HOW CAN WE IMPROVE Air Pollution Control?

We as a society should keep these lessons in mind as we set future environmental goals, policies, laws and regulations.

Herbert C. McKee,
Environmental Consultant

Sometimes the nation's political desires get ahead of the scientific knowledge and the technology available to satisfy those desires. Environmental standards have been set based on desirable goals, but even after years of continual progress, some of these goals have not been met.

Two such situations involve the ambient air quality standard for ozone and the blending of methyl tertiary butyl ether (MTBE) into gasoline. In 1970, the Clean Air Act established National Ambient Air Quality Standards that were to be attained in seven years. Today, however, Los Angeles, Chicago, Houston, New York, and many other urban areas are still working to attain the ozone standard. Ozone has been reduced over the past 30 years, but attaining the strict federal standard still seems like a distant goal. In the case of MTBE in gasoline, the failure to use the available knowledge led to the formation of questionable policies.

If we do not understand history, we are doomed to repeat it. Perhaps our 20/20 hindsight over the past three decades will give us clues to help us do a better job in the future, not only regarding ozone but other air-pollution problems as well (such as the new standard for small particulates). This article outlines some important lessons learned from the ozone and MTBE experiences. It is not intended as a criticism of the people or agencies involved in the early decisions and programs — they did the best they could with the knowledge and tools available at the time. Fortunately, both scientific knowledge and control technology have improved greatly over the years (although there are still serious limitations). But we need to learn from history if we hope to make the most of those advances.

Ozone nonattainment

Over the past 50 years, probably more money and effort have been spent to control ozone than on all other air-pollution problems combined. Our mediocre success so far is due in part to one aspect of this very complex problem.

Ozone is formed in urban atmospheres by reactions of two classes of contaminants: volatile organic compounds (VOCs), including emissions from industrial processes, vehicles, solvent evaporation, neighborhood service stations and many other sources; and oxides of nitrogen (NO_x), generated primarily by combustion processes such as those found in power plants, industrial boilers and motor vehicles. Significant ozone formation also requires sunlight to catalyze the reactions and a relatively stagnant atmosphere to provide several hours of reaction time before the precursors (VOC and NO_x) disperse.

In the 1970s, scientific knowledge about ozone photochemistry was meager. The state regulatory agencies charged with developing State Implementation Plans had a big problem — there was no way to select the necessary control strategies to attain the ozone standard based on any reliable scientific evidence. No wonder the standard was not attained by 1975 or 1977, as the law then required!

There has always been some uncertainty about which category of precursor to control — VOCs, NO_x, or some combination of both. EPA's instructions to the states in 1971 were to control VOCs; NO_x control was not considered important.

Decisions were made on the basis of those instructions, and tremendous resources were expended on VOC control for about 25 years, with very little effort to reduce NO_x. VOC emissions were reduced dramatically, but the reduction in ozone levels was proportionately far less. These disappointing results left many areas far short of attaining the standard. As Congress and EPA began work on what became the Clean Air Act Amendments of 1990, approximately 100 urban areas still exceeded the ozone standard — many by a significant margin. Mandatory attainment deadlines came and went, only to be extended — 1975, 1977, 1982, 1987, and now, a sliding scale based on the severity of the ozone problem in each urban area. For example, the deadline for Los Angeles, which has been designated as an extreme nonattainment area, is 2010, while for cities that are severe nonattainment areas the deadline is 2007 or 2005.

As early as 1960, a few biologists occasionally asked about vegetation. Plants emit various organic compounds as a natural part of the photosynthesis process. Could these materials change the conventional understanding about the roles of VOC and NO_x as ozone precursors? Usually, the question got little attention and the answer was a quick "no." But by the early 1990s, enough people had looked at this issue to propose an important hypothesis, which was confirmed by further work and study. In many urban areas, the so-called biogenic emissions (*i.e.*, those of natural origin) were a major part of the total VOC inventory for the area (60%–70% for some areas).

Furthermore, computer modeling indicated that even the complete elimination of all VOC emissions from human activities in some areas would not result in attainment of the ozone standard. If those computer projections were accurate, a strategy involving only VOC reduction would *never* lead to attainment of the standard!

So, after many years of emphasizing VOC control, NO_x control suddenly became the major focus of regulatory action. Many agencies are now developing and starting to implement comprehensive plans to require major NO_x reductions. Of course, we don't have another 30 years — the latest deadline, for Los Angeles, is now just nine years away.

It is easy now to see that a few research projects on biogenic emissions during the 1970s could have made a tremendous difference. That would have made it possible to maintain a better balance between VOC reductions and NO_x reductions over the past two decades or longer. No doubt that would have reduced by many years the total time required to attain the ozone standard, with cost savings to the public that would have run into many billions of dollars.

In the past, scientists have occasionally reminded us that we need to understand the underlying science before a lot of money and effort are expended on control programs. The ozone nonattainment example proves the wisdom of that statement.

MTBE in gasoline

During the 1980s, some people thought that our progress in building cleaner and cleaner cars was reaching a plateau and that further significant advances were unlikely. (That soon proved to be wrong.) Attention then shifted from the vehicles to the fuel, to see if cleaner-burning gasoline and diesel fuel would help reduce ozone and clean up the air. In the 1990 Clean Air Act Amendments, Congress included two major initiatives based on that concept:

• oxygenated gasoline, intended to reduce emissions of carbon monoxide (gasoline suppliers were required to add 2.7% oxygen to gasoline, in the belief that this would reduce the incomplete combustion that resulted in a higher CO content in the exhaust)

• reformulated gasoline, intended to reduce ozone formation by reducing some of the gasoline constituents that are highly reactive in forming ozone (the addition of a smaller amount of oxygen, 2.0%, was required).

Several oxygen-containing organic compounds compatible with gasoline were investigated as candidates to supply the necessary oxygen. The most suitable appeared to be MTBE and ethanol, but several factors made it difficult to make a clear choice. Among these factors was political pressure from the grain-growing states in favor of ethanol. However, ethanol/gasoline mixtures have a higher vapor pressure, causing a greater loss by evaporation and a presumed increase in VOC emissions and therefore ozone. MTBE has been the favorite, but some suppliers chose ethanol because of political preferences or a lower cost unique to a particular location.

After the oxygenated gasoline requirement went into effect, a few complaints about odor and other potential problems with MTBE were heard, but most of these subsided and MTBE use continued. But in 1999, the governor of California banned the use of MTBE, to be effective as soon as substitutes could be provided. The reason had nothing to do with air pollution. Rather, it was found that MTBE had contaminated numerous water wells because it had leaked from underground gasoline storage tanks into groundwater.

A little more prior study and evaluation could have prevented these problems, for two reasons. First, adding oxygen to gasoline made sense in the 1980s, when most cars on the road had mechanical carburetors to control the air/fuel ratio and mechanical distributors to regulate spark timing. But by the time the 1990 Amendments were passed, new cars were being equipped with fuel injection and much-more-precise computerized control systems. They also had oxygen sensors in the exhaust line with a feedback control system. Oxygen added to gasoline causes the computer to compensate by reducing the air/fuel ratio, so, with or without oxygen in the gasoline, the computer is going to do its best to operate the engine exactly according to the instructions in the software. Today's technology is said to be highly efficient in doing just that.

Second, organic compounds with oxygen in the molecule are likely to have a higher water solubility than hydrocarbons. The possibility of groundwater contamination with MTBE should have been suspected from the beginning.

In this case, knowledge was available concerning the use of MTBE, and this knowledge should have been considered before policy decisions were implemented. The reasons for adding oxygen to gasoline no longer applied by the time such action became mandatory. Of course, if a gasoline supplier chooses to use MTBE or other oxygenates to increase octane or for some other reason, this can be done safely, since comprehensive EPA regulations to control leaks from underground storage tanks became fully effective in 1998.

Further Reading

Numerous publications have appeared concerning ozone and other contaminants produced by photochemical processes in urban areas. Many of these are limited in scope. One of the best overall reviews is the following report: National Research Council, "Rethinking the Ozone Problem in Urban and Regional Air Pollution," National Academy Press, Washington, DC (1991). Even though it is now ten years old, it provides excellent detailed information on many factors involved in ozone and related problems. This was one of the first publications to identify the uncertainty about VOC vs. NO_x control as a major factor that had been largely overlooked up to that time. For those interested in less detail, the executive summary and the summaries at the end of each chapter can provide useful information.

Ozone problems vary widely among different urban areas. The best source of information for a particular area is likely to be the state regulatory agency, or a regional council of governments or similar organization.

A great deal of useful information can be found on the U.S. EPA's website at www.epa.gov.

This article is based on a paper presented at the AIChE Spring Meeting, Houston, TX, Apr. 22–26, 2001, which can be found in "Proceedings of the Houston Air Quality Topical Conference."

Conclusions

I believe several conclusions should be kept in mind as we plan additional steps to meet the current ozone standard, expand our ozone control programs to comply with the new 8-h standard, evaluate small particles ($PM_{2.5}$), and do whatever else may be dictated by future scientific knowledge and legislative mandates. Others may have different ideas. But there is no indication that air-pollution control experts are about to work themselves out of a job. Future meetings and discussions will help us all do a better job so that we can meet the public's demand to continue improving air quality. Here are some of my ideas.

We need to understand the underlying science before major commitments of money and effort are made to implement new programs. This has been said before, but often disregarded. It is obvious and requires no further discussion here.

The mandatory attainment deadlines in the federal Clean Air Act appear to have been counterproductive. The public has been misled by Congressional promises (in the form of laws) to clean up the air within a few years. People feel betrayed by the many promises that were not fulfilled. But every atmospheric chemist I knew in the early 1970s laughed at the idea of eliminating such a complex problem in five or six years, when none of them understood much about the basic atmospheric chemistry involved.

Incidentally, the standard then was 80 ppb, 1-h average, a concentration so close to natural background that many said it would never be achieved in a large urban area. Even after the standard was changed in 1978 to the current 120 ppb, 1-h average, some were speculating that it would take 20 to 30 years to attain that.

The mandatory deadlines also make it more difficult to justify the long-range research that is necessary for major new innovations. The previous 5-, 7- and 10-yr deadlines left most companies scrambling to find quick solutions that could be implemented in a few years. Consequently, many changes were not major improvements, but rather incremental improvements to well-established technologies. That rush to find quick solutions eliminated some of the opportunities for long-range research and development that eventually could have provided much better solutions.

Looking back with a 30-yr perspective, the cleanest cars and the most-effective industrial controls have resulted from cumulative successes achieved over two or three decades. During that time, mandatory deadlines followed one another in quick succession, with little effect on the ultimate outcome.

The Clean Air Act requires EPA to set National Ambient Air Quality Standards at levels that will eliminate all adverse health effects and then add a factor of safety. That's a noble goal, requiring a high degree of perfection. There's certainly nothing wrong with setting high goals. But this one was tied to short deadlines to achieve a goal for a problem that no one knew how to solve.

Looking back with a 30-yr perspective, the cleanest cars and the most-effective industrial controls have resulted from cumulative successes achieved over two or three decades.

This is analogous to adopting a law that requires the medical profession to absolutely, positively cure all cases of cancer by 2005. As desirable as that would be, most people understand that the medical profession doesn't know enough about the causes of cancer and its treatment to be able to accomplish that goal.

The public is influenced by many misunderstandings regarding air-pollution problems. Most environmental problems are too complex for the average citizen to understand based only on 10-second sound bites. Scientists and engineers need to learn to communicate better outside their professional groups. Perhaps then we would see fewer simplified news stories, such as pictures or TV clips incorrectly showing plumes of steam condensate used to illustrate stories about air pollution.

Concerning the steam plumes, I once asked a TV reporter if he knew that the big discharge shown coming out of a stack was harmless water from condensing steam. His reply was "Oh sure, we know that, but this is television. We have to have something moving or some kind of action to get the viewer's attention." I don't think I convinced him that this is misleading to his viewers, causing them to reach erroneous conclusions about air pollution.

Perhaps steam plumes aren't the most serious problem of miscommunication, although they're an obvious one that I consider important. I believe that chemical engineers, and all environmental professionals, have a professional and ethical obligation to try to improve the public's understanding any time there is an opportunity. CEP

HERBERT C. McKEE, PhD, (8010 Neff St., Houston, TX 77036; Phone: (713) 774-7127) is a chemical engineer with over 40 years of experience in the environmental control field. In the private sector, he has extensive experience in research and consulting on many topics dealing with air pollution and other environmental problems. In the public sector, he served as Chairman of the Texas Air Control Board (the state regulatory agency at that time) and later as Assistant Health Director for the City of Houston, where he directed the city's environmental regulatory programs. He holds a BS in chemistry and mathematics from Muskingum College, and MS and PhD degrees in chemical engineering from Ohio State Univ. He is active in AIChE and other professional associations and also teaches part time at Rice Univ. (Houston, TX).