Occurrence of MTBE and Other Volatile Organic Compounds in Community Drinking-Water Sources of the United States

Summary
by
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The large-scale use of the gasoline oxygenate methyl *tert*-butyl ether (MTBE) has resulted in its detection in ground water and surface water in many places throughout the United States. Studies by researchers, industry, water utilities, and local environmental agencies have discovered high concentrations of MTBE in soils and ground water at leaking underground gasoline-storage-tank sites and frequent occurrence of low to intermediate concentrations of MTBE in some reservoirs used for public water supply and recreational boating.

In response to these findings, the American Water Works Association Research Foundation sponsored an investigation of MTBE and other volatile organic compounds (VOCs) in the Nation's sources of drinking water. The Metropolitan Water District of Southern California in collaboration with the U.S. Geological Survey and the Oregon Health & Science University completed an investigation to determine the frequency of occurrence, concentration, and distribution of MTBE and 3 other ether gasoline oxygenates, their degradation products, and 62 other VOCs in source waters used by community water systems (CWSs) in the United States. All water samples in the investigation were collected prior to treatment and distribution to the public. U.S. Environmental Protection Agency approved Method 524.2 was used for VOC analyses. A research method was used to analyze ether oxygenate degradation products. Also, extensive laboratory and field quality-control samples were collected to further assure a high-quality data set.

The investigation was completed in two stages: (1) review of available literature for MTBE and (2) the collection of new data (Ivahnenko and others, 2001). Two literature reviews were completed. The first described the occurrence and concentration of MTBE in drinking-water sources based on studies that were national, regional, or state-sized in scope (Delzer and Ivahnenko, 2003a). Review of public and private water-supply assessments included 3 national, 2 regional, and 13 State studies. Collectively, these assessments indicated that MTBE had been detected in public and (or) private drinking-water supplies from ground- and surface-water sources in 36 States at concentrations ranging from 0.1 to 17,800 micrograms per liter (µg/L). However, MTBE concentrations generally were less than 20 µg/L and the median of detected concentrations, when available, was less than 5.0 µg/L. In addition, the review indicated that population density and reformulated gasoline use were significant risk factors for MTBE detection in water supplies. However, type of well, water supply, and proximity to gasoline storage tanks did not seem to be associated with MTBE detection. The second literature review (not contained in this distribution) summarized MTBE taste and odor studies (Dale and others, 1997). This review indicated that levels of MTBE ranging from 14 to 71 µg/L can cause an unpleasant aroma and flavor to water. This range is congruous with the U.S. Environmental Protection Agency's taste and odor consumer advisory of 20 to 40 µg/L.

Two surveys to collect new water-quality data were conducted. The surveys sampled wells, springs, galleries, rivers, aqueducts, canals, lakes and reservoirs. The first survey, termed the Random Survey, employed a statistically stratified design for sampling source waters from randomly selected CWSs (Grady, 2003). The general intent of the Random Survey was to ascertain the concentration of VOCs in ground-water versus surface-water source waters, and to determine if the detection of VOCs differed by the size of the CWS. The design also considered the ability to extrapolate results to obtain national estimates. Source waters of 954 CWSs were sampled during 1999-2000.

The second survey, termed the Focused Survey, sampled 134 CWSs source waters during 1999-2001. The source waters sampled in the Focused Survey were biased to locations where MTBE and other gasoline components were suspected or known to occur. The general intent of the Focused Survey was to: (1) compare occurrence results with the Random Survey, (2) sample additional CWSs in MTBE high-use areas, and (3) provide information on temporal variability and anthropogenic factors associated with MTBE and other frequently detected VOCs (Delzer and Ivahnenko, 2003b). Some samples in the Focused Survey also were analyzed for *tert*-butyl alcohol, *tert*-butyl formate, *tert*-amyl alcohol, and other ether oxygenate degradation products. Results for these ether oxygenate degradation products are presented elsewhere (Koch and others, 2003).

Random Survey Findings

A total of 42 of 66 VOCs analyzed were detected at or above a reporting level of 0.2 µg/L. Twenty-seven percent (257 of 954) of source-water samples contained at least one VOC and concentrations were generally low; 95 percent of the samples had concentrations less than 10 µg/L. Chloroform, a trihalomethane (THM), was the most frequently detected compound occurring in 13% of source waters followed by MTBE in 8.7% of source waters. Proportionally, slightly more surface-water samples (30 percent) than ground-water samples (25 percent) contained VOCs. Gasoline compounds collectively (as well as MTBE alone) were detected significantly more often in surface water (15 percent) than ground water (6.6 percent), whereas, the opposite was true of solvents and refrigerants. The more frequent occurrence of MTBE in surface water (14 percent) than in ground water (5.4 percent) is likely related to emissions, leaks or spills from motorized watercraft.

The detection frequency of most VOCs was significantly related to urban land use and population density. For example, detections of MTBE, gasoline hydrocarbons as a group (i.e. benzene, toluene, ethylbenzene, and xylenes), and any specific gasoline hydrocarbon were significantly greater in areas with more than 60% urban land use and (or) a population density greater than 1,000 people per square mile, than elsewhere. Furthermore, MTBE detections were five times more frequent in source waters from MTBE high-use areas than elsewhere. Interestingly, and in agreement with the results of the literature review, MTBE detections did not appear to be related to the density of gasoline storage tanks near drinking-water sources.

Focused Survey Findings

A weak seasonal pattern was observed in samples collected from reservoirs and lakes. Gasoline oxygenates and gasoline hydrocarbons were detected more frequently during the spring and summer. In contrast, seasonal patterns were not observed for these two gasoline contaminant groups in rivers and streams. Also, there were no statistical differences in comparing concentrations in ground-water samples, collected approximately 6 months apart. Explanatory analysis indicated that the concentration of ether gasoline oxygenates was slightly correlated with watercraft use on reservoirs inside MTBE high-use areas (r^2=0.3783), but not outside these areas (r^2=0.042). In general, the concentration of gasoline oxygenates increased as watercraft use increased.

Finally, THMs, commonly referred to as disinfection by-products because they occur in drinking water that has been treated with chlorine, were detected in about 30 percent of reservoir samples with no significant seasonal trend identified. The lack of any substantial trend suggests the possibility of a common and continuous source of contamination for these compounds. In all cases, it was determined that the presence of THMs was the result of chlorinated waters that ultimately were recycled back to, or upstream of, the reservoir that was sampled.

References

Dale, M.S., Moylan, M.S., Koch, Bart, and Davis, M.K., 1997, Taste and odor threshold determinations using the flavor profile method: Proceedings of the American Water Works Association Water-Quality Technology Conference, Denver, Colorado.

Delzer, G.C., and Ivahnenko, Tamara, 2003a, A review of literature for methyl *tert*-butyl ether (MTBE) in sources of drinking water in the United States: U.S. Geological Survey Open-File Report 01-322, 16 p.

------2003b, Occurrence and temporal variability of methyl *tert*-butyl ether (MTBE) and other volatile organic compounds in select sources of drinking water -- Results of the focused survey: U.S. Geological Survey Water-Resources Investigations Report 02-4084, 65 p.

Grady, S.J., 2003, A national survey of methyl *tert*-butyl ether and other volatile organic compounds in drinking-water sources -- Results of the random survey: U.S. Geological Survey Water-Resources Investigations Report 02-4079, 85 p.

Ivahnenko, Tamara, Grady, S.J., and Delzer, G.C., 2001, Design of a national survey of methyl tert-butyl ether and other volatile organic compounds in drinking-water sources: U.S. Geological Survey Open-File Report 01-271, 42 p.

Koch, Bart, Dale, M.S., Zogorski, J.S., Delzer, G.C., Grady, S.J., Ivahnenko, Tamara, Clawges, R.M., and Tratnyek, Paul, 2003, Occurrence of MTBE and VOCs in drinking water sources of the United States: Denver, Colorado, American Water Works Association Research Foundation, 189 p.