Wander LUST

by Hal White

A column by Hal White that explores "a dimension as vast as space and as timeless as infinity—representing the middle ground between light and shadow, science and superstition . . . between the pit of man's fears, and the summit of his knowledge."

The Eleven Myths about MTBE

myth: a fiction or half-truth, esp. one that forms part of the ideology of a society. (*Webster's Dictionary*)

In an article in a recent issue of Contaminated Soil, Sediment, and Water *(Spring, 2001—which was just released this past spring) authors Dick Woodward and Dick Sloan outline 11 so-called myths, misconceptions, and assumptions about MTBE. The article, titled "Common Myths, Misconceptions and Assumptions about MTBE: Where Are We Now?" is based on presentations from a series of seminars sponsored by Lyondell Chemicals (a major producer of MTBE) through the consulting firm of Tighe and Bond, Inc. The seminars, many of which were led by Woodward and Sloan, were presented in dozens of cities across the United States (and also around the world). These myths have also been immortalized in a giant, full-color, wall-sized poster.*

But with all of the resources that have been poured into this information dissemination effort on behalf of Lyondell, can we safely assume that we've been presented with the truth, the whole truth, and nothing but the truth about MTBE? I decided to explore this question by taking a closer look at the 11 MTBE myths put forth in Woodward and Sloan's article. For consistency and ease of comparison, I present each myth in the same order and with the same title as it appears in the article. (See my references for a URL). My critiques consist of a brief summary of the major points from the article that purportedly support their classification as a myth, a comprehensive analysis of each major point, and finally a conclusion as to whether or not the alleged myth is in fact a myth. After examining each of the myths and determining its status as a myth, I tally up the results.

Note: In each "Major points" section below, I have quoted the text exactly as published in *Contaminated Soil, Sediment, and Water*. It has not been edited for grammar or clarity of content.

MYTH #1: MTBE DEGRADES STORAGE/HANDLING FACILITIES

Major points: (1) "MTBE has been an important component of unleaded gasoline and subsequently reformulated gasoline (RFG) for more than 20 years. MTBE containing formulations have been successfully shipped nationwide in a variety of truck transports, pipelines and rail transfer facilities. Historically, the materials of these gasoline-handling facilities have been compatible with MTBE and have tested tight."

(2) "Several detailed reviews over the last three years have not revealed any specific instances where MTBE in gasoline caused premature failure of systems components or resulted in material incompatibility."

Analysis: (1) At face value there's no dispute with this point. However, despite the title of this myth, this point explicitly mentions "gasoline-handling" facilities (i.e., truck transports, pipelines, and rail transfer facilities), not "storage" facilities. The claim that any gasoline-handling facility has "tested tight" is not necessarily an indication that there hasn't been a release. UST systems are not air-tight, and vapor releases in particular are not detected by most leak-detection devices.

(2) Admittedly, definitive examples of compatibility-related UST system failures are rare. But it is due more to the fact that this type of information is difficult to ascertain and rarely collected, and not because such problems never occur. Virtually all UST-system compatibility studies to-date have been conducted in the laboratory and not in the field.

Couch and Young (1998) conducted a comprehensive evaluation of MTBE-UST compatibility issues. Although their review of available literature found no significant threat to most UST materials from fuels containing up to 20 percent MTBE, published data indicate that the service life of some elastomer products is shortened due to swelling, softening, and permeation when in contact with fuel containing 15 to 20 percent MTBE or when in contact with MTBE vapors.

Couch and Young (1998) also concluded that despite the fact that numerous compatibility studies had been conducted, none were long term, most were qualitative rather than quantitative in nature, and most of the investigators were industry purveyors or materials suppliers.

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Due to this "lack of objective, independent, and quantitative research," Couch and Young (1998) suggest that further investigation is warranted, especially with regard to elastomer performance.

Davidson (1998) also reviewed the available knowledge regarding the compatibility of MTBE with UST systems in an article for *LUSTLine* (Bulletin #28). Although he concluded that there were no obvious compatibility problems, he also noted that available information was either limited or contradictory. He recommended that more research be conducted, especially in the areas of seal and gasket material compatibility with MTBE and the effect of MTBE-enriched vapors and condensates on UST system components.

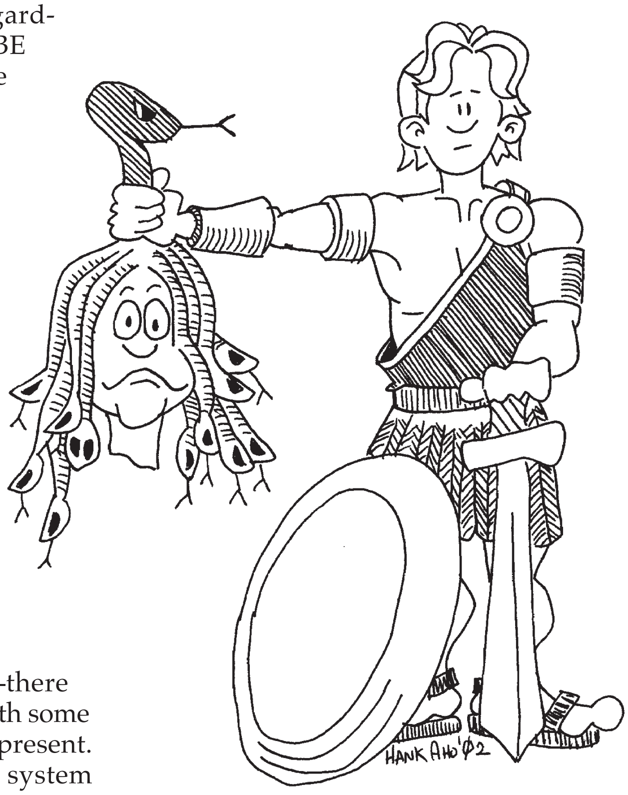
Conclusion: It's no myth—there are compatibility concerns with some UST components, at least at present. Even if all of the other UST system components are eventually shown to be compatible with gasoline that contains MTBE, some data indicate that certain elastomeric materials that are in use today are degraded to some extent when in contact with MTBE (and especially vapors) and could potentially fail sooner than anticipated. Until these materials are no longer in use in UST systems, there is still a potential for a release.

MYTH #2: MTBE ALONE LEAKS FROM GASOLINE TANKS

Major points: (1) "when an [UST] fails, all of the chemical components of the fuel are released into the subsurface soils and likely into the underlying groundwater…"

(2) "Typically, gasoline may contain 6% MTBE by volume, which means that 94% of what leaks into the soil and groundwater is other gasoline components…"

Analysis: (1) This point assumes that all releases from USTs are liquid releases that are the result of tank failure. However, the majority of releases from UST systems are low-volume, chronic releases, not catastrophic tank failures. There is an increasing body of evidence that indicates that *vapor* releases from UST systems may be a significant source of groundwater contamination. For fuels oxygenated with MTBE, vapor releases are composed almost entirely of MTBE, which readily diffuses in soil moisture and begins a downward migration toward groundwater. BTEX, on the other hand, tends to sorb to organic carbon in soil, therefore traveling a shorter distance, and often degrading relatively close to the source area (though there are lots of exceptions).



Even when a liquid release does occur, and components other than MTBE are released into the subsurface, MTBE will be preferentially depleted from the residual fuel source and dissolve into soil moisture and groundwater. As a result of the relatively lower solubility of BTEX, MTBE will end up in the groundwater more quickly than will BTEX.

(2) MTBE may be present in oxygenated fuels at volumes from 11 to 15 percent (much higher than the 6 percent stated in the article). While this still means that 85 to 89 percent of the total volume of the fuel is composed of other chemical constituents, it also means that for every seven to nine gallons of oxygenated gasoline released into the environment, one gallon of MTBE is also released. If this one gallon of MTBE is evenly distributed in groundwater at a concentration of 20 ppb, a volume of more than 4 million gallons of water would be polluted.

Another point that the article doesn't make is that MTBE is increasingly found in fuels other than gasoline (e.g., diesel fuel, heating oil, and jet fuel). Since these fuels consist primarily of heavier, less-soluble constituents than gasoline and sorb to soils more readily, it is entirely possible that a plume originating from one of these releases could be composed solely of MTBE.

Conclusion: It's no myth. It is possible that MTBE may be the only fuel component released to the environment in any significant quantity, especially in the case of vapor-only releases or releases of fuels other than gasoline.

MYTH #3: MTBE TRAVELS FAR BEYOND BTEX PLUMES

Major points: (1) "Dissolved chemicals cannot travel faster than the groundwater but they may travel slower if their movement is retarded by adsorption to the soil."

(2) "The net result is that MTBE will tend to exist on the leading edge of a typical groundwater plume, however the other gasoline components, e.g. BTEX, will tend to exist immediately behind the leading edge of the plume."

(3) "Several recent studies of groundwater plumes associated with gasoline releases have confirmed that MTBE and BTEX plumes generally coincide."

Analysis: (1) No hydrogeologist would say that dissolved chemicals travel faster than groundwater. What can be said, however, and what may be misinterpreted as meaning the same thing as the preceding statement, is that some dissolved chemicals travel faster than the *average* *linear velocity* of the groundwater. As groundwater flows through the aquifer matrix, water molecules twist around individual grains and pass through interconnected pore spaces at differing velocities. Some water molecules, therefore, reach a given point faster than others.

Dissolved chemical molecules also travel at differing velocities but none faster than the fastest water molecule. At any given point in space, a breakthrough curve—a plot of concentration versus time—has the shape of an elongated "S." The inflection point of this curve represents the hypothetical arrival time of an undiluted slug of contaminant that is moving at the *average* linear groundwater velocity. The upper and lower tails of the "S" represent the effect of dispersion—the lower tail represents molecules that travel faster than the average linear groundwater velocity, the upper tail represents molecules that travel slower.

For a perfectly nonreactive chemical (i.e., one whose movement is not "retarded"), the breakthrough curve would be a step function; that is, the concentration would be zero until first arrival and then it would jump (step) to 100 percent concentration instantaneously. While the movement of BTEX is retarded, the movement of MTBE is relatively unimpeded such that its movement through the aquifer is generally at a velocity that is higher than that of BTEX, although no faster than groundwater.

(2) All other conditions being equal, if BTEX and MTBE are released into flowing groundwater at the same time, MTBE will almost certainly jump out ahead of BTEX in the plume that forms and be present as the leading edge. Because of its greater solubility, MTBE will be preferentially depleted from the residual source sooner than will BTEX. Once the source is exhausted, both BTEX and MTBE plumes may detach and continue to migrate downgradient as slugs of contaminants rather than as an attached plume. However, BTEX sources tend to persist for longer periods of time than do MTBE sources because the MTBE is depleted more quickly from the source, and BTEX source areas tend to be anaerobic, so biodegradation is slower. In groundwater environments that are not conducive to biodegradation of MTBE, given enough time the MTBE slug will eventually migrate farther downgradient than will BTEX.

(3) The degree of plume separation is dependent upon many other factors in addition to time. One factor that is frequently overlooked is the adequacy of the monitoring network from which groundwater data are derived. Because MTBE behaves differently than BTEX, MTBE often will not be detected in the same wells as those with BTEX, especially with increasing downgradient distance from the source.

Perhaps the best-recognized example of MTBE moving independently of BTEX is the plume at East Patchogue, New York. The MTBE plume is about 20 feet below the water table with a leading edge ("toe") that is over 6,000 feet from the source; the trailing edge ("heel") is nearly 4,000 feet from the source. On the other hand (or perhaps a better word in this case would be "foot"), the toe of the benzene plume is over 5,000 feet from the source and still attached to the source area. *LUSTLine* #36 (November 2000, pp.12–15) contains an article by Jim Weaver and John Wilson (EPA/ORD) that presents this example along with a comprehensive discussion of plume diving and the inadequacy of conventional monitoring well networks for detecting MTBE plumes.

Conclusion: It's no myth. MTBE does have the potential to migrate farther (and faster) than BTEX. There are numerous examples from around the country that support this observation. For example, several MTBE plumes on Long Island are up to several thousand feet ahead of BTEX plumes. From the 2000 NEIWPCC survey, 27 states reported that MTBE plumes were often or sometimes longer than BTEX plumes, and 19 states indicated that they had MTBE plumes in excess of 1,000 feet in length. But it is also important to realize that this won't necessarily be the case at every site.

MYTH #4: MTBE PLUMES SINK (OR DIVE)

Major points: (1) "MTBE and the other components of gasoline have a specific gravity of less than 1, consequently free phase gasoline, with MTBE or without, floats on the groundwater water table."

(2) "If recharge occurs from the surface, older aquifer water and its dissolved constituents may be pushed downward in the formation."

(3) "Likewise, pumping of an aquifer at depth may pull the water table and constituents dissolved in the groundwater to deeper locations in the formation."

(4) "…it is important to conduct complete, three-dimensional characterization of plumes prior to remedial action."

Analysis: (1) No disagreement here. Free-phase LNAPLs will certainly float on the water table. But it's the dissolved phase, not the free phase, that's of concern with regard to MTBE plumes.

(2) No disagreement here. This is one of the three mechanisms by which MTBE plumes have been observed to sink (or "dive").

(3) No disagreement here either. This is the second of the three mechanisms by which MTBE plumes have been observed to sink (or dive). The third mechanism can be referred to as "stratigraphically" or "structurally" induced. In this situation, preferential pathways that occur in the subsurface act as conduits that allow contaminants to migrate deeper into the aquifer than they might otherwise have were the aquifer composed of media that was homogeneous and isotropic.

(4) Absolute, 100 percent agreement with this statement, especially in the context of the article as a whole, which is that there is essentially no difference between an MTBE site and a BTEX site—both need a comprehensive, three-dimensional site characterization.

Conclusion: It's no myth. Curiously, the arguments made in the journal article fully support the observation that MTBE plumes *do* sink (or dive), thus this behavior is no myth. (Regardless of whether or not I agree with any of the other arguments presented in the journal article, I couldn't agree more with their statement: "…it is important to conduct complete, three-dimensional characterization of plumes…")

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■ **Myths** *from page 11*

MYTH #5: MTBE CAUSES CANCER

Main points: (1) "Several studies have shown the formation of tumors in animals exposed to high concentrations of MTBE."

(2) "However, there is some doubt about the relevance of these data to assessing the carcinogenicity of MTBE to humans and whether the doses are environmentally realistic."

(3) "Furthermore, human epidemiology studies failed to support the classification of MTBE as a carcinogen."

(4) "No national or inter-national regulatory agency has classified MTBE as a human carcinogen, and the available genotoxicity data suggest that MTBE is not mutagenic."

(5) "The weight of evidence suggests that ingestion of water [containing MTBE] below or close to the taste threshold is unlikely to result in adverse health effects.

(6) "…MTBE has been used to treat gall stones both in the UK and the US…"

Analysis: (1) Oddly, this first point succinctly refutes the argument that MTBE does not cause cancer—MTBE does cause cancer. Both benign and malignant (cancer) tumors have been observed in two animal species at multiple organ sites in long-term studies. Generally this is sufficient for a substance to be classified as a potential human carcinogen at the very least.

(2) The relevance of animal carcinogenicity studies to humans is always uncertain. But, in the world of toxicological testing, the use of animals under strict protocols is a necessity for a variety of reasons. First, and probably foremost, is that it's generally prohibitively expensive to use human subjects. It is also difficult to get human volunteers to be willingly exposed to substances that stand a chance of giving them cancer. Humans also live considerably longer than laboratory animals and the time required for cancer to manifest is generally a significant portion of the lifespan of an organism. To compensate, lab animals with shorter life spans are given higher doses of toxicants in the hope of inducing cancer in them before they would die naturally. So while it's easy to belittle animal studies, there are good reasons why they are conducted the way they are. The fact remains, MTBE is an animal carcinogen.

(3) While no known studies of human MTBE epidemiology have conclusively demonstrated that MTBE is a human carcinogen, neither have they removed all doubt as to whether or not it is in fact carcinogenic in humans. EPA presented cancer slope factors associated with MTBE in the 1997 publication: "Drinking Water Advisory: Consumer Acceptability Advice and Health Effects Analysis on MTBE." The National Science and Technology Council (NTSC) concluded that MTBE is an animal carcinogen and has carcinogenic *potential* for humans (National Toxicology Program 1998).

Considering the fact that the best possible (least likely to cause cancer) rating on the scale used by the International Association of Research on Cancer (IARC) is Group 4, which indicates that a substance is "probably not carcinogenic to humans," even extremely long-term studies are unlikely to completely vindicate MTBE or any other potentially hazardous chemical. Human studies take decades to complete, and the wise course of action in the interim is to assume that a chemical is dangerous rather than expose entire populations (especially our children) and wait to see what happens. Have our experiences with lead, arsenic, mercury, asbestos, cigarette smoke, coal dust, and silica dust (to name but a few) taught us nothing?

(4) The same points made in #3 apply here. But, the half of the story that is not being told is that such decisions are done by committee vote and that generally the votes are not unanimous—they're usually a narrow majority. For example, when the National Toxicology Program voted on whether or not to list MTBE as *reasonably anticipated to be a human carcinogen,* the final vote was six to five against listing after two subgroups split four to three in favor of listing and three to four against listing.

The fact that a committee as a whole has not supported a resolution declaring that MTBE is reasonably anticipated to be a *human carcinogen* obscures the fact that there is a great deal of disagreement about MTBE not being classified as a potential human carcinogen. Further, these votes have been against declaring that MTBE is a human carcinogen because there is insufficient evidence that it is positively a human carcinogen, not because there is evidence that MTBE is a noncarcinogen.

This is a very important distinction, as such rulings are a far cry from concluding that MTBE is noncarcinogenic. In fact, the body of data is sufficiently persuasive for some regulatory bodies. For example, the California Office of Environmental Health Hazard Assessment (OEHHA) concluded in March 1999 that the data on the carcinogenicity of MTBE were sufficient to propose a Public Health Goal (PHG) of 13 ppb for MTBE, based on the carcinogenic effects observed in animals. And, as indicated in the analysis of point #3 above, the NTSC has concluded that MTBE has carcinogenic *potential* in humans.

(5) It is unclear which taste threshold Woodward and Sloan are talking about here. Several studies have been conducted, and there has been a wide range of results. But, let's play it safe and assume that the taste threshold we're talking about is the one that Campden Food and Drink Research Association of Chipping Campden, England, conducted in 1993 at the request of Arco Chemicals.

This study (which only grudgingly became part of the public record as a result of the lawsuit that South Lake Tahoe Public Utility District recently won against the petroleum industry) established a taste threshold of between 0.04 and 0.06 ppb!!! That's right, *parts per billion!* This threshold is nearly three orders of magnitude lower than EPA's current drinking water advisory (which is based on policy, not science). So, I'd tend to agree with this point at face value—if concentrations in our drinking water are lower than 0.04 ppb, then there probably wouldn't be any adverse health effects.

But, I'm only comfortable with this concession if there is absolutely nothing else in the water. There have been no studies published that present incontrovertible evidence that small (even minute) amounts of MTBE (or any other potentially toxic chemical) in drinking water are safe to consume if any other potentially toxic chemicals are also present. Study of the toxic effects of mixtures has largely been ignored, and the data do not exist (at least not in the public record.)

(6) Whether the pure phase of an environmental contaminant has been used for medical purposes isn't really germane to this debate. Doubtless, countless examples could be presented where toxic compounds have been used (not wholly without risk) to remedy an ill that may be imminently debilitating (if not fatal) if not treated immediately. Obviously in such a case the mere chance of contracting cancer (or manifesting other long-term adverse effects) is greatly outweighed by the necessity of treatment with the potentially toxic substance.

Conclusion: It's no myth. MTBE is an *animal* carcinogen, and while there is disagreement over its classification as a potential human carcinogen, the best that can be said right now is that we just don't know for sure. But, in deference to the "precautionary principle," if a substance is known to cause cancer in animals, why in the world would human beings want to be unnecessarily exposed to it?

MYTH #6: MTBE IS A THREAT TO DRINKING WATER RESOURCES

Main points: (1) "Any chemicals, metals or other toxic substances are a potential threat to drinking water supplies…"

(2) "MTBE is not toxic to human beings."

(3) "The presence of MTBE in spilled or leaked gasoline does not increase the treat [sic] that the gasoline poses to drinking water resources."

Analysis: (1) General agreement with this point; however, any substance present in water can be considered to be a "contaminant." Whether or not the substance is a "pollutant" (and therefore a "threat") depends on the concentration and the question of whether the usability of the water has been diminished. The presence of any pollutant that renders a drinking water supply undrinkable for *any* reason is most certainly a threat. And even low levels of MTBE render water supplies undrinkable.

(2) This statement is false. MTBE exhibits quite a number of toxic effects on human beings; just check any Material Safety Data Sheet (MSDS) or EPA's Drinking Water Advisory (U.S. EPA 1997). Documented symptoms include irritation of the eyes, nose, and throat; dizziness; nausea; weakness; and potential kidney damage. The carcinogenic potential of MTBE in humans has not yet been definitively established. (See the discussion of Myth # 5.) Whether any of these effects will occur depends on the concentration, length of exposure, route of exposure, and sensitivity of the receptor. And, let's not ignore metabolites of MTBE; in particular TBA and TBF (*tertiary*-butyl formate). Both of these are toxic substances with known toxic effects on humans.

(3) This statement is also false. Let's look at it from two different perspectives: (a) water resources, and (b) drinking water supplies.

(a) MTBE has had an impact on water resources—both groundwater and surface water—at tens of thousands of sites nationwide. In fact, anywhere MTBE is detected in water in the environment is an impact (and not a positive one). At a significant number of sites, no gasoline constituent except MTBE has been detected. This is directly attributable to the properties of MTBE that enable it to move more rapidly through the environment than other non-ether gasoline constituents.

(b) Consider the financial impacts to drinking water supplies: conservatively hundreds of millions of dollars have been spent nationwide remediating and treating MTBE-contaminated groundwater. At all of the major, headline-grabbing MTBE cases (e.g., Santa Monica; Lake Tahoe; Long Island—too many sites to list; Pascoag, RI; and most recently Roselawn, IN) MTBE is the only significant contaminant detected in the drinking water.

The U.S. Geological Survey (U.S.G.S.) reported (2001) on the occurrence and distribution of MTBE and other volatile organic compounds in drinking water in the Northeast and Mid-Atlantic regions. From 1993 to 1998, MTBE was detected in nearly seven times as many drinking water supplies as was benzene. A recent U.S.G.S. study of 30 public water supplies in Delaware found four wells with benzene detections and 17 with MTBE detections. Two of the MTBE detections were above regulatory levels, but none of the benzene levels were above the MCL.

Conclusion: It's no myth. Clearly, the statement that MTBE in gasoline poses no additional threat to drinking-water resources is false.

MYTH #7: MTBE CAN'T BE REMEDIATED

Main points: (1) "MTBE responds to the same types of physical, chemical and biological treatment processes effective with other hydrocarbon contamination. Gasoline plumes containing MTBE can be managed by traditional approaches of hydraulic control, impermeable barriers, reactive barriers and excavation. The same *in-situ* chemical oxidation or bioremediation processes used for other hydrocarbons can destroy MTBE."

(2) "Indeed, the physical properties and resulting behavior of MTBE expedite remediation by conventional, physical processes. Classic treatment technology like pump and treat is particularly effective at removing MTBE from the saturated zone due to the high solubility, low Henry's constant and low adsorption coefficient of MTBE in groundwater. In the unsaturated zone, the low vapor pressure of MTBE makes soil vapor extraction (SVE) a particularly effective approach to removing the components of gasoline and MTBE."

(3) "A variety of processes including, air stripping, adsorption of activated carbon or resins, biological treatment and advance [sic] oxidation have been used to remove MTBE from groundwater brought to the surface."

Analysis: (1) As MTBE is seldom the remediation driver, it is often treated along with other petroleum constituents in systems designed for treatment of the other constituents alone. Of the four "traditional" approaches listed in the article as being effective in managing MTBE plumes, only one, reactive barriers, is anything more than a containment method, and it is hardly "tradi-

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■ **Myths** *from page 13*

tional." Permeable reactive barriers (PRBs) are cutting-edge science and the optimization of these systems for MTBE in all subsurface environments is a long way off.

There's no dispute that chemical oxidation and bioremediation (see also the discussion of Myth #8) may be effective in remediating MTBE contamination. The problem with bioremediating MTBE is the rate of the reaction and the question of whether it will be fast enough to achieve remediation objectives in a reasonable period of time. In many environments, even where the contaminant source has been removed, bioremediation can be expected to take years, even decades, to meet regulatory levels.

(2) These statements are deceiving, as almost all of MTBE's properties make it more difficult and expensive than BTEX to remediate, not easier and less expensive. While pump-and-treat may be very effective in pumping MTBE out of the ground (assuming that the plume is captured by the extraction wells), the process generates large volumes of groundwater that must be treated. Technologies that force MTBE out of the dissolved phase and into the vapor phase (e.g., air-stripping) generally require multiple passes through the system, plus off-gas treatment, and these expenses may significantly increase the overall cost of remediation. Let's look at how MTBE's properties would affect remediation costs in both the saturated and unsaturated zones.

In the saturated zone, the high solubility of MTBE is one of the primary reasons it creates such difficult (and expensive) groundwater remediation problems in the first place. MTBE plumes may be significantly larger than BTEX plumes, meaning a larger volume of water must be treated, and more wells will probably be required to capture the plume. MTBE's low Henry's law constant means that once dissolved in water, MTBE will tend to stay in the water—air sparging and air stripping are not nearly as effective for MTBE as they are for BTEX. And its low adsorptive coefficient means that although MTBE will move virtually unretarded through the subsurface, treatment by granular-activated carbon is much less cost-effective because MTBE exhausts carbon much more quickly than does BTEX, so the carbon must be changed more frequently.

In the unsaturated zone, the effectiveness of SVE is dependent upon properties other than just vapor pressure. If a release is acted on immediately, while it is still in the vadose zone, and if the vadose zone has relatively low soil moisture, then SVE can be very effective. But, MTBE's affinity for soil moisture and it's low Henry's law constant mean that MTBE will tend to dissolve quickly in soil moisture where it isn't as amenable to SVE. In fact, SVE performance is significantly reduced by high soil moisture.

(3) The term "removal" is misleading, as it is probably very rare indeed that contaminants are actually completely removed from groundwater as opposed to merely "reduced in concentration." For example, if a treatment system is 99 percent effective at "removing" MTBE, then to achieve a final concentration of 10 ppb, the influent water cannot have a concentration greater than 1 mg/L. As stated in #2 of this section, air stripping, adsorption, and biological treatment all have limitations. Advanced oxidation techniques may be highly effective, but some of them aren't without significant risk. For instance, use of Fenton's Reagent on gasoline releases has resulted in catastrophic explosions and loss of life. Advanced oxidation processes also generate degradation products (e.g., *tertiary*-butyl alcohol, *tertiary*-butyl formate, formaldehyde) whose toxicity is greater than that currently ascribed to MTBE.

Conclusion: It is a myth. MTBE *can* be remediated. However, the situation is not nearly as rosy as the journal article (and poster and seminars) would have one believe.

MYTH #8: MTBE DOESN'T BIODEGRADE

Main points: (1) "Increasing evidence is being found and reported on the biological natural attenuation of MTBE in gasoline contaminated aquifers."

(2) "While defined biodegradation pathways are predominantly aerobic, recent evidence indicates that some organisms indigenous to the subsurface can utilize MTBE as a carbon and energy source by reducing iron in the presence of humates or under methanogenic conditions."

Analysis: (1) No disagreement here. The body of literature supporting biodegradation of MTBE is indeed increasing in volume. This is not to say, however, that MTBE will biodegrade in every subsurface environment at a rate that is sufficient to achieve remediation objectives in a reasonable period of time. It is important to note that MTBE-degrading microorganisms are not nearly as ubiquitous as are BTEX degraders (Deeb and Kavanaugh 2002).

In some environments, MTBE biodegradation occurs very quickly, about as quickly as benzene biodegradation (this is usually in situations where the groundwater is sufficiently oxygenated such that oxygen is not the limiting factor). In other environments, the rate is so slow as to be almost nonexistent. The problem is that researchers are currently unable to predict *a priori* for any given environment whether MTBE biodegradation will be fast or slow. Such a determination can only be made in real time (*a posteriori*) and with *field data,* not laboratory data.

(2) There is no disagreement as to whether MTBE biodegrades anaerobically. Kolhatkar et al. (2000) studied MTBE (and TBA) plumes at 74 gas stations in the U.S. They found that natural biodegradation of MTBE could be demonstrated only under strongly anaerobic conditions (methanogenic with or without sulfate) but not weakly anaerobic/anoxic conditions (weakly methanogenic and sulfate available, or nitrate depleted and sulfate available).

This study also presents a compilation of MTBE biodegradation rates from the literature. It points out that MTBE biodegradation under iron-reducing conditions in the field is very slow, and biodegradation under sulfate-reducing conditions had not yet been demonstrated.

Deeb and Kavanaugh (2002) cite four more recent studies of anaerobic biodegradation under a variety of conditions. These studies support the observation that anaerobic biodegradation of MTBE is highly site-specific and that microorganisms capable of degrading MTBE in the absence of oxygen have not yet been cultured. Therefore, the mechanisms of anaerobic biodegradation have not yet been identified and hence can't be optimized until cultures have been isolated for study.

Conclusion: It is a myth. MTBE *is* biodegradable; however, not in all environments and not always at rates that are fast enough for remediation objectives to be met in a reasonable period of time or within a reasonable distance from the source so that receptors are protected.

MYTH #9: MTBE WON'T NATURALLY ATTENUATE

Main points: (1) "…the process of natural attenuation includes both destructive (mass reduction) and nondestructive processes. Destructive processes include biological degradation and abiotic chemical degradation. Nondestructive processes include dilution, adsorption, dispersion and volatilization."

(2) "Aerobic biodegradation of MTBE occurs when the concentration of other degradable substrates becomes limited and sufficient dissolved oxygen is present. Consequently, biologically based natural attenuation at the leading edge of the plume has been used to explain many mature, static plumes."

(3) "Recent investigations into biological degradation of MTBE under anaerobic conditions have verified biodegradation by ferric iron reduction in the laboratory and by methanogenic conditions…in the field."

Analysis: (1) For petroleum hydrocarbons, biodegradation is the most important (and preferred) attenuation mechanism because it is the only natural process that results in actual reduction in the mass of petroleum hydrocarbon contamination. Neither dispersion nor dilution are particularly effective since many documented MTBE plumes are several thousand feet in length and at concentrations that are high enough to cause adverse impacts on drinking water supplies. In the subsurface, there are no significant abiotic transformation processes for MTBE. MTBE does not sorb well to soil organic carbon nor mineral surfaces, and once dissolved into water it doesn't tend to volatilize readily, so neither of these mechanisms are very helpful *in-situ.*

(2) Aerobic biodegradation consumes available oxygen, resulting in anaerobic conditions in the core of the plume and a zone of oxygen depletion along the outer margins. The anaerobic zone is typically more extensive than the aerobic zone due to the abundance of anaerobic electron acceptors relative to dissolved oxygen (Weidemeier et al. 1999). For this reason, anaerobic biodegradation is typically the dominant process.

For both aerobic and anaerobic processes, the rate of contaminant degradation is limited by the rate of supply of the electron acceptors, not the rate of utilization of the electron acceptors by the microorganisms. As long as there is a sufficient supply of the electron acceptors, the rate of metabolism does not make any practical difference in the length of time required to achieve remediation objectives.

(3) So as not to reiterate, see the analysis of point #2 in myth #9. It is also extremely important to realize that laboratory-derived rates of biodegradation are almost never comparable to rates observed in the field. Almost without exception, laboratory rates are much higher, and estimations (or simulations) of the time required to reach remediation objectives should never be based on laboratory-derived rates.

Conclusion: It is a myth. However, this entire point is really a continuation of the preceding myth about biodegradability of MTBE. It is not a discussion of other natural attenuation mechanisms. And, in fact, biodegradation is the only significant natural attenuation process for MTBE in most subsurface environments.

MYTH #10: MTBE REMEDIATION COSTS SIGNIFICANTLY MORE THAN BTEX REMEDIATION

Main points: (1) "It is true that some gasoline spills and leaks were ignored in the past, but today all leaks and spills must be assessed and remediated."

(2) "…gasoline does not belong in groundwater."

(3) "Numerous case studies over the last few years have confirmed that the presence of MTBE in gasoline does not significantly impact the cost for assessment and remediation."

(4) "The site assessment, design and remediation – are generally independent of the gasoline components."

Analysis: (1) In theory anyway, this should be the case. But, the fact of the matter is that we're leaving ever larger masses of contaminants in the ground at increasing numbers of sites. And in many cases, site characterization data are too sparse, and of such poor quality, that the real magnitude of the problem at the site isn't adequately defined. Comprehensive three-dimensional site characterization hasn't been universally implemented and not all states routinely require appropriate sampling and analysis for MTBE (and even fewer for the other common oxygenates).

(2) I agree 100 percent with this point. The trouble is that UST systems do leak, and they will continue to leak. With a leak detection threshold of a mere 0.1 gallon per hour, a "tight" system could potentially leak about 900 gallons of fuel per year, which means about 50 to 135 gallons of MTBE would be released into the environment.

(3) One of the many factors affecting cleanup costs is target cleanup standards. In the survey that NEIWPCC conducted in 2000, 16 states that had (at that time) groundwater standards or cleanup and/or action levels for MTBE reported that MTBE had made a noticeable impact on the cost of remediation; seven of these states indicated that cost increases at some sites were 20 percent to more than twice as expensive. Of the 25 states that indicated that MTBE had no noticeable impact on the cost of remediation, 15 either had no cleanup standards for MTBE or didn't require analysis for MTBE. Undoubtedly the picture has changed somewhat over the past two years. More states have cleanup standards, action levels, or require analysis for MTBE (and other oxygenates).

(4) Hopefully, the days of long-screened, three- to four-well site characterizations are gone (and just as hopefully not simply replaced by

■ *continued on page 16*

■ **Myths** *from page 15*

the drive-by site/risk assessment). The presence of MTBE in groundwater has opened up our eyes to the fact that "conventional" monitoring wells are particularly poorly suited for three-dimensional site characterization. Far more data, and data analysis, are required to adequately characterize contaminant plumes, especially those made up of MTBE, which can be deeper and longer than previously envisioned for BTEX (although the vision of relatively well-behaved BTEX plumes is in serious need of "revision"). And, none of this is cheap. So, site characterization costs more, remediation costs more, and performance monitoring is generally required for a longer period of time and, hence, costs more. The bottom line is that dealing with MTBE plumes appropriately will cost more than dealing with BTEX plumes.

Conclusion: It's no myth. The assessment and remediation of an MTBE plume has the potential to cost significantly more than a BTEX-only plume.

MYTH #11: MTBE ALWAYS DRIVES REMEDIATION DESIGN, PROGRESS, AND COST

Main points: (1) "…remediation technology selection; progress and costs are very site specific."

(2) "Remediation progress and costs are primarily driven by the: A. Amount and duration of the release, B. Physical nature of the subsurface, C. Concentrations of the gasoline components in the soils and groundwater, D. Rates and direction of chemical migration, E. Nearest receptors and exposure pathways, F. Required cleanup objectives."

(3) "However, benzene, due to its toxicity, has driven progress and costs at some sites."

Analysis: (1) I agree 100 percent. This point is too often glossed over. It is folly to assume that, if the same type of remediation technology were implemented at multiple sites without first conducting comprehensive, three-dimensional site characterization, each of the systems would operate optimally. Remediation *is* site-specific.

(2) All of the listed factors certainly affect remediation costs. A couple of critical factors that are not on this list are contaminant "treatability" and system performance. If an inappropriate treatment technology is selected for a specific site, then it will operate inefficiently, if at all. The remediation time frame will be extended, and long-term performance monitoring costs will increase. Likewise, if the system isn't designed optimally for the site, it will operate inefficiently and ineffectively, thereby increasing the cost of remediation.

(3) According the NEIWPCC (2000) MTBE survey, 37 states indicated that BTEX and free product are the two factors that are their primary remediation drivers. However, 10 states indicated that MTBE drives remediation at greater than 20 percent of their LUST sites.

As more states establish action levels and cleanup levels or MCLs, this percentage will probably increase.

Conclusion: It is a myth, though perhaps only because of the word "always," which covers a lot of bases. It should also be noted that regulatory levels for MTBE in groundwater (and drinking water) have been decreasing, and that it is possible that MTBE *will* drive many more cleanups in the future, especially as more states adopt regulatory levels.

The Score

Now that we've analyzed each of the 11 myths, what's the score? I count 4 myths and 7 nonmyths. Thus, more than half of what Woodward & Sloan's article claims are myths, are, in fact, not myths. Or stated another way, the article presents "half-truths" and as a whole the article itself can, by definition, be considered a myth! Hmm, does that make it 12 myths? ■

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