ENVIRONMENTAL AND ECONOMIC IMPLICATIONS OF OXYGENATED GASOLINE USE IN COLORADO: COLORADO'S OXYGENATED GASOLINE PROGRAM

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Abstract

Starting in the winter of 1987-1988, Colorado instituted an oxygenated gasoline program to control winter-time carbon monoxide emissions from motor vehicles. As a result of this and other air quality programs, as well as fleet turn over, the number of days exceeding the federal carbon monoxide standard has been reduce from 32 days in 1986 to 5 days in 1992.

The Colorado Department of Health estimates that for the winter of 1992-1993, carbon monoxide emissions from motor vehicles were reduced by 25% on a fleet wide basis. This reduction is credited with preventing a possible four additional high pollution days from occurring. The use of these gasolines increased the cost of gasoline in the Denver area by 3.5 cents per gallon.

Introduction

The Front Range area of Colorado is subject to numerous carbon monoxide (CO) high pollution episodes each winter. These are produced by the interaction of cold temperatures, temperature inversions, and carbon monoxide emissions from gasoline powered automobiles and trucks, as well as from residential wood burning and other sources. Of the total CO emissions, mobile sources contribute approximately 85%.

Elevated carbon monoxide concentrations occur on calm winter days, when temperature inversions develop which inhibit the dispersion of carbon monoxide produced from motor vehicle traffic and residential wood burning. Exceedances of the federal eight hour CO standard may result, especially in low laying, high traffic volume areas, such as downtown Denver.

As one of several strategies aimed at reducing motor vehicle CO emittions, the Colorado Department of Health (CDH) instituted an oxygenated gasoline program beginning in the winter of 1987-1988. Implementation of this program resulted from a comprehensive vehicle mass emissions test program conducted by the CDH in the 1980s.

Vehicle Mass Emissions Testing

Beginning with vehicle mass emissions testing in the late 1970s by the U.S. EPA, and soon after, by the Colorado Department of Health, it was noted that gasolines blended with alcohols, such as ethanol and methanol, produced lower carbon monoxide emissions than non-blended gasolines (1,2). Later testing involving methyl tert-butyl ether (MTBE) blends produced similar results (3).

The test method used in this program is a mass-emissions test called the Federal Test Procedure (FTP). It is used by the U.S. EPA to certify emissions for new model light duty cars and trucks. In this test, a vehicle is placed on a dynamometer and is driven over a simulated driving cycle lasting 1372 seconds. Vehicle emissions are collected during this period, and the mass of these emissions are determined. The driving cycle involves both cold and hot vehicle starts, accelerations, decelerations, and steady cruise conditions, designed to simulate a typical urban commute.

Analyzing mass emissions results from these tests indicated that fuel oxygen content, rather than the particular oxygenate, was the most important parameter in producing carbon monoxide changes. In determining this effect, the CDH examined both linear and logarithmic relationships to correlate the mass emissions database (4). For the logarithmic models, both positive as well as negative curves could be fitted to the data, depending on the individual study analyzed. Because of the differences in curvatures, as well as because the linear model fit equally as well as the logarithmic models, a linear model has been adopted in describing the CO effect of using oxygenated gasolines. Table 1 describes the CDH carbon monoxide FTP mass emissions results using the linear model, averaged for oxygen content, and differentiated by vehicle emissions control technology class.

The U.S. EPA and other organizations have also conducted mass emission test programs which have corroborated and expanded upon the CDH mass emissions testing. In the latest study, the Auto/Oil Air Quality Improvement Research Program, fuel composition parameters, including oxygen content, have been varied to study emissions effects (5). Again, directionally, increasing oxygen content was found to reduce carbon monoxide emissions.

CO Vehicle Emission Reductions

In analyzing the CO vehicle emission reduction of oxygenated gasolines, the CDH relies on the U.S. EPA MOBILE vehicle emissions model. Employing this computer model, vehicle emissions from an area's motor vehicle fleet can be averaged and estimated. This model takes the CO emission reductions seen in the FTP mass emissions testing, and applies it across the entire motor vehicle fleet, and under different driving conditions. Inputs to the model include: vehicle age and distribution, speed, road type, time of day, and area type.

Utilizing the present MOBILE 5a emissions model, the CDH estimates that in the winter of 1992-1993, carbon monoxide exhaust emissions from motor vehicles, in the Front Range area, were reduced by 26.6% in October and November, and by 24.9% in January and February (6). Reductions in ambient CO concentrations are less, since mobile sources are not the sole source of CO emissions, and concentrations are dependent on the rates of production and dispersion.

Contributing to the effectiveness of the 1992-1993 program was the increased percentage of ethanol blended gasoline sold along the Front Range area. Ethanol blends made up 45% of the total gasoline sales of this winter, compared to 20% the winter before. When blended at the 10% vol. level, ethanol blends have a higher oxygen content than 15% MTBE blends (3.5% vs. 2.7% wt.). A higher oxygen content produces a greater average CO reduction. 15% vol. MTBE blends constituted the balance of the oxygenated gasoline sold.

During the winter of 1992-1993, the average oxygen content of the Front Range gasoline pool was 3.0% percent in November and December, dropping to 2.8% for January and February, when a new I.R.S. ruling took effect, permitted the blending of ethanol at a reduced level (7.8% vs. 10% vol.).

Air Quality

In terms of ambient air quality, there were five exceedances of the 9ppm eight-hour average national ambient air quality standard (NAAQS) for CO in the winter of 1992-1993. An additional four possible exceedances were prevented because of the use of oxygenated gasolines (6). Figure 1 documents the daily 8-hour maximum reading for the winter of 1992-1993. The lower clear bar represents monitored values. The solid dark bars represent estimated concentrations, if oxygenated gasolines were not used.

For the calendar year 1992, there were five days exceeding the NAAQS 8-hour average CO standard, a declined from 32 days in the calendar year of 1986. The continuing reduction in CO exceedances as shown in Figure 2, is due to a continuing decline in CO emissions due to fleet turn over, the use of oxygenated gasolines, vehicle inspection and maintenance programs, and no woodburning on high pollution days, as well as favorable weather conditions.

Costs

The Colorado Department of Health analyzed the costs associated with the 1992-1993 oxygenated gasoline program. The costs of base gasoline, oxygenates, transportation costs, as well as octane and butane credit savings were examined to determine oxygenated gasoline costs. These were then compared to the differential costs observed between oxygenated and non-oxygenated gasolines Denver RACK prices received from the Oil Price Information Service. Retail prices were also observed.

For the winter of 1992-1993, the average cost of gasoline increased by three and a half cents per gallon because of the Oxygenated Gasoline Program (6), a similar amount as for previous season's program. This cost represents increased refiner and blender costs due to oxygenate blending and does not take into account any changes in vehicle fuel economy.

While the average cost associated with blending oxygenates remained the same as the previous winter, the cost of gasoline blended with ethanol rose slightly. Average program costs remained similar to the 1991-1992 season however, because the market share for ethanol blends increased, and ethanol blended gasoline costs remained below MTBE blended gasoline costs (2.75 cents/gal. vs 3.75 cents/gal.).

Supplies

This year over 360 million gallons of oxygenated gasoline were sold along the Front Range during the oxygenated gasoline program period (November 1, 1992 through February 28, 1993). Statewide, over 500 million gallons of gasoline (much of it oxygenated) was sold during this period.

Fuel Economy

Oxygenated gasolines have a small affect on fuel economy at high altitude. CDH fuel economy testing conducted during vehicle mass emission FTP testing, has shown on average, fuel economy reductions of up to 1.5% for some vehicle classes to slight increases of less than 1.0% for other motor vehicle classes.

Oxygenated gasolines lean the air to fuel ratio of a vehicle, increasing the engine's efficiency and in some older vehicles slightly improving fuel economy. Oxygenated gasolines have a slightly lower heating value though, which may decrease fuel economy in some vehicles, especially vehicles equipped with the latest oxygen sensors and feedback fuel injection. Altitude and the partial pressure at Denver (5280 feet) may also lessen fuel economy impacts of oxygenated gasolines. Table (2) gives CDH high altitude fuel economy test results for three types of emission control technologies, using 11% and 15% MTBE blends, and 10% ethanol blends.

Conclusions

Based on mass emissions testing, using the Federal Test Procedure, oxygenated gasoline have been demonstrated to decrease carbon monoxide emissions from gasoline powered motor vehicles. This decrease is related to oxygen content, and varies according to vehicle emission control technology class and vehicle operating modes. For the FTP, based on a linear oxygen effect, oxygenated gasolines decrease exhaust CO emissions by 4.83% to 6.45% for each one percent oxygen content, by weight, the gasoline contains.

Using the U.S. EPA MOBILE 5a motor vehicle emissions model, the CDH estimates that carbon monoxide emissions were reduced by 24.9 to 26.6% in the winter of 1992-1993. As a result of this and other air quality programs, as well as fleet turn over, the number of days exceeding the federal carbon monoxide standard has been reduce from 30 days in 1986 to 5 days in 1992. The use of these gasolines increased the cost of gasoline in the Denver area by 3.5 cents per gallon.

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TABLE 1

CDH MASS EMISSIONS RESULTS

AVERAGE PERCENT CARBON MONOXIDE REDUCTION BY VEHICLE EMISSION CONTROL TECHNOLOGY CLASS AND OXYGEN CONCENTRATION

Vehicle Emissions Control Technology Group	2.0% Oxygen by wt. (11% MTBE)	2.7% Oxygen by wt. (15% MTBE, 7.8% ethanol)	3.5% Oxygen by wt. (10% ethanol 5% methanol)	1.0% Oxygen by wt.
Pre-Catalytic Converter	12.84%	17.33%	22.47%	6.42%
Two-way Oxidation Catalytic Converter Equipped	12.90%	17.4%	22.58%	6.45%
Three-way, Closed-loop, Catalytic Converter Equipped	9.66%	13.04%	16.91%	4.83%

Figure 1

Winter-time CO Concentrations
With and Without Oxygenated Gasoline

(8-HR DAILY MAX)

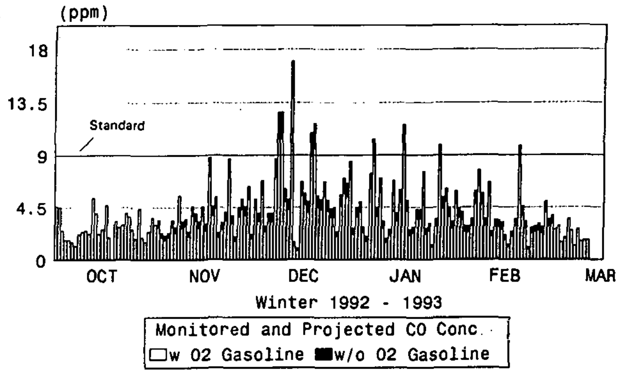

Figure 2

Colorado CO Exceedances

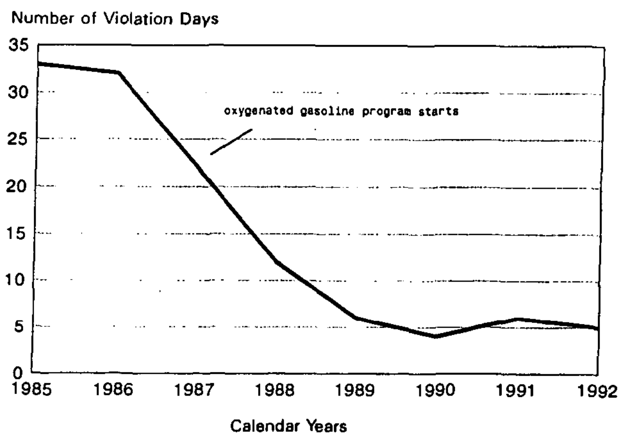

TABLE (2) FUEL ECONOMY EFFECTS			
VEHICLE TECHNOLOGY	CDH FTP Measured Fuel Economy Change		
	11% MTBE	15% MTBE	10% ethanol
Non-Catalyst	+0.82%	+0.21%	+0.11%
Catalyst	+0.84%	+0.18%	+0.33%
Closed Loop	+0.7%	-1.13%	-1.41%