0.77	0.79	0.69
Octane Number	94	110	115	112	105	100	100
Neat Solubility (g/100g H_2O)	0.178	4.8	miscible	1.2	1.2	miscible	<< 0.01
Solubility into H_2O from Gasoline (g/100g H_2O)	<.01	0.55	5.7[b]	0.33	0.24	2.5[b]	–
Taste Threshold in Water (ug/L)	500	20 to 40	–	47	128	–	–
Odor Threshold (ppm)	0.5	0.053	49	0.013	0.027	21	–

[a] Adapted from USGS. For a detailed discussion of the solubility in water from gasoline mixture containing 2% oxygen, see p. 2-50 - 2-53 of the National Science and Technology Council, *Interagency Assessment of Oxygenated Fuels* (June 1997).

[b] The water solubilities of the alcohols are estimates based on partitioning properties.

Sources:

[1] D.L. Conrad, Texaco Research and Development Department, *The Impacts of Gasoline Oxygenate Releases to the Environment -- A Review of the Literature* (Port Arthur, Texas, 1995).

[2] Donald Mackay, W.Y. Shiu, and K.C. Ma, *Illustrated Handbook of Physical-Chemical Properties and Environmental Fate for Organic Chemicals: Vol. III, Volatile Organic Compounds* (Boca Raton, FL: Lewis Publishers, Inc, 1993) p. 916.

[3] Donald Mackay, W.Y. Shiu, and K.C. Ma, *Illustrated Handbook of Physical-Chemical Properties and Environmental Fate for Organic Chemicals: Vol. III, Volatile Organic Compounds* (Boca Raton, FL: Lewis Publishers, Inc, 1993) p. 962.

Key:

" – " signifies "Not Applicable."
g/mol = Grams Per Mole
°C = Degrees Celsius
mm Hg = Millimeters of Mercury
g/L = Grams Per Liter
g/100g H_2O = Grams Per 100 Grams of Water
ug/L = Micrograms Per Liter
ppm = Parts Per Million

CHAPTER 3. FINDINGS AND RECOMMENDATIONS OF THE BLUE RIBBON PANEL

Findings

Based on its review of the issues, the Panel made the following overall findings:

- The distribution, use, and combustion of gasoline poses risks to our environment and public health.

- RFG provides considerable air quality improvements and benefits for millions of US citizens.

- The use of MTBE has raised the issue of the effects of both MTBE alone and MTBE in gasoline. This Panel was not constituted to perform an independent comprehensive health assessment and has chosen to rely on recent reports by a number of state, national, and international health agencies. What seems clear, however, is that MTBE, due to its persistence and mobility in water, is more likely to contaminate ground and surface water than the other components of gasoline.

- MTBE has been found in a number of water supplies nationwide, primarily causing consumer odor and taste concerns that have led water suppliers to reduce use of those supplies. Incidents of MTBE in drinking water supplies at levels well above EPA and state guidelines and standards have occurred, but are rare. The Panel believes that the occurrence of MTBE in drinking water supplies can and should be substantially reduced.

- MTBE is currently an integral component of the U.S. gasoline supply both in terms of volume and octane. As such, changes in its use, with the attendant capital construction and infrastructure modifications, must be implemented with sufficient time, certainty, and flexibility to maintain the stability of both the complex U. S. fuel supply system and gasoline prices.

The following recommendations are intended to be implemented as *a single package* of actions designed to simultaneously maintain air quality benefits while enhancing water quality protection and assuring a stable fuel supply at reasonable cost. The majority of these recommendations could be implemented by federal and state environmental agencies without further legislative action, and we would urge their rapid implementation. We would, as well, urge all parties to work with Congress to implement those of our recommendations that require legislative action.

Recommendations to Enhance Water Protection

Based on its review of the existing federal, state and local programs to protect, treat, and remediate water supplies, the Blue Ribbon Panel makes the following recommendations to enhance, accelerate, and expand existing programs to improve protection of drinking water supplies from contamination.

Prevention

1. EPA, working with the states, should take the following actions to enhance significantly the Federal and State Underground Storage Tank programs:

   a. Accelerate enforcement of the replacement of existing tank systems to conform with the federally-required December 22, 1998 deadline for upgrade, including, at a minimum, moving to have all states prohibit fuel deliveries to non-upgraded tanks, and adding enforcement and compliance resources to ensure prompt enforcement action, especially in areas using RFG and Wintertime Oxyfuel.

   b. Evaluate the field performance of current system design requirements and technology and, based on that evaluation, improve system requirements to minimize leaks/releases, particularly in vulnerable areas (see recommendations on Wellhead Protection Program in 2. below).

   c. Strengthen release detection requirements to enhance early detection, particularly in vulnerable areas, and to ensure rapid repair and remediation.

   d. Require monitoring and reporting of MTBE and other ethers in groundwater at all UST release sites.

   e. Encourage states to require that the proximity to drinking water supplies, and the potential to impact those supplies, be considered in land-use planning and permitting decisions for siting of new UST facilities and petroleum pipelines.

   f. Implement and/or expand programs to train and license UST system installers and maintenance personnel.

   g. Work with Congress to examine and, if needed, expand the universe of regulated tanks to include underground and aboveground fuel storage systems that are not currently regulated yet pose substantial risk to drinking water supplies.

2. EPA should work with its state and local water supply partners to enhance implementation of the Federal and State Safe Drinking Water Act programs to:

   a. Accelerate, particularly in those areas where RFG or Oxygenated Fuel is used, the assessments of drinking water source protection areas required in Section 1453 of the Safe Drinking Water Act, as amended in 1996.

   b. Coordinate the Source Water Assessment program in each state with federal and state Underground Storage Tank Programs using geographic information and other advanced data systems to determine the location of drinking water sources and to identify UST sites within source protection zones.

c. Accelerate currently-planned implementation of testing for and reporting of MTBE in public drinking water supplies to occur before 2001.

d. Increase ongoing federal, state, and local efforts in Wellhead Protection Areas including:

- enhanced permitting, design, and system installation requirements for USTs and pipelines in these areas;
- strengthened efforts to ensure that non-operating USTs are properly closed;
- enhanced UST release prevention and detection; and
- improved inventory management of fuels.

3. EPA should work with states and localities to enhance their efforts to protect lakes and reservoirs that serve as drinking water supplies by restricting use of recreational water craft, particularly those with older motors.

4. EPA should work with other federal agencies, the states, and private sector partners to implement expanded programs to protect private well users, including, but not limited to:

a. A nationwide assessment of the incidence of contamination of private wells by components of gasoline as well as by other common contaminants in shallow groundwater;

b. Broad-based outreach and public education programs for owners and users of private wells on preventing, detecting, and treating contamination; and

c. Programs to encourage and facilitate regular water quality testing of private wells.

5. Implement, through public-private partnerships, expanded Public Education programs at the federal, state, and local levels on the proper handling and disposal of gasoline.

6. Develop and implement an integrated field research program into the groundwater behavior of gasoline and oxygenates, including:

a. Identifying and initiating research at a population of UST release sites and nearby drinking water supplies including sites with MTBE, sites with ethanol, and sites using no oxygenate; and

b. Conducting broader, comparative studies of levels of MTBE, ethanol, benzene, and other gasoline compounds in drinking water supplies in areas using primarily MTBE, areas using primarily ethanol, and areas using no or lower levels of oxygenate.

Treatment and Remediation

7. EPA should work with Congress to expand resources available for the up-front funding of the treatment of drinking water supplies contaminated with MTBE and other gasoline components to ensure that affected supplies can be rapidly treated and returned to service, or that an alternative water supply can be provided. This could take a number of forms, including but not limited to:

   a. Enhancing the existing Federal Leaking Underground Storage Tank Trust Fund by fully appropriating the annual available amount in the Fund, ensuring that treatment of contaminated drinking water supplies can be funded, and streamlining the procedures for obtaining funding;

   b. Establishing another form of funding mechanism which ties the funding more directly to the source of contamination; and

   c. Encouraging states to consider targeting State Revolving Funds (SRF) to help accelerate treatment and remediation in high priority areas.

8. Given the different behavior of MTBE in groundwater when compared to other components of gasoline, states in RFG and Oxyfuel areas should reexamine and enhance state and federal "triage" procedures for prioritizing remediation efforts at UST sites based on their proximity to drinking water supplies.

9. Accelerate laboratory and field research, and pilot projects, for the development and implementation of cost-effective water supply treatment and remediation technology, and harmonize these efforts with other public/private efforts underway.

Recommendations for Blending Fuel for Clean Air *and* Water

Based on its review of the current water protection programs, and the likely progress that can be made in tightening and strengthening those programs by implementing Recommendations 1 - 9 above, the Panel agreed broadly, although not unanimously, that even enhanced protection programs will not give adequate assurance that water supplies will be protected, and that changes need to be made to the RFG program to reduce the amount of MTBE being used, while ensuring that the air quality benefits of RFG, and fuel supply and price stability, are maintained.

Given the complexity of the national fuel system, the advantages and disadvantages of each of the fuel blending options the Panel considered (see Appendix A), and the need to maintain the air quality benefits of the current program, the Panel recommends an *integrated package* of actions by both Congress and EPA that should be *implemented as quickly as possible*. The key elements of that package, described in more detail below, are:

- Action agreed to broadly by the Panel to reduce the use of MTBE substantially (with some members supporting its complete phase-out), and action by Congress to clarify

federal and state authority to regulate and/or eliminate the use of gasoline additives that threaten drinking water supplies;

- Action by Congress to remove the current 2 percent oxygen requirement to ensure that adequate fuel supplies can be blended in a cost-effective manner while quickly reducing usage of MTBE; and

- Action by EPA to ensure that there is no loss of current air quality benefits.

The Oxygen Requirement

10. The current Clean Air Act requirement to require 2 percent oxygen, by weight, in RFG must be removed in order to provide flexibility to blend adequate fuel supplies in a cost-effective manner while quickly reducing usage of MTBE and maintaining air quality benefits.

The Panel recognizes that Congress, when adopting the oxygen requirement, sought to advance several national policy goals (energy security and diversity, agricultural policy, etc) that are beyond the scope of our expertise and deliberations.

The Panel further recognizes that if Congress acts on the recommendation to remove the requirement, Congress will likely seek other legislative mechanisms to fulfill these other national policy interests.

Maintaining Air Benefits

11. Present toxic emission performance of RFG can be attributed, to some degree, to a combination of three primary factors: (1) mass emission performance requirements; (2) the use of oxygenates; and (3) a necessary compliance margin with a per gallon standard. In Cal RFG, caps on specific components of fuel is an additional factor to which toxics emission reductions can be attributed.

Outside of California, lifting the oxygen requirement as recommended above may lead to fuel reformulations that achieve the minimum performance standards required under the 1990 Act, rather than the larger air quality benefits currently observed. In addition, changes in the RFG program could have adverse consequences for conventional gasoline as well.

Within California, lifting the oxygen requirement will result in greater flexibility to maintain and enhance emission reductions, particularly as California pursues new formulation requirements for gasoline.

In order to ensure that there is no loss of current air quality benefits, EPA should seek appropriate mechanisms for both the RFG Phase II and Conventional Gasoline programs to define and maintain in RFG II the real world performance observed in RFG Phase I

while preventing deterioration of the current air quality performance of conventional gasoline.[32]

There are several possible mechanisms to accomplish this. One obvious way is to enhance the mass-based performance requirements currently used in the program. At the same time, the Panel recognizes that the different exhaust components pose differential risks to public health due in large degree to their variable potency. The Panel urges EPA to explore and implement mechanisms to achieve equivalent or improved public health results that focus on reducing those compounds that pose the greatest risk.

Reducing the Use of MTBE

12. The Panel agreed broadly that, in order to minimize current and future threats to drinking water, the use of MTBE should be reduced substantially. Several members believed that the use of MTBE should be phased out completely. The Panel recommends that Congress act quickly to clarify federal and state authority to regulate and/or eliminate the use of gasoline additives that pose a threat to drinking water supplies.[33]

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[32] The Panel is aware of the current proposal for further changes to the sulfur levels of gasoline and recognizes that implementation of any change resulting from the Panel's recommendations will, of necessity, need to be coordinated with implementation of these other changes. However, a majority of the Panel considered the maintenance of current RFG air quality benefits as separate from any additional benefits that might accrue from the sulfur changes currently under consideration.

[33] Under §211 of the 1990 Clean Air Act, Congress provided EPA with authority to regulate fuel formulation to improve air quality. In addition to EPA's national authority, in §211(c)(4) Congress sought to balance the desire for maximum uniformity in our nation's fuel supply with the obligation to empower states to adopt measures necessary to meet national air quality standards. Under §211(c)(4), states may adopt regulations on the components of fuel, but must demonstrate that 1) their proposed regulations are needed to address a violation of the NAAQS and 2) it is not possible to achieve the desired outcome without such changes.

The Panel recommends that Federal law be amended to clarify EPA and state authority to regulate and/or eliminate gasoline additives that threaten water supplies. It is expected that this would be done initially on a national level to maintain uniformity in the fuel supply. For further action by the states, the granting of such authority should be based upon a similar two part test:

1) states must demonstrate that their water resources are at risk from MTBE use, above and beyond the risk posed by other gasoline components at levels of MTBE use present at the time of the request.

2) states have taken necessary measures to restrict/eliminate the presence of gasoline in the water resource. To maximize the uniformity with which any changes are implemented and minimize impacts on cost and fuel supply, the Panel recommends that EPA establish criteria for state waiver requests including but not limited to:

a. Water quality metrics necessary to demonstrate the risk to water resources and air quality metrics to ensure no loss of benefits from the federal RFG program.
b. Compliance with federal requirements to prevent leaking and spilling of gasoline.
c. Programs for remediation and response.
d. A consistent schedule for state demonstrations, EPA review, and any resulting regulation of the volume of gasoline components in order to minimize disruption to the fuel supply system.

Initial efforts to reduce should begin immediately, with substantial reductions to begin as soon as Recommendation 10 above - the removal of the 2 percent oxygen requirement - is implemented[34]. Accomplishing any such major change in the gasoline supply without disruptions to fuel supply and price will require adequate lead time - up to 4 years if the use of MTBE is eliminated, sooner in the case of a substantial reduction (e.g. returning to historical levels of MTBE use).

The Panel recommends, as well, that any reduction should be designed so as to not result in an increase in MTBE use in Conventional Gasoline areas.

13. The other ethers (e.g. ETBE, TAME, and DIPE) have been less widely used and less widely studied than MTBE. To the extent that they have been studied, they appear to have similar, but not identical, chemical and hydrogeologic characteristics. The Panel recommends accelerated study of the health effects and groundwater characteristics of these compounds before they are allowed to be placed in widespread use.

In addition, EPA and others should accelerate ongoing research efforts into the inhalation and ingestion health effects, air emission transformation byproducts, and environmental behavior of <u>all</u> oxygenates and other components likely to increase in the absence of MTBE. This should include research on ethanol, alkylates, and aromatics, as well as of gasoline compositions containing those components.

14. To ensure that any reduction is adequate to protect water supplies, the Panel recommends that EPA, in conjunction with USGS, the Departments of Agriculture and Energy, industry, and water suppliers, should move quickly to:

a. Conduct short-term modeling analyses and other research based on existing data to estimate current and likely future threats of contamination;

b. Establish routine systems to collect and publish, at least annually, all available monitoring data on:

- use of MTBE, other ethers, and Ethanol;
- levels of MTBE, Ethanol, and petroleum hydrocarbons found in ground, surface and drinking water;
- trends in detections and levels of MTBE, Ethanol, and petroleum hydrocarbons in ground and drinking water;

c. Identify and begin to collect additional data necessary to adequately assess the current and potential future state of contamination.

<u>The Wintertime Oxyfuel Program</u>

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[34] Although a rapid, substantial reduction will require removal of the oxygen requirement, EPA should, in order to enable initial reductions to occur as soon as possible, review administrative flexibility under existing law to allow refiners who desire to make reductions to begin doing so.

The Wintertime Oxyfuel Program continues to provide a means for some areas of the country to come into, or maintain, compliance with the Carbon Monoxide standard. Only a few metropolitan areas continue to use MTBE in this program. In most areas today, ethanol can and is meeting these wintertime needs for oxygen without raising volatility concerns given the season.

15. The Panel recommends that the Wintertime Oxyfuel program be continued (a) for as long as it provides a useful compliance and/or maintenance tool for the affected states and metropolitan areas, and (b) assuming that the clarification of state and federal authority described above is enacted to enable states, where necessary, to regulate and/or eliminate the use of gasoline additives that threaten drinking water supplies.

Recommendations for Evaluating and Learning From Experience

The introduction of reformulated gasoline has had substantial air quality benefits, but has at the same time raised significant issues about the questions that should be asked before widespread introduction of a new, broadly-used product. The unanticipated effects of RFG on groundwater highlight the importance of exploring the potential for adverse effects in all media (air, soil, and water), and on human and ecosystem health, before widespread introduction of any new, broadly-used, product.

16. In order to prevent future such incidents, and to evaluate of the effectiveness and the impacts of the RFG program, EPA should:

    a. Conduct a full, multi-media assessment (of effects on air, soil, and water) of any major new additive to gasoline prior to its introduction;

    b. Establish routine and statistically valid methods for assessing the actual composition of RFG and its air quality benefits, including the development, to the maximum extent possible, of field monitoring and emissioos characterization techniques to assess "real world" effects of different blends on emissions;

    c. Establish a routine process, perhaps as a part of the Annual Air Quality trends reporting process, for reporting on the air quality results from the RFG program; and

    - Build on existing public health surveillance systems to measure the broader impact (both beneficial and adverse) of changes in gasoline formulations on public health and the environment.

Appendix A

In reviewing the RFG program, the Panel identified three main options (MTBE and other ethers, ethanol, and a combination of alkylates and aromatics) for blending to meet air quality requirements. They identified strength and weaknesses of each option:

MTBE/other ethers	A cost-effective fuel blending component that provides high octane, carbon monoxide and exhaust VOCs emissions benefits, and appears to contribute to reduction of the use of aromatics with related toxics and other air quality benefits; has high solubility and low biodegradability in groundwater, leading to increased detections in drinking water, particularly in high MTBE use areas. Other ethers, such as ETBE, appear to have similar, but not identical, behavior in water, suggesting that more needs to be learned before widespread use.
Ethanol	An effective fuel-blending component, made from domestic grain and potentially from recycled biomass, that provides high octane, carbon monoxide emission benefits, and appears to contribute to reduction of the use of aromatics with related toxics and other air quality benefits; can be blended to maintain low fuel volatility; could raise possibility of increased ozone precursor emissions as a result of commingling in gas tanks if ethanol is not present in a majority of fuels; is produced currently primarily in Midwest, requiring enhancement of infrastructure to meet broader demand; because of high biodegradability, may retard biodegradation and increase movement of benzene and other hydrocarbons around leaking tanks.
Blends of Alkylates and Aromatics	Effective fuel blending components made from crude oil; alkylates provide lower octane than oxygenates; increased use of aromatics will likely result in higher air toxics emissions than current RFG; would require enhancement of infrastructure to meet increased demand; have groundwater characteristics similar, but not identical, to other components of gasoline (i.e. low solubility and intermediate biodegradability).

CHAPTER 4. DISSENTING OPINIONS

State of Nebraska, Nebraska Ethanol Board

Oxygen Standard Should Be Maintained

Insufficient Evidence to Support Recommendation to Remove Oxygen Standard

Blue Ribbon Panel Dissenting Opinion

Submitted for the Record By

Todd C. Sneller, Panel Member

In its report regarding the use of oxygenates in gasoline, a majority of the Blue Ribbon Panel on Oxygenates in Gasoline (BRP) has based its recommendation to support removal of the oxygen standard on several conclusions which I believe to be inaccurate:

1). That aromatics can be used as a safe and effective replacement for oxygenates without resulting in deterioration in VOC and air toxic emissions. In fact, a review of the legislative history behind the passage of the *Clean Air Act Amendments of 1990* clearly shows that Congress found the increased use of aromatics to be harmful to human health and intended that their use in gasoline be reduced as much as technically feasible.

2). That oxygenates fail to provide overwhelming air quality benefits associated with their required use in gasoline. The BRP recommendations do not accurately reflect the benefits provided by the use of oxygenates in reformulated gasoline. Congress correctly saw a minimum oxygenate requirement as a cost effective means to both reduce levels of harmful aromatics and help rid the air we breathe of harmful pollutants.

3). That the BRP recommendation to urge removal of the oxygen standard does not fully take into account other public policy objectives specifically identified during Congressional debate on the 1990 *CAAA*. While projected benefits related to public health were a focal point during the debate in 1990, energy security, national security, the environment and economic impacts of the *Amendments* were clearly part of the rationale for adopting such amendments. It is my belief that the rationale behind adoption of the *Amendments* in 1990 is equally valid, if not more so, today.

As Congress debated the Reformulated Gasoline (RFG) provisions of the *Clean Air Act Amendments of 1990*, it became clear that aromatics (e.g. benzene, xylene, and toluene) added to gasoline were extremely toxic, and lead to the further deterioration of U.S. air quality. To specifically reduce aromatic levels in RFG – and help remove harmful air toxics from the air – an overwhelming bi-partisan majority of Congress specifically required the addition of cleaner burning oxygenates to gasoline. As stated in the record, a primary purpose behind the addition of oxygenates to gasoline was the reduction in carbon monoxide emissions in winter, ozone formation in summer, and air toxic emissions year-round.

Recognizing the harmful effects increased aromatic use has on public health, Senate Democratic Leader Tom Daschle (D-SD), a primary sponsor of the RFG provision, said on March 29, 1990;

"The primary aromatics used in gasoline are benzene, toluene and xylene, all of which are EPA-listed hazardous chemicals. The amount of benzene emitted from the tailpipe is directly related to the amount of benzene found in gasoline. However, *a gasoline can have no benzene and still produce benzene exhaust because of the chemical transformation that toluene and xylene undergo during the combustion process.*"..."*The most significant single step that can be taken to improve urban air quality is to limit aromatic content in gasoline.*" (Emphasis added)

Echoing that Congressional sentiment, Senator Tom Harkin (D-IA) said;

"The aromatic hydrocarbons in gasoline include benzene, toluene, and xylene. Benzene is a known carcinogen, one of the worst air toxics. Eighty-five percent of all benzene in the air we breathe comes from motor vehicle exhaust. Xylene, another aromatic, is highly photoreactive – meaning that it forms ozone very rapidly in sunlight. Xylene from automobile exhaust in the morning rush hour forms ozone in sunlight to choke our lungs by the afternoon trip home. Toluene, another aromatic, usually forms benzene during the combustion process, and thus becomes carcinogenic along with benzene in the gasoline. Today, about 33 percent of gasoline is composed of aromatics by volume... Worse yet, the aromatics tend to reduce the effectiveness of catalytic converters....By reducing the amount of aromatics by volume, you substantially reduce the amount of carbon monoxide, hydrocarbons, and nitrogen oxide emitted into the atmosphere...*Fortunately, there are other choices than aromatics to maintain octane level in gasoline. Guess what they are? The oxygenated fuel additives.*"

"...Fuels high in aromatics cause deposits in the combustion chamber interfering with combustion and increasing emissions. Aromatics have higher carbon content than the rest of gasoline, so gasoline high in aromatics contributes more to global warming. Aromatics were only about 20 percent of fuel in 1970, but percentages have increased substantially because the aromatics have been used to replace the octane that was lost as a result of the lead phase-down." (emphasis added)

The refining industry has informed the BRP that it will, in fact, increase use of aromatics in gasoline if the oxygenate provisions of the RFG program are removed. The BRP recommendations further state that, in most instances, oxygenates can be "effectively" replaced by aromatics. This position is directly counter to the vast weight of evidence on the harmful effects of aromatics and the positive air quality effects of oxygenates. Further, it is in direct conflict with the clear intent of Congress to improve U.S. air quality by restricting use of aromatics.

The BRP has not heard evidence supporting the "safe and effective" use of increased levels of aromatics in gasoline. In fact, according to evidence presented to the BRP on March 1-2, 1999, by William J. Piel, Technical Director of the Clean Fuels Development Coalition (CFDC), increased use of aromatics will lead directly to increases in air toxic emissions, exhaust VOC emissions, combustion chamber deposits, carbon monoxide emissions, and worsen fuel factors contributing to vehicle performance (i.e. the driveability index). Use of aromatics will also increase VOC emissions at both stationary and mobile sources.

In fact, the BRP majority's apparent willingness to accept <u>higher</u> aromatic levels runs directly counter to Congressional intent. In his October 27, 1990 statement in support of the *CAAA* Conference report,

Senate Environment and Public Works Committee member David Durenberger stated that the performance standard for post-2000 RFG should logically lead to a 25 percent or lower cap on aromatics.

According to Durenberger;

> "The so-called formula gasoline which contains a cap on benzene at one percent and a cap on aromatics at 25 percent should achieve substantial reductions in the aggregate amounts of the five [toxic] pollutants... After the year 2000, the situation is different because the Administrator is to choose the performance standard for toxics which reflects the maximum reduction in toxic emissions that is feasible taking cost into account. The formula gasoline may well achieve a reduction in toxics which exceeds 20 percent, and *if so, whatever it does achieve would be a floor for the performance standards after the year 2000* (emphasis added). In this Senator's view, controls on benzene and aromatics more stringent than those in the formula gasoline are certainly feasible... The performance standards and the formula stated explicitly in the legislation are only minimum requirements."

As a Nebraska state official and Panel member, I find it troubling that the majority of the BRP members have chosen to ignore such evidence -- as well as the clear intent of Congress -- in its recommendation to remove the oxygenate standard from RFG. It also concerns me that the BRP recommendation regarding the oxygenate standard will likely lead directly to the increased use of aromatics – compounds universally condemned for their harmful effects on air quality.

Finally, the legislative history clearly shows that Congress specifically required the use of oxygenates in gasoline for other important public policy goals: national energy security through the reduction in oil imports; and, stimulating domestically produced renewable fuels made from agricultural products.

As Sen. Harkin stated;

> "[Use of oxygenates] will reduce our health care costs. We can have reduced farm support costs. And reduced oil imports. By lowering reformer severity and aromatics content as a means of achieving octane, and replacing it with high octane oxygenates, you conserve large quantities of oil in two ways – first, savings in gasoline because of the lower severity of the refining operation of the base gasoline; and second, straight physical displacement of gasoline by oxygenates. This amendment will save millions of barrels of oil every year."

And in a May 2, 1990 "Dear Colleague" letter, Representatives Bill Richardson (now Energy Secretary) and Ed Madigan urged their colleagues to support the House version of the Daschle-Dole RFG provision. They wrote;

> "Cleaner gasoline also slashes foreign imports. Today's gasoline relies on imported aromatic compounds. When we replace these compounds with domestically produced alcohols and ethers made from corn, wheat, barley and other crops, we shift trade from OPEC to our farmers. According to the GAO, this new market could save taxpayers over $1.2 billion that is now spent annually on farm price supports."

These and other references make it clear that Congress thoughtfully considered and debated the benefits of reducing aromatics and requiring the use of oxygenates in RFG. Based on the weight of evidence presented to the BRP, I remain convinced that maintenance of the oxygenate standard is necessary to ensure cleaner air and a healthier environment. I am also convinced that water quality must be better protected through significant improvements to gasoline storage tanks and containment facilities. Therefore, because it is directly counter to the weight of the vast majority of scientific and technical evidence and the clear intent of Congress, I must respectfully disagree with the BRP recommendation that the oxygenate provisions of the RFG Program be removed. I also request that the final report from the BRP include a recommendation to place a cap on the use of aromatics in gasoline at 25 percent by volume, in keeping with the Panel's commitment to preserve air quality improvements.

Todd Sneller serves as Administrator of the Nebraska Ethanol Board, a state agency. He is the past chairman of the Clean Fuels Development Coalition, and currently serves as the Nebraska representative of the 22 state Governors' Ethanol Coalition. Mr. Sneller was appointed to the EPA Blue Ribbon Panel in December 1998.

Lyondell Chemical Company's Dissenting Report

Summary

While the Panel is to be commended on a number of good recommendations to improve the current underground storage tank regulations and reduce the improper use of gasoline, the Panel's recommendations to limit the use of MTBE are not justified.

Unfortunately, there appears to be an emotional rush to judgement regarding the use of MTBE. The recommendation to reduce the use of MTBE substantially is unwarranted for the following four reasons:

Firstly, the Panel was charged to review public health effects posed by the use of oxygenates, particularly with respect to water contamination. The Panel did not identify any increased public health risk associated with MTBE use in gasoline.

Secondly, no quantifiable evidence was provided to show the environmental risk to drinking water from leaking underground storage tanks (LUST) will not be reduced to manageable levels once the 1998 LUST regulations are fully implemented and enforced. The water contamination data relied upon by the Panel is largely misleading because it predates the implementation of the LUST regulations.

Thirdly, the recommendations will not preserve the air quality benefits achieved with oxygenate use in the existing RFG program. The air quality benefits achieved by the RFG program will be degraded because they fall outside the control of EPA's Complex Model used for RFG regulations and because the alternatives do not match all of MTBE's emission and gasoline quality improvements.

Lastly, the Panel's recommendation options depend upon the use of alternatives that have not been adequately studied for air quality and health risk impacts. These alternatives will also impose an unnecessary additional cost of 1 to 3 billion dollars per year (3 – 7 c/gal. RFG) on consumers and society without quantifiable offsetting social benefits or avoided costs with respect to water quality in the future.

Discussion of Issues

No increase in public health risk associated with the use of MTBE has been identified.

Based on the Panel's review of the available health studies, the Panel did not identify any increased health risk associated with MTBE's normal use in gasoline and the Panel's review is best summarized by the following paragraph from the *Issue Summary* E, "Comparing the Fuel Additives."

"In terms of neurotoxicity and reproductive effects, inhalation toxicity testing to date generally has not shown MTBE to be any more toxic than other components of gasoline. At very high doses, MTBE has caused tumors in two species of rat and one species of mouse at a variety of sites; it is uncertain, however, whether these effects can be extrapolated to humans. The International Agency for Research on Cancer (IARC) and the National Institute of Environmental Health Sciences (NIEHS) have indicated that at this time there are not adequate data to consider MTBE a probable or known human carcinogen."

No quantifiable evidence has been provided to show that full compliance with the 1998 LUST regulations will not achieve its purpose of substantially reducing the release of gasoline, and thereby MTBE, from UST systems today and in the future.

The Panel states that enhanced UST programs will not give adequate assurance that water supplies will be protected. However, this statement is made without any quantifiable analysis or support. The facts are that most MTBE detects are very low level concentrations and have occurred prior to UST systems being upgraded to meet the 1998 deadlines. The MTBE detection data presented to the Panel by the USGS was collected between 1988 and 1998 when most UST systems were still out of compliance. In addition, data summarized by the Association of State and Territorial Solid Waste Management Officials (ASTSWMO) shows that less than 50 percent of all UST's were in compliance prior to 1998 and that as recent as 1996 only 30 percent were in compliance.[35] Therefore, the detection data reflects a time period before most of the underground tanks were upgraded.

In addition, the risk of drinking water contamination by MTBE and other gasoline constituents has been greatly reduced with the onset of LUST regulation compliance. The UC Davis study[36] which was presented to the PANEL estimates that tank failure rates (leak occurrences) decrease by over 95 percent (from 2.6 percent failures per year for non-upgraded tanks to 0.07 percent per year for upgraded tanks) once UST systems are upgraded to meet the current LUST regulations. Also, with the required installation of early leak detection monitoring, the time between when a leak occurs and when it is detected will now be significantly reduced. As a result, the amount of gasoline released from a new leaking site before it has been remediated is substantially minimized. Both of these effects combined should lead to substantial reductions (orders of magnitude) in the amount of gasoline and MTBE that escapes undetected from the UST population which therefore makes it a much more manageable situation for protecting drinking water supplies.

The recommendations fail to recognize the full emission benefits from using MTBE and oxygenates in RFG, and that the alternatives do not equal the emission reductions and combustion enhancing blending properties of MTBE in gasoline. Therefore, a reduction in MTBE use will result in a net loss in air quality.

Although the Panel was charged with "examining the role of oxygenates in meeting the nation's goal of clean air" and "evaluating each product's efficiency in providing clean air benefits and the existence of alternatives," the Panel did not identify and quantify all the emission benefits realized when oxygenates are used to make cleaner burning and low polluting gasolines. Neither was the Panel able to identify combinations of alternatives that could match both the emission reductions and the combustion enhancing blending properties of MTBE in gasoline. The Panel did not recognize the fact that the simple use of oxygenates along with a vapor pressure reduction were the only requirements used to achieve the ozone precursor reduction goals in the first three years of a very successful RFG program.[37] Since all other alternatives have one or more inferior properties as compared to MTBE in gasoline, it would be difficult if not nearly impossible to achieve the same real air quality efficiency provided by MTBE. And

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[35] Sausville, Paul, Dale Marx and Steve Crimaudo: A Preliminary State Survey with Estimates based on a Survey of 17 State databases of early 1999. ASTSWMO UST Task Force, 11th Annual EPA UST/LUST National Conference, March 15-17, 1999. Daytona Beach, Florida.

[36] Keller, Arturo, et. al. Health & Environmental Assessment of MTBE, Report to the Governor and Legislature of the State of California as Sponsored by SB 521. November 1998.

[37] "Overview of Fuel Oxygenate Development", William J. Piel For Lyondell Chemical Co., Presentation to the EPA's Blue Ribbon Panel, January 22, Arlington, VA.

since sulfur reductions are also expected to occur under other fuel regulations, it would be a double-accounting of emissions benefits if sulfur reductions in RFG are to be used to compensate or make-up for any increase of emissions resulting from reduced oxygenate use in RFG.

Beyond reducing VOC's, NO_x and toxics, improving gasoline properties through the use of oxygenates reduce many other vehicles pollutants such as CO (carbon monoxide), PM (particulate matter) and CO2 (carbon dioxide) as well as the ozone reactivity of VOC's. Also, gasoline property changes associated with oxygenate use in RFG provide additional emission reductions of VOC, NO_x, toxics and CO (an ozone precursor) over the life of the vehicle by lowering combustion chamber deposits and therefore the vehicle's emissions deterioration rates over time. Since none of these additional emission reductions are reflected or controlled in EPA's Complex Emissions Model used for RFG, reducing MTBE in RFG will result in a loss of these extra emission benefits.[38]

Unfortunately, the Panel recommendations limit themselves to only meeting the regulatory requirements established in EPA's existing RFG rules and did not focus on capturing all the real world emission benefits associated with MTBE's use in RFG. Though the Panel recommends reducing the use of oxygenates in RFG, they failed to explain how equivalent air quality is to be maintained when the only identifiable fuel alternatives cannot match all of MTBE's emission reductions and combustion enhancing blending properties in gasoline. Therefore, replacing MTBE with the alternatives under the current recommendations will contribute to a net loss in air quality with regards to Peak Ozone levels, PM, toxics and CO2 (greenhouse gas) in addition to higher costs.

Alternatives have not been adequately studied for their health risk impacts, availability or their cost effectiveness in RFG

From a scientific, policy, and political perspective, no one should rush to judgement on MTBE without a thorough evaluation of the alternatives. The Panel cannot afford to be wrong about MTBE's benefits or deficiencies. As a matter of sound public policy, any alternative needs to be held up to the same rigorous examination as MTBE, while adhering to the following criteria.

- To assure the public that any alternative will produce the same real air quality benefits as MTBE.
- That any alternative will be abundantly and economically available.
- That any alternative will not be a probable or known human carcinogen nor increase the risks to human health.

These criteria are consistent with the Panel's recommendation to investigate more fully any major new additives to gasoline prior to its introduction and therefore should equally apply to the alternatives already identified by the Panel, namely Ethanol, Alkylates, and Aromatics. The expanded use of these alternatives should not occur without a more rigorous analysis of the impacts on health, air quality, and water quality as well as their availability and costs.

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[38] "Staff Report: Proposed Amendments to the California Regulation Requiring Deposit Control Additives in the Motor Vehicle Gasoline" Calif. Environ. Protection Agency, Air Resources Board, Aug 7, 1998; "Benefits of the Federal RFG Program And Clean Burning Fuels with Oxygenates", William J. Piel of Lyondell Chemical Co., Presentation to EPA Blue Ribbon Panel, March 1, 1999, Boston.

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GLOSSARY OF TERMS

ACRONYMS

AQMD	Air Quality Management District
AS	Air Sparging
AST	Aboveground Storage Tank
ASTM	American Society for Testing & Material
AWWARF	American Water Works Association Research Foundation
BTEX	Benzene, Toluene, Ethylbenzene, and Xylene
Btu	British Thermal Unit
CAA	Clean Air Act
CAAA	Clean Air Act Amendments of 1990
CAFÉ	Corporate Average Fuel Economy
CalEPA	California Environmental Protection Agency
CARB	California Air Resources Board
CaRFG	California Reformulated Gasoline
CEC	California Energy Commission
CG	Conventional Gasoline
CIIT	Chemical Industry Institute of Toxicology
CO	Carbon Monoxide
CO_2	Carbon Dioxide
CWSRF	Clean Water State Revolving Fund
DIPE	Di-isopropyl Ether
DOE	U.S. Department of Energy
DOT	U.S. Department of Transportation
DWSRF	Drinking Water State Revolving Fund
EIA	U.S. Energy Information Administration
EPA	U.S. Environmental Protection Agency
EPACT	Energy Policy Act of 1992
ETBE	Ethyl Tertiary Butyl Ether
E_{10}	10% Ethanol/90% Gasoline by volume
FCC	Fluid Catalytic Cracked
HC	Hydrocarbons
HEI	Health Effects Institute
IARC	International Agency for Research on Cancer
ILEV	Inherently Low Emission Vehicle
LEV	Low Emission Vehicle
LLNL	Lawrence Livermore National Laboratory
LUST	Leaking Underground Storage Tank
MNA	Monitored Natural Attenuation
MTBE	Methyl Tertiary Butyl Ether
NAAQS	National Ambient Air Quality Standards
NAPL	Non-Aqueous Phase Liquid

NAWQA	National Water Quality Assessment Program
NESCAUM	Northeast States for Coordinated Air Use Management
NMOG	Non-Methane Organic Gases
NO_x	Oxides of Nitrogen
NRC	National Research Council
OMS	U.S. Environmental Protection Agency, Office of Mobile Sources
OSTP	White House Office of Science and Technology
OUST	U.S. Environmental Protection Agency, Office of Underground Storage Tanks
OXY	Winter Oxyfuel Program
PADD	Petroleum Administration for Defense Districts
PAN	Peroxyacetyl Nitrate
PM	Particulate Matter
POM	Polycyclic Organic Matter
ppb	Parts Per Billion
ppm	Parts Per Million
psi	Pounds Per Square Inch (pressure)
RBCA	Risk-Based Corrective Action
RFG	Reformulated Gasoline
RVP	Reid Vapor Pressure
SDWA	Safe Drinking Water Act
SIP	State Implementation Plan
SPCC	Spill Control and Counter Control
SULEV	Super Ultra Low Emission Vehicle
SVE	Soil Vapor Extraction
TAME	Tertiary Amyl Methyl Ether
TBA	Tertiary Butyl Alcohol
TLEV	Transitional Low Emission Vehicle
ULEV	Ultra Low Emission Vehicle
USDA	U.S. Department of Agriculture
U.S. EPA	U.S. Environmental Protection Agency
USGS	United States Geological Survey
T_{50}	50% Distillation Temperature
T_{90}	90% Distillation Temperature
UST	Underground Storage Tank
VOC	Volatile Organic Compound
ZEV	Zero Emission Vehicle

TERMS

Additives: Chemicals added to fuel to improve and maintain fuel quality. Detergents and corrosion inhibitors are examples of gasoline additives.

Air Toxics: Toxic air pollutants defined under Title II of the CAA, including benzene, formaldehyde, acetaldehyde, 1,3 butadiene, and polycyclic organic matter (POM). Benzene is a constituent of motor vehicle exhaust, evaporative, and refueling emissions. The other compounds are exhaust pollutants.

Alcohols: Organic compounds that are distinguished from hydrocarbons by the inclusion of a hydroxl group. The two simplest alcohols are methanol and ethanol.

Aldehydes: A class of organic compounds derived by removing the hydrogen atoms from an alcohol. Aldehydes can be produced from the oxidation of an alcohol.

Alkanes: See Paraffins.

Alkylate: The product of an alkylation reaction. It usually refers to the high octane product from alkylation units. This alkylate is used in blending high octane gasoline.

Aromatics: Hydrocarbons based on the ringed six-carbon benzene series or related organic groups. Benzene, toluene, ethylbenzene, and xylene are the principal aromatics, commonly referred to as the BTEX group. They represent one of the heaviest fractions in gasoline.

Attenuation: The reduction or lessening in amount (*e.g.*, a reduction in the amount of contaminants in a plume as it migrates away from the source). Attenuation occurs as a result of in-situ processes (including biodegradation, dispersion, dilution, sorption, volatilization), and chemical or biological stabilization, transformation, or destruction of contaminants.

Benzene: Benzene is a six-carbon aromatic that is common gasoline component. Benzene has been identified as toxic and is a known carcinogen.

Biodegradation: A process by which microbial organisms transform or alter (through metabolic or enzymatic action) the structure of chemicals introduced into the environment.

Biomass: Renewable organic matter, such as agricultural crops, crop-waste residues, wood, animal and municipal wastes, aquatic plants, or fungal growth, used for the production of energy.

British Thermal Unit (Btu): A standard unit for measuring heat energy. One Btu represents the amount of heat required to raise one pound of water one degree Fahrenheit (at sea level).

Butane: An easily liquefied gas recovered from natural gas. Used as a low-volatility component of motor gasoline, processed further for a high-octane gasoline component, used in LPG for domestic and industrial applications, and used as a raw material for petrochemical synthesis.

Butyl Alcohol: Alcohol derived from butane that is used in organic synthesis and as a solvent.

CAA: The original Clean Air Act was signed in 1963, setting emissions standards for stationary sources. The CAA was amended several times, most recently in 1990. The Amendments of 1970 introduced motor vehicle emission standards. Criteria pollutants included lead, ozone, CO, SO_2, NO_x, and PM, as well as air toxics. In 1990, reformulated gasoline (RFG) and oxygenated gasoline (OXY) provisions were added. The RFG provision requires use of RFG all year in certain areas. The OXY provision requires the use of oxygenated gasoline during certain months, when CO and ozone pollution are most serious. The regulations also require certain fleet operators to use clean-fuel vehicles in 22 cities.

California Low Emissions Vehicle Program: State requirement for automakers to produce vehicles with fewer emissions than current EPA standards. The five categories of the Program, from least to most stringent are as follows: TLEV; LEV; ULEV; SULEV; and ZEV.

Carcinogens: Chemicals and other substances known to cause cancer.

Distillation Curve: The percentages of gasoline that evaporate at various temperatures. The distillation curve is an important indicator for fuel standards such as volatility (vaporization).

Ethanol: Can be produced chemically from ethylene or biologically from the fermentation of various sugars or from carbohydrates found in agricultural crops and cellulosic residues from crops or wood. Ethanol is used in the United States as a gasoline octane enhancer and oxygenate. It increases octane 2.5 to 3.0 numbers at 10 percent concentration. Ethanol also can be used in higher concentrations in alternative-fuel vehicles optimized for its use.

Ethers: A family of organic compounds composed of carbon, hydrogen, and oxygen. Ether molecules consist of two alkyl groups linked to one oxygen atom. Light ethers such as ETBE, MTBE, TAME, and DIPE have desirable properties as gasoline blendstocks and are used as oxygenates in gasoline.

Ethyl Tertiary Butyl Ether (ETBE): An aliphatic ether similar to MTBE. This fuel oxygenate is manufactured by reacting isobutylene with ethanol. Having high octane and low volatility characteristics, ETBE can be added to gasoline up to a level of approximately 17 percent by volume.

E10: Ethanol/gasoline mixture containing 10 percent denatured ethanol and 90 percent gasoline, by volume.

Evaporative Emissions: Hydrocarbon vapors that escape from a fuel storage tank, a vehicle fuel tank, or vehicle fuel system.

Exhaust Emissions: Materials that enter the atmosphere through the exhaust, or tailpipe, of a vehicle. Exhaust emissions include carbon dioxide (and water vapor), carbon monoxide, unburned fuel, products of incomplete combustion, fuel contaminants, and the combustion products of lubricating oils.

Feedstock: Any material converted to another form of fuel or energy product.

Fungible: A term used within the oil refining industry to denote products that are suitable for transmission by pipeline.

Ground Water: The water contained in the pore spaces of saturated geologic media. Ground water can be confined by overlying less permeable strata (confined aquifer) or open to the atmosphere (water table or unconfined aquifers).

In-situ: In its original place; unmoved; unexcavated; remaining in the subsurface.

Methyl Tertiary Butyl Ether (MTBE): An ether manufactured by reacting methanol and isobutylene. The resulting ether has high octane and low volatility. MTBE is a fuel oxygenate and is permitted in unleaded gasoline up to a level of 15 percent by volume.

National Ambient Air Quality Standards: Ambient standards for criteria air pollutants specifically regulated under the CAA. These pollutants include ozone, particulate matter, carbon monoxide, nitrogen dioxide, sulfur dioxide, and lead.

Neat Fuel: Fuel that is free from admixture or dilution with other fuels.

Neat Alcohol Fuel: Straight or 100 percent alcohol (not blended with gasoline), usually in the form of either ethanol or methanol.

Nonattainment Area: A region, determined by population density in accordance with the U.S. Census Bureau, which exceeds minimum acceptable NAAQS for one or more "criteria pollutants." Such areas are required to seek modifications to their State Implementation Plans (SIPs), setting forth a reasonable timetable using EPA-approved means to achieve attainment of NAAQS for these criteria pollutants by a certain date. Under the CAA, if a nonattainment area fails to attain NAAQS, EPA may superimpose a FIP with stricter requirements or impose fines, construction bans, cutoffs in Federal grant revenues, etc., until the area achieves the applicable NAAQS.

Octane Enhancer: Any substance such as MTBE, ETBE, toluene, xylene and alkylates that is added to gasoline to increase octane and reduce engine knock.

Oxyfuel Program: Nonattainment areas for carbon monoxide are required to use oxygenated fuel during the winter season.

Oxygenate: A term used in the petroleum industry to denote fuel additives containing hydrogen, carbon, and oxygen in their molecular structure. Includes ethers such as MTBE and ETBE and alcohols such as ethanol and methanol.

Oxygenated Gasoline: Gasoline containing an oxygenate such as MTBE or ethanol. The increased oxygen content may promote more complete combustion, thereby reducing tailpipe emixsions of CO.

Paraffins: Also referred to as Alkanes, a group of chain saturated aliphatic hydrocarbons, including methane, ethane, propane, butane, and alkanes (not including cycloalkanes).

Particulate Matter (PM): A generic term for a broad class of chemically and physically diverse substances that exist as discrete particles (liquid droplets or solids) over a wide range of sizes; a NAAQS pollutant.

Recalcitrant: Unreactive, nondegradable; refractory. Slowly degraded compounds.

Reformulated Gasoline (RFG): Gasolines that have had their compositions and/or characteristics altered to reduce vehicular emissions of pollutants, particularly pursuant to EPA regulations under the CAA.

Reid Vapor Pressure (RVP): A standard measurement of a liquid's vapor pressure in psi at 100 degrees Fahrenheit. It is an indication of the propensity of the liquid to evaporate.

State Implementation Plan (SIP): Plan that a state must submit to EPA under the CAA to demonstrate compliance to NAAQS.

Tertiary Amyl Methyl Ether (TAME): An ether based on reaction of C_5 olefins and methanol.

Toluene: Basic aromatic compound derived from petroleum and used to increase octane. A hydrocarbon commonly purchased for use in increasing octane.

Toxic Emission: Any pollutant emitted from a source that can negatively affect human health or the environment.

Toxics: Pollutants defined by the CAAA, including benzene, formaldehyde, acetaldehyde, 1,3 butadiene, and polycyclic organic material. Benzene is emitted both in exhaust and evaporative emissions; the other compounds are exhaust emissions.

Volatile Organic Compounds (VOCs): Reactive gases released during combustion or evaporation of fuel and regulated by EPA. VOCs react with NO_X in the presence of sunlight and form ozone.

Volatilization: The process of transfer of a chemical from the aqueous or liquid phase to the gas phase. Solubility, molecular weight, vapor pressure, mixing of the liquid, and the nature of the gas-liquid interface affect the rate of volatilization.

Vapor Pressure or Volatility: The tendency of a liquid to pass into the vapor state at a given temperature. With automotive fuels, volatility is determined by measuring RVP.

Wellhead: The area immediately surrounding the top of a well, or the top of the well casing.

Wellhead Protection Area: The recharge area surrounding a drinking water well or wellfield, which is protected to prevent contamination of a well.