United States General Accounting Office

GAO

Report to the Chairman, Subcommittee on Oversight and Investigations, Committee on Energy and Commerce House of Representatives

December 1985

AIR POLLUTION

EPA's Strategy to Control Emissions of Benzene and Gasoline Vapor

About Our New Look . . .

This GAO report was produced using a new design and printing process to help you get the information you need more easily.

GAO is phasing in this new design. As we do so, we welcome any comments you wish to share with us.

GAO

United States
General Accounting Office
Washington, D.C. 20548

Resources, Community, and
Economic Development Division

B-221037

December 18, 1985

The Honorable John D. Dingell
Chairman, Subcommittee on Oversight
and Investigations
Committee on Energy and Commerce
House of Representatives

Dear Mr. Chairman:

As requested in your letter of January 5, 1984, and subsequent discussions with your office, this report discusses the Environmental Protection Agency's (EPA's) decision to regulate benzene emissions, including its plans to regulate benzene emitted during automobile refueling. The report also discusses several other factors affecting EPA's decision to regulate benzene emissions from automobile refueling, including the health effects of gasoline vapor and EPA's ozone standard.

As arranged with your office, unless you publicly release its contents earlier, we will make this report available to other interested parties 30 days after its issue date. At that time copies of the report will be sent to appropriate congressional committees; the Administrator, EPA; and the Director, Office of Management and Budget.

Sincerely yours,

J. Dexter Peach
Director

Executive Summary

Nearly everyone in the United States is exposed to benzene, a toxic chemical emitted from automobiles, trucks, refineries, and steel and chemical plants. Benzene is also one of a group of pollutants called hydrocarbons which contributes to the production of ozone and other constituents of smog.

In 1977 the Environmental Protection Agency (EPA) identified benzene as a hazardous air pollutant, and in December 1983 EPA announced its decision on how best to control benzene emitted from certain chemical and steel plants. EPA has identified automobile refueling as a source of benzene emissions and, as of October 1985, was continuing to study how best to control these emissions.

The Chairman, Subcommittee on Oversight and Investigations, House Committee on Energy and Commerce, requested that GAO determine

- the basis for EPA's December 1983 decision to control benzene emissions from chemical and steel plants and
- EPA's plans to require control of benzene and other pollutants that are emitted during automobile refueling.

Background

The Clean Air Act requires that EPA identify hazardous pollutants and develop regulations to control their presence in the environment. These regulations are to provide an "ample margin of safety" to protect the public health. Benzene is the first hazardous air pollutant for which EPA has issued final standards since 1976.

EPA based its December 1983 benzene decision primarily on risk assessments that evaluated the relationship between benzene exposure and the potential occurrence of leukemia. EPA focused on leukemia because health studies have documented an association between it and benzene exposure. In its assessments, EPA evaluated data on health effects, industry emissions, and the populations that live near five types of benzene sources (called "source categories"). EPA then ranked the relative risks and concluded that two of the five "source categories" presented significant risk to the public.

GAO reviewed each component of the EPA benzene risk assessments to determine how they were developed and what uncertainties are associated with each component. EPA officials told GAO that, although the risk estimations are uncertain, it is important that they be as accurate as possible to ensure public acceptance of the estimates.

On the issue of regulating automobile refueling emissions, EPA is considering two options for regulating benzene and other pollutants—controls on gasoline pumps or controls on automobiles. This decision is important to states because refueling vapor-recovery controls could help states meet ozone standards by the congressionally mandated 1987 deadline.

Results in Brief

The risk assessments upon which EPA relied in its December 1983 decision did not use the most current health and census data available at that time, and EPA's verification of benzene emission data was limited. EPA officials who developed the assessments explained that (1) they used their professional judgment in deciding what data to include and verify, (2) they were not aware if certain data were available, and (3) there was no written agency guidance on how its risk assessments are to be developed, although EPA's air office plans to develop such guidance in 1986. EPA has determined that the more current and accurate data would increase its risk estimates but would not change its decision on which benzene "source categories" to regulate.

In late 1985 or early 1986, EPA plans to decide how best to control automobile refueling emissions. EPA's plans will be based on a decision as to whether nationwide or local controls should be implemented. Controls on automobiles would be implemented nationwide. Controls on the gas pump could be applied either nationwide, or only in those areas not in compliance with EPA's ozone standard. EPA estimates that more than 2 years will be required for implementing either of these options. As a result, EPA's decision will probably be too late to contribute to the states' attainment of the national ozone standard by 1987.

Principal Findings

EPA's December 1983 Decision to Control Benzene

The risk assessments EPA used in its December 1983 decision estimated that, given certain assumptions, emissions from the five benzene "source categories" would result in an increased risk of leukemia ranging from one additional case every 100 years to five additional cases every 2 years.

The health, emission, population, and modeling data EPA used in its December 1983 benzene decision have uncertainty and are based on assumptions. For example, EPA's benzene health data are based on limited information about workers (some of whom developed leukemia) who were exposed to benzene in the 1940's and 1950's. Since the workers' actual exposure levels to benzene are not known, EPA made assumptions about their exposure levels to project potential leukemia incidence.

EPA's benzene risk assessments did not consider three relevant health studies completed between 1981 and December 1983 because EPA believed the new studies would not significantly change its benzene health assessment. In addition, EPA's population data were based on projections of 1970 census data, rather than 1980 census data. EPA officials said they did not know the updated information was available. Also, EPA's emission data showed that three plants used benzene to manufacture a product used in making plastics and chemicals. However, only one plant was actually using benzene at the time EPA issued its final decision. EPA officials told GAO that at the time of the decision, they were aware that one of the plants had stopped using benzene but that EPA had not verified this and wanted to be conservative in its risk calculations. (See ch. 2.)

As of October 1985, EPA's air office had updated some information and was planning further improvements to its benzene risk assessments. For example, EPA evaluated the three new health studies and other recently available benzene health data and, as a result, increased by 18 percent its estimate of leukemia incidence from benzene exposure. EPA officials said the more current and accurate information changed their estimation of risk to the public but that this was not significant enough to change its December 1983 decision. EPA officials believe that, given the large uncertainty inherent in an assessment dependent upon assumptions and estimates, the benzene risk numbers are reasonable.

As of October 1985, EPA did not have written guidance detailing how it develops quantitative risk assessment numbers for hazardous air pollutants but was planning to develop guidance in 1986. (See ch. 2.)

EPA Plans to Regulate Automobile Refueling

EPA identified automobile refueling vapor as a benzene "source category" in 1979, but has been considering regulating this vapor for ozone control since 1973. In the absence of EPA regulations for controlling refueling vapor, California and the District of Columbia have implemented controls on gasoline pumps. (See ch. 3.)

In studying the automobile refueling issue, EPA is considering information that indicates that gasoline vapor—apart from its benzene component—may be carcinogenic. If EPA decides the risk from this vapor is significant, it could require nationwide controls. Conversely, if EPA believes the risk to the public from gasoline vapor and/or benzene is not significant, it could require controls only in those areas where states are having difficulty attaining the ozone standard. EPA is also examining the control efficiency, implementation time, and cost-effectiveness of the automobile refueling control options. (See ch. 4.)

Recommendations

To improve quantitative risk assessments used to make decisions on hazardous air pollutants, such as benzene, GAO recommends that the EPA Administrator direct that the guidance it develops include a requirement that, to the extent possible, current and verified data be used in developing quantitative risk assessments or that an explanation be included in the assessment as to why those data are not being used. (See ch. 2.) GAO also makes a recommendation to the EPA Administrator on improving the analysis used to support its decision on automobile refueling controls. (See ch. 4.)

Agency Comments

GAO discussed matters in the report with EPA officials but did not obtain their views on the report's conclusions and recommendations. Their comments were considered in preparing this report.

Contents

Appendixes

Tables

Figures

Abbreviations

CARB	California Air Resources Board
EPA	Environmental Protection Agency
GAO	General Accounting Office
RCED	Resources, Community, and Economic Development Division (GAO)

Introduction

Benzene is a clear, colorless, highly toxic liquid that is used widely throughout the United States. It ranks 16th in production among all chemicals in the United States; an estimated 9.9 billion pounds was produced in 1981. Benzene occurs naturally in crude oil and is a constituent of gasoline and diesel fuel, generally comprising 1 to 3 percent of gasoline by weight. Benzene is also a by-product of petroleum and coal and an intermediate in the production of other industrial chemicals which, in turn, are used to manufacture a wide range of products, including plastics, nylon, insecticides, and polyurethane foams.

Benzene has been recognized since 1900 as a toxic substance capable of causing short-term and long-term effects on the blood-forming system. It is one of the few substances for which both animal and human studies show significant evidence of carcinogenic effects. Several human studies have documented an association between benzene exposure and leukemia. Futhermore, benzene has been found to cause other types of cancer in rats and mice. Benzene is also one of a group of pollutants called hydrocarbons, many of which contribute to smog formation.

Human exposure to benzene emissions is widespread. People are exposed to benzene from stationary sources (such as refineries and chemical plants) and mobile sources (such as cars and trucks). Stationary source emissions may occur, for example, when benzene is used in producing another chemical. Emissions can occur from the transport or storage of benzene, from leaks in certain chemical plant pipes and valves, or from releasing benzene from vents or stacks to the atmosphere during a chemical-manufacturing process. Mobile source emissions stem from gasoline vapor and exhaust created while driving an automobile or truck. The Environmental Protection Agency (EPA) estimated in 1984 that at least 30 million to 50 million people are annually exposed to large quantities of benzene emitted from stationary sources.

Section 112 of the Clean Air Act

Section 112 of the Clean Air Act, known as National Emission Standards for Hazardous Air Pollutants, requires EPA to publish a list of each pollutant for which it plans to establish an emission standard. It requires EPA to propose emission standards applicable to both new and existing sources within 180 days after the pollutant is included on the list. Section 112 also requires EPA to issue final standards within 180 days of publishing proposed standards. According to the act, standards must be set at a level that provides "an ample margin of safety" to protect the public health. EPA estimates that since 1977 it has spent $6.1 million in developing standards to control benzene as a hazardous air pollutant under Section 112 of the Clean Air Act. (See app. I for a break out of EPA-estimated benzene expenditures.)

EPA has issued standards under section 112 for mercury, beryllium, asbestos, vinyl chloride, radionuclides, and benzene. EPA has also proposed standards for arsenic under section 112. On August 26, 1983, we issued a report[1] to the Chairman, Subcommittee on Oversight and Investigations, House Committee on Energy and Commerce, which discussed the delays EPA had experienced in proposing and issuing national emission standards for hazardous air pollutants. EPA's experience with benzene is important because benzene is the first hazardous air pollutant for which EPA has issued final standards under section 112 since it regulated sources of vinyl chloride in 1976.

Benzene As a Hazardous Air Pollutant

EPA added benzene to its list of hazardous air pollutants under section 112 on June 8, 1977. On the basis of three studies showing that occupational levels of benzene cause a higher incidence of leukemia in workers, EPA concluded that benzene in the environment also increases the public's risk of contracting leukemia.

EPA subsequently identified the major industry groups, or source categories, responsible for emitting the majority of benzene into the air. In determining where it would concentrate its regulatory efforts, EPA developed the following list of 12 source categories in 1979:

Table 1.1: EPA's 1979 List of 12 Source Categories of Benzene Emissions

Gasoline marketing	Ethylene production[a]
Automobile refueling	Nitrobenzene production[a]
Maleic anhydride production[a]	Chlorobenzene production[a]
Fugitive emissions[b]	Linear alkylbenzene production[a]
Coke by-product recovery plants[a]	Benzene storage
Ethylbenzene/Styrene production[a]	Benzene handling

[a]Various chemical manufacturing processes that emit benzene.

[b]Originally identified by EPA as two separate source categories—petroleum refineries fugitive emissions and chemical fugitive emissions.

[1]Delays in EPA's Regulation of Hazardous Air Pollutants (GAO/RCED-83-199, Aug. 26, 1983).

After ranking these source categories, EPA selected five of them[2] for regulatory action. EPA believed that controlling this combination of source categories would result in the most beneficial impact in terms of reducing benzene emissions and exposure in the shortest time for the least cost. EPA proposed standards for four (all except coke by-product recovery plants) of the five benzene source categories between April 1980 and January 1981. EPA obtained and analyzed public comments on the proposals and developed plans to issue final standards.

By mid-1983 EPA had not issued final standards for any of the source categories it had identified for regulatory action. On July 14, 1983, two environmental groups—the Environmental Defense Fund and the Natural Resources Defense Council—filed a citizen suit in the United States District Court for the District of Columbia to compel EPA to (1) issue final standards for the four source categories for which it had proposed standards and (2) propose emission standards for the remainder of the 12 source categories EPA identified in 1979. Several affected industry groups, including the American Petroleum Institute and the Chemical Manufacturers Association, entered the case in an attempt to have EPA remove benzene from its list of hazardous air pollutants.

While this lawsuit was pending, EPA announced on December 16, 1983, its intention to (1) issue final standards for fugitive emissions, (2) propose standards for coke by-product recovery plants, and (3) withdraw proposed standards for benzene storage, maleic anhydride, and ethylbenzene/styrene. At the time, EPA did not indicate if it had any plans to regulate any other benzene source categories. On January 27, 1984, the court ordered EPA to publish in the Federal Register its determination for the five source categories. The court did not take action as to the other source categories. This portion of the lawsuit is still pending. In response to the court order, EPA issued a proposed withdrawal notice on March 6, 1984, and issued a final withdrawal notice on June 6, 1984. As shown in table 1.2, EPA also took further action on coke by-product recovery plants and fugitive emissions.

[2]Maleic anhydride, ethylbenzene/styrene, storage, fugitive emissions, and coke by-product recovery plants.

Table 1.2: Benzene Source Categories for Which EPA Has Proposed Standards

Source category	Date standard proposed	Date standard issued
Maleic anhydride	Apr. 18, 1980	[a]
Ethylbenzene/Styrene	Dec. 18, 1980	[a]
Benzene storage	Dec. 19, 1980	[a]
Fugitive emissions	Jan. 5, 1981	May 24, 1984
Coke by-product recovery plants	June 6, 1984	•

[a]Standards withdrawn on June 6, 1984.

The Natural Resources Defense Council challenged EPA's final decision in two separate actions. On October 17, 1984, the council petitioned EPA to reconsider its decision to withdraw the proposed standards for the three benzene source categories and to reconsider its final standard for fugitive emissions. The council also filed a similar petition in the United States Court of Appeals. On August 23, 1985, EPA denied the administrative petition, stating that the objections raised by the council do not provide substantial support for revising EPA's benzene decisions. The court action is still pending. Appendix II discusses EPA's plans to regulate all of the sources of benzene emissions it has identified.

EPA Action on Benzene From Automobile Refueling

Automobile refueling is one of the benzene source categories that EPA is studying for possible control. While refueling an automobile at a service station, an individual is exposed to gasoline vapor, which contains benzene and other hydrocarbons. Automobile refueling is the last step in a gasoline-marketing process that includes an extensive network of storage; transportation; and dispensing facilities used by refiners, marketers, distributors, and dealers to deliver an estimated 280 million gallons of gasoline per day to consumers. Emission of vapors occurs when transporting gasoline between each distribution facility in the gasoline-marketing network—pipelines, bulk terminals, tank trucks, bulk plants, service stations, and automobiles.

Controls on emissions from the gasoline-marketing network would address concern about several pollutants other than benzene. Exposure to gasoline vapor and other constituents of that vapor, including ethylene dibromide and ethylene dichloride, may result in serious health risks. Futhermore, gasoline vapor participates in atmospheric photochemical reactions that produce ozone and other constituents of smog.

In response to the 1970 Clean Air Act Amendments, EPA established national air quality standards for several pollutants, including ozone.

The 1970 amendments required that each state submit to EPA an implementation plan detailing the state's program for achieving the EPA-established standards. To the extent standards would be exceeded, the amendments require that the state impose controls on sources to reduce emissions. EPA classifies as a "non-attainment area" any air quality region or portion thereof that is violating the standards.

The Clean Air Act Amendments of 1977 established December 31, 1982, as the deadline for states to demonstrate achievement of the air quality standards, including those for ozone. As allowed by the 1977 amendments, EPA extended the date for attainment of the ozone standard to December 31, 1987. Under the 1977 amendments and EPA regulations, states not meeting the deadlines are subject to economic sanctions, such as construction bans on new facilities or a reduction of certain federal highway grants.[3]

Efforts to Control Gasoline Vapor

EPA has designated as "stage I" controls any equipment designed to contain and recover gasoline vapor during the early phases of the gasoline-marketing network—storage tanks, bulk terminals, bulk plants, and in loading at service stations. Stage I systems provide for the recovery of gasoline vapor from the vessel being filled into the vessel from which the liquid gasoline is being discharged (i.e., from the service station underground tank back into the gasoline tank delivery truck). Many states require stage I systems to help control smog.

In 1973 EPA began considering the use of equipment installed on the gasoline pump (called stage II controls) to help control ozone and smog from the last phase of gasoline marketing—automobile refueling. Section 202(a)(6) of the Clean Air Act as amended in 1977 required EPA to determine the feasibility and desirability of requiring controls on the automobile (called onboard controls) to avoid the necessity of stage II controls. After adding benzene to its list of hazardous air pollutants in 1977, EPA began studying whether automobile refueling and other gasoline-marketing controls might also be used to control benzene as well as other smog-causing hydrocarbons. EPA is still studying the issue and plans to make a decision in late 1985 or early 1986 as to whether controls on gasoline pumps or automobiles should be used.

[3]We recently issued a report on this matter—EPA's Sanctions Policy Is Not Consistent With the Clean Air Act (GAO/RCED-85-121, Sept. 30, 1985).

As discussed on page 4, the Natural Resources Defense Council and the Environmental Defense Fund filed a citizen suit in the United States District Court for the District of Columbia requesting that EPA propose emission standards for several benzene source categories, including automobile refueling. On August 24, 1984, they filed an amended complaint requesting that EPA be required to control automobile refueling vapor under either section 112 or section 202(a)(6) of the act. In October 1985 the district court transferred the citizen suit to the District of Columbia Court of Appeals, where the case was pending as of November 1985.

Objectives, Scope, and Methodology

In a January 5, 1984, letter and subsequent discussions with his office, the Chairman, Subcommittee on Oversight and Investigations, House Committee on Energy and Commerce, asked us to determine

- the basis for EPA's December 1983 decision to take action on five benzene source categories under Section 112 of the Clean Air Act, and
- EPA's plans to regulate benzene emissions through controls on automobile refueling.

We performed our review between November 1984 and October 1985 at the following locations:

- EPA headquarters, Washington, D.C.; EPA's Office of Air Quality Planning and Standards, Durham, North Carolina; EPA's Office of Mobile Sources, Ann Arbor, Michigan; EPA's Environmental Criteria and Assessment Office, Research Triangle Park, North Carolina; and EPA Region 9, San Francisco, California.
- California's Air Resources Board, Sacramento, California; California's Department of Health Services, Berkeley, California; the San Diego Air Pollution Control District, San Diego, California; and the South Coast Air Quality Management District, El Monte, California.
- The District of Columbia's Department of Consumer and Regulatory Affairs, Washington, D.C.

Basis for EPA's December 1983 Decision

To review EPA's efforts to regulate benzene emissions under Section 112 of the Clean Air Act, including the basis for its December 1983 decision to take action on five source categories, we reviewed the Clean Air Act; EPA's files on benzene emissions; EPA's proposed, withdrawn, and issued standards for benzene source categories; the public comments EPA has received in response to these standards; EPA draft health assessment and cancer assessment documents for benzene; and EPA's methodology for developing quantitative risk assessments for benzene source categories.

We visited several chemical and steel plants that have been subjected to EPA's proposed and final benzene standards, including Monsanto Company in Texas City, Texas, and St. Louis, Missouri; Amoco Chemicals Corporation, Texas City, Texas; American Hoechst, Pasadena, Texas; Arco Chemical, Monaca, Pennsylvania; and Bethlehem Steel Corporation, Bethlehem, Pennsylvania. We discussed EPA's efforts to regulate benzene as a hazardous air pollutant with officials from these companies, as well as the U.S.S. Chemicals Company, the American Petroleum Institute, the American Lung Association, the Natural Resources Defense Council, the American Iron and Steel Institute, and the State and Territorial Air Pollution Program Administrators.

We obtained an estimate of benzene emissions from (1) all stationary source categories from EPA's Office of Air Quality Planning and Standards and (2) all mobile sources from EPA's Office of Mobile Sources. We also obtained EPA's plans to control each of the source categories EPA identified.

In order to review the basis for EPA's December 1983 decision to take action on five benzene source categories, we examined the quantitative risk assessments that EPA used as the primary basis for those decisions. We reviewed the two key elements of EPA's benzene risk assessment—the health assessment and the exposure assessment—as well as the modeling techniques EPA utilized to combine these and obtain the risk numbers for the December 1983 decision.

We identified the assumptions and uncertainties associated with the studies EPA used as the basis for its benzene health data. We discussed the strengths and limitations of the health data with officials from the three offices primarily responsible for developing and utilizing the health data—the Office of Air Quality Planning and Standards, the Environmental Criteria and Assessment Office, and the Carcinogen Assessment Group. We also discussed EPA's use of health data with officials from the U.S. Occupational Safety and Health Administration, the California Air Resources Board, the California Department of Health Services, and EPA's Science Advisory Board.

To review EPA's benzene exposure assessment, we examined EPA's files to determine how EPA developed benzene emission data. We discussed with EPA and industry officials the extent to which EPA verified the emission data it obtained from industry. We also discussed with EPA officials how they developed information on the number of people at risk near each benzene source.

We also reviewed EPA's use of mathematical modeling, which is used to calculate estimated human cancers from exposure to chemicals, such as benzene. To do so, we examined the model's assumptions and discussed the model's accuracy with EPA officials. We also ran the model to determine how EPA uses it to calculate its risk numbers.

We also discussed EPA's withdrawal of proposed standards with officials from air pollution control agencies in those states—Indiana, Louisiana, Missouri, Pennsylvania, and Texas—with maleic anhydride and ethylbenzene/styrene plants to determine their plans to regulate these benzene source categories.

Plans to Control Automobile Refueling Emissions

To determine the status of EPA and state efforts to control automobile refueling emissions, we discussed the history of EPA and state involvement with officials from EPA headquarters and Offices of Mobile Sources and Air Quality Planning and Standards. We also discussed the effectiveness, implementation, and enforcement of gasoline pump controls with officials from the two jurisdictions (California and the District of Columbia) with programs in place, including officials from the California Air Resources Board, the San Diego Air Pollution Control District, the South Coast Air Quality Management District, the San Francisco Bay Area Management District, and the District of Columbia Department of Consumer and Regulatory Affairs. We reviewed California and District of Columbia reports on the effectiveness of gasoline pump technology and visited stations in San Diego, Los Angeles, Sacramento, and the District of Columbia to examine the differences in the various gasoline pump technologies. We also discussed state and EPA efforts to implement refueling vapor-recovery technology with officials from the remaining 49 states and the State and Territorial Air Pollution Program Administrators. We also discussed automobile refueling technology and performance with other affected parties, including the Service Station Association, the Motor Vehicle Manufacturers Association, the American Petroleum Institute, and Sierra Research, Inc., a California-based research firm that has conducted work on gasoline pump technology for the Ford Motor Company.

We visited EPA's Mobile Sources Laboratory in Ann Arbor, Michigan, for a demonstration of refueling controls on automobiles. We also discussed safety issues related to these controls with officials from the National Highway Traffic Safety Administration.

In order to review EPA's plans to regulate benzene emissions through controls on automobile refueling, we reviewed EPA's files and documentation from 1973 to the present to develop a history of EPA's activity on this issue; two EPA gasoline-marketing documents—Estimation of the Public Health Risk From Exposure to Gasoline Vapors via the Gasoline Marketing System (June 1984) and Evaluation of Air Pollution Regulatory Strategies for Gasoline Marketing Industry (July 1984); and the public comments received on each document. We also reviewed two internal EPA options papers (June 1985 and July 1985) on automobile refueling and discussed them with EPA officials. We also evaluated the cost-effectiveness analyses on the automobile refueling control options that EPA had conducted as of July 1985 to determine if these analyses were complete and accurate. We determined the key factors that EPA is considering in making its decision on automobile refueling controls but we did not identify a preferred regulatory strategy.

We discussed the matters contained in the report with EPA officials responsible for benzene standards and gasoline-marketing controls. Their comments have been incorporated where appropriate. However, we did not obtain the views of the responsible EPA officials on our conclusions and recommendations, nor did we request official EPA comments on a draft of this report. With this exception, our review was performed in accordance with generally accepted government audit standards.

EPA's Decisions for Regulating Benzene Emissions on the Basis of Risk Assessment

EPA based its decisions to regulate benzene emissions under Section 112 of the Clean Air Act on risk assessment and risk management. Risk assessment is an analytical tool used to evaluate the relationship between exposure to toxic substances and the potential occurrence of disease. In developing these risk assessments, EPA uses relevant health studies, emission data, population information, and environmental-modeling techniques. Risk management is EPA's attempt to decide what, if anything, should be done to control those risks.

When analyzing the relevant benzene health studies, EPA developed a unit risk factor that estimates the total probability of leukemia deaths from benzene exposure. The unit risk factor plays an integral part in the risk assessment process because it is used to indicate the potency of cancer from benzene exposure.

In December 1983 EPA combined the benzene unit risk factor with emission and population data from each source of benzene (e.g., chemical plant process vents) and developed quantitative risk assessment numbers quantifying estimated risk to the public near each of five source categories. EPA then ranked these numbers for each source category and determined it would regulate two source categories and not regulate three others.

This chapter discusses the methodology EPA used to develop the quantitative risk numbers for the five source categories and identifies some of the uncertainties associated with the risk numbers. Some of the uncertainties are the result of factors beyond EPA's control while others could have been controlled by EPA.

EPA Relies on Risk Assessment and Risk Management to Control Benzene Emissions

According to EPA officials, in 1983 EPA shifted its basis for regulating hazardous air pollutants, such as benzene, from a reliance on best available technology to what it terms a risk assessment-risk management approach. EPA develops quantitative estimates of individual and aggregate risk and uses these estimates to determine which source categories should be regulated. To develop these risk assessments, EPA uses relevant health studies, emission data, population information, and environmental modeling techniques.

Prior to 1983, EPA's policy for regulating hazardous air pollutants was based on controlling emissions, as a minimum, to levels corresponding with the best available technology. EPA developed risk assessments to determine the risk of public exposure to an emission source of a pollutant and then identified the best available technology—taking costs and technological factors into consideration—to control those emissions. EPA would have required additional controls to eliminate unreasonable residual risk if application of the best available technology did not sufficiently reduce exposure risk to the public.

However, in 1983, the EPA Administrator shifted EPA's hazardous air pollutant standard-setting process away from a technology-based approach in favor of a risk-based approach. The EPA Administrator outlined EPA's position on risk assessment and risk management in a June 1983 speech in which he stated that disease-causing pollutants are widespread in the environment and that exposure, however small, to a genetically active substance embodies some risk of an effect. The administrator's decision was also consistent with a 1983 National Academy of Sciences report [1] which recommended that risk assessment and risk management be used by regulatory agencies dealing with scientific uncertainties.

EPA now uses a two-step process—risk assessment and risk management—to determine whether a hazardous air pollutant emission source should be controlled. The risk assessment step includes a quantification of health and exposure data to estimate the magnitude of risk posed by sources of carcinogens, such as benzene. Risk management involves evaluating all source categories of a pollutant and determining which, if any, of these source categories should be controlled to reduce or eliminate the risk. Risk management policy also requires information on control technologies, their effectiveness, and costs, but according to EPA officials, risk to the public is the overriding factor used in the decision. Using the risk assessment-risk management approach, EPA may decide not to regulate a source category that it considers to present insignificant risk to the public, even if a low-cost "available technology" to control emissions is available.

Quantitative Risk Assessment

Quantitative risk assessment is a method of characterizing the potential adverse health effects of human exposures to environmental hazards on the basis of numerical data. EPA quantifies health and exposure data and combines them to estimate the human hazards of a certain pollutant.

[1] Risk Assessment in the Federal Government: Managing the Process, National Research Council National Academy Press, Washington, D.C. 1983.

The health data used for the quantitative estimate can come from epidemiological or animal studies. Epidemiological data showing the prevalence of diseases such as cancer are derived largely from studies of workers that have been exposed to high concentrations of a particular substance. To define risks to the general population, these high occupational exposure levels and the resulting incidence of disease must be extrapolated to lower, ambient air concentration levels. The incidence of diseases in animals is obtained from controlled studies where animals are given high doses of a substance; as with epidemiological studies, these high-dose results must be extrapolated to lower dose ambient air levels. EPA prefers epidemiological studies because they show health effects in humans, though often at uncertain exposure levels. Animal studies, while not indicating human health effects, are often more precise in that the exact dose parameters can be controlled.

EPA extrapolates the results from the epidemiological and/or animal studies and determines a "unit risk factor" for the pollutant. The unit risk factor is the probability that an individual will develop cancer if exposed to a continual concentration of a pollutant over a lifetime.

EPA then develops exposure information for each source category by using emission estimates, population data, and air quality dispersion models. For any given level of emissions, EPA dispersion models predict the concentration levels in the air at different distances from the emission source. EPA combines these estimates with census data on population densities and estimates the number of people exposed to the emissions at different concentration levels.

EPA then combines the unit risk factor with the exposure estimates to obtain two final risk estimates—maximum individual risk and annual incidence. The former describes the risk to the most exposed individual, and the latter describes the overall health impact on the entire exposed population.

The maximum individual risk is an estimate of the increased lifetime risk from a source for an individual who spends his or her entire life at the point where predicted concentrations are the highest. Maximum individual risk is expressed as a probability; a risk of 1 in 10,000 means that the "most exposed" individual faces an increased risk of cancer of 1 in 10,000.

Providing a measure of the overall impact on public health, the annual incidence figure takes into account persons exposed at all concentrations—low and high—of an air pollutant. For example, a total population impact of 0.05 per year means that pollutant emissions from a source will cause one case of cancer every 20 years.

EPA's Risk Numbers for Five Categories of Benzene Emissions

EPA combined the benzene unit risk factor with exposure data from sources of benzene emissions and computed annual incidence and maximum individual risk numbers for the five benzene source categories it was considering regulating. In December 1983 EPA announced its decision to (1) issue final standards for benzene fugitive emissions, (2) propose standards for coke by-product recovery plants, and (3) withdraw proposed standards on three other benzene source categories. EPA based this decision on quantitative risk estimates that indicate a general reduction in public health risk since 1981 for three source categories.

Table 2.1 shows the risk numbers EPA generated in 1983 for the five benzene source categories. According to officials in EPA's Cancer Assessment Group, these numbers represent excess leukemia cases over the general leukemia incidence for the population of the United States.

Table 2.1: EPA's Risk Numbers for Five Source Categories

	Annual U.S. cancer incidence (excess cases per year)		Maximum individual risk (per 10,000 population)	
Source category	**1980-81**	**Dec. 1983**	**1980-81**	**Dec. 1983**
Maleic anhydride	0.46	0.03	2.30	0.76
Ethylbenzene/ Styrene	.03[a]	.01	6.20[a]	1.40[a]
Benzene storage tanks	.12[b]	.04	1.50[b]	.36
Benzene fugitive emissions	.42	.15[c]	4.45	1.70[c]
Coke by-product recovery plants[d]	2.60	2.60	83.00	83.00

[a]Annual incidence ranged from 0.03 to 0.02, and maximum individual risk ranged from 6.20 to 44.00.

[b]Annual incidence ranged from 0.12 to 0.82, and maximum individual risk ranged from 1.50 to 10.0.

[c]Annual incidence ranged from 0.15 to 1.14, and maximum individual risk ranged from 1.70 to 12.00.

[d]The standard for coke by-product recovery plants was proposed in March 1984.

Table 2.1 shows a decline in risk for several benzene source categories. When EPA proposed the benzene standard for maleic anhydride process vents in April 1980, it estimated that 0.46 persons per year (or about 1 case every 2 years) would get cancer from these emissions. Because a significant number of maleic anhydride plants stopped using benzene by

1983, the projected number of cancer cases per year dropped from 0.46 to 0.03 (or from about one case every 2 years to about one case every 33 years). Table 2.1 shows similar declines in EPA's risk estimates for ethylbenzene/styrene and benzene storage tanks primarily because EPA revised its assumptions about emission rates for these source categories.

Table 2.1 also shows annual cancer incidence rates in December 1983 for benzene fugitive emissions (0.15, or about one case every 6 years), and coke by-product recovery plants (2.60, or about five cases every 2 years) to be higher than for the other three source categories. On the basis of these risk figures, EPA concluded the public health risks for these two source categories were significant enough to require federal emission control standards. EPA also concluded that the risks to public health for the other three source categories were small and that no significant health benefits would accrue from adopting standards to control them.

EPA officials do not believe it is appropriate to establish any one cancer incidence or individual risk number as a threshold level of concern for decision making. In other words, EPA will not automatically regulate a source category because it estimates emissions will result in a certain number of cancer cases per year. EPA officials note that, while risk was the most important factor EPA considered in the benzene decisions, other factors such as the cost of controls or number of sources can affect a hazardous air pollutant decision. Furthermore, they believe that the uncertainties associated with the hazardous air pollutant risk numbers make it difficult to establish a clear threshold level of concern.

In our review we determined how EPA developed its risk numbers for these five benzene source categories.

EPA Health Data Based on Assumptions and Uncertainties

EPA developed a unit risk factor for benzene that it combined with exposure information to determine the quantitative risk assessment for each benzene source category. In 1979 EPA developed its initial unit risk factor for benzene on the basis of data obtained from three epidemiological studies,[2] and updated it in 1982 on the basis of public comments it

[2]Askoy, M., et al, "Leukemia in Shoe-Workers Exposed Chronically to Benzene," Blood, Vol. 44, No. 6 (1974), pp. 837-841.

Infante, P.F., et al, "Leukemia in Benzene Workers," Lancet, July 9, 1977, pp. 76-78.

Ott, M.G., et al, "Mortality Among Individuals Occupationally Exposed to Benzene," Exhibit 154, OSHA Benzene Hearings, July 9-Aug. 10, 1977.

received. EPA used this 1982 unit risk factor in its December 1983 decisions to regulate benzene. The usefulness of the data in these studies is limited for several reasons, including uncertainties about the duration and concentration of benzene exposure in the studies. EPA is reevaluating its initial benzene unit risk factor on the basis of several new studies and an examination of those studies conducted by the California Department of Health Services.

Assumptions Behind EPA's Use of Benzene Health Data

In 1979 EPA published its initial unit risk factor estimating the total probability of leukemia deaths from benzene exposure. The unit risk concept assumes that an individual is exposed continually to an estimated benzene concentration (e.g., 1 part per million) over a lifetime of 70 years. The unit risk factor plays an integral part in the risk assessment process because it is used to indicate the potency of cancer from benzene exposure. EPA's initial benzene unit risk factor corresponded to a probability that 24 excess cases of leukemia would occur per 1,000 persons exposed to benzene, given the assumption stated above. EPA derived this estimate for cancer risks from the three epidemiological studies. EPA normally incorporates animal studies into such assessments, but animal studies showing positive benzene carcinogenicity were not available for inclusion in 1979. EPA's 1979 risk assessment document stated that EPA would update its risk analysis to take into account future animal studies.

EPA acknowledges that the process by which it develops its unit risk factor involves uncertainty. For example, one step involving great uncertainty is EPA's extrapolation from high-dose epidemiological studies to the far lower exposure levels found in the environment. According to a December 1983 background paper on EPA's benzene decisions, the health data showing increased risk from benzene are based on workers exposed to many parts per million; the paper notes, however, that most environmental exposures for the general public are not higher than several parts per billion. In other words, EPA had to extrapolate to doses a thousand or more times lower than those at which cancer rates had been observed.

The correlation between high dose studies and actual environmental exposure is unknown and scientists have proposed many different mathematical models to estimate that correlation. EPA generally relies on the linear, nonthreshold model which assumes that risk is proportional to dose. EPA believes that the linear model generally yields a higher estimate of potency than other models and that it provides a plausible upper limit estimate for a chemical's potency at low levels of exposure. In other words, EPA believes the potency of a substance is unlikely to be higher than estimated using the linear model, and could be substantially lower. According to the December 1983 EPA background paper on benzene, using the linear model reflects EPA's decision to err on the side of caution in the face of uncertainties.

The three epidemiological studies upon which EPA relied in developing its initial unit risk factor utilized occupational data of workers who were exposed to benzene and died of leukemia. EPA acknowledges the inherent limitations associated with using epidemiological studies. For example, according to officials in EPA's Carcinogen Assessment Group, epidemiological studies are based on historical data, which often do not contain the actual duration and concentration of emissions to which the subjects were exposed. The three benzene studies EPA used in its risk assessment estimated health effects on the basis of workers' records dating back to the 1940's and 1950's. Several workers exposed to benzene died of leukemia but, unlike animal studies, where exact dosage is known, no one knows the actual amount and duration of benzene to which the workers were exposed. As a result, EPA had to estimate the exposure levels in order to develop its unit risk factor. EPA does not know the actual benzene exposure levels used in its evaluation of the incidence of leukemia in workers.

The benzene unit risk factor has other limitations. EPA's risk figure focused on the leukemia response resulting from pure benzene exposure. EPA did not evaluate cancer potentials other than leukemia or the cumulative or synergistic (combined effects of two or more chemicals) effects of benzene exposure. EPA's estimates also did not take into account risks for people potentially more sensitive to benzene exposure such as women, children, and the elderly.

EPA is aware of these limitations but, according to its June 1984 notice to withdraw proposed benzene standards, considers its unit risk factor to be plausible, if not conservative. The notice stated that EPA did not have data that would identify potentially sensitive populations or quantify their increased risk. The notice also stated that it appeared that other cancer associations with benzene exposure would not be as strongly related as the benzene-leukemia association. Officials at EPA's Carcinogen Assessment Group said that EPA does not normally conduct cumulative or synergistic evaluations for most pollutants because these effects are not easily measured. They also said that EPA's unit risk factor for benzene is intended to be a rough but plausible estimate, given the uncertainties and assumptions used.

EPA Changed Health Estimate After Public Review

Prior to publishing its results in 1979, EPA submitted three benzene-related draft documents—health assessment, population exposure, and cancer risk—to its Science Advisory Board[3] for review. The board conducts such reviews to assure that EPA's documents are scientifically accurate and adequately represent the latest knowledge on health effects. The Science Advisory Board issued a preliminary report of its opinions on EPA's benzene documents in early 1978. According to the report, the board was uncertain about the validity and significance of EPA's attempt to quantify population risk to ambient benzene exposures for regulatory decision making. The report also suggested modifications for all three documents that would strengthen the assessments, including the recalculation of several estimates, the addition of other data, and a suggestion not to rely too much on a specific study. On the basis of the board's comments, EPA revised the documents and published them in late 1978-early 1979.

After publishing the documents, EPA received comments from industrial and environmental interest groups. After considering the comments and reevaluating its estimates, EPA lowered its unit risk factor from 24 to 22 leukemia cases out of 1,000 persons exposed. EPA published its revised unit risk factor in May 1982 and used this number in computing risk numbers for the five source categories included in its December 1983 decision.

New Benzene Studies Were Not Included in the December 1983 Decision

By December 1983 three new epidemiological and animal studies[4] were available to EPA concerning benzene health effects. The Rinsky study, a follow-up to one of the three original epidemiology studies EPA used in developing its unit risk factor, was published in 1981. The Chemical

[3]The Science Advisory Board is comprised of several committees of scientists and engineers outside of the federal government who advise the EPA Administrator on the scientific basis for regulatory standards.

[4]National Toxicology Program (NTP), "NTP Technical Report on the Toxicology and Carcinogenesis Studies of Benzene (CAS No. 71-43-2) in F344/N Rats and B 6C3FI Mice (gavage studies)," NIH Publication No. 84-2545, NTP-84-072, 1984.

Rinsky, R.A., et al, "Leukemia in Benzene Workers," American Journal of Industrial Medicine, Vol. 2, 1981.

Wong O., et al, "An Industry-wide Mortality Study of Chemical Workers Occupationally Exposed to

Manufacturers Association sponsored an epidemiological study which was published in December 1983. The National Toxicology Program published results of a 2 year animal study in 1984; a draft of the study was provided to EPA in September 1983.

EPA did not analyze these new studies to determine their impact on its benzene unit risk factor before making its December 1983 decision (or by the time the decision was issued as final in June 1984). EPA officials told us that the new studies' results did not appear to alter significantly EPA's benzene unit risk factor and that such a reexamination would have taken time and delayed the EPA decision. EPA officials told us that new health effects studies on various substances under regulatory consideration are constantly being published and that EPA is often faced with a dilemma of making a decision or waiting for new health evidence.

As part of its state regulatory efforts for benzene, the California Department of Health Services examined the epidemiological and animal data developed between 1974 and 1984, as well as the three studies used in EPA's original assessment. The Department issued a final report[5] in November 1984. The report indicated higher risk estimates than EPA's 1982 assessment.

A science advisor in the California Department of Health Services told us that, because of limitations associated with human studies, EPA's 1982 assessment would provide the lower limit estimate of risk. While animal studies also had limitations, their results, nevertheless, showed other possible human cancer potentials. On the basis of these findings, animal studies provided the upper limit of risk in the California assessment. The final report showed the potential risks to Californians from exposure to 1 part per billion of benzene was between 22 (derived from EPA's 1982 assessment) and 170 (derived from animal studies) excess cancer cases per million people exposed.[6]

In October 1984 the Natural Resources Defense Council petitioned EPA to reconsider its proposed withdrawal of three benzene standards claiming

Benzene." Submitted to Chemical Manufacturers Association. Environmental Health Associates, Inc., Dec. 3, 1983.

[5]Report to the Scientific Review Panel on Benzene, California Air Resources Board and the Department of Health Services, November 1984.

[6]The California study used different units of exposure (million persons exposed to 1 part per billion instead of thousand persons exposed to 1 part per million). According to a primary author of the California study, the numbers are comparable to EPA's method of expressing excess cancer cases.

that, among other things, EPA based its decision on outdated health data. EPA's Carcinogen Assessment Group evaluated the new data cited in the petition. In February 1985, EPA completed an internal report revising its estimates. The report was based on two updates of an original epidemiological study used in EPA's 1979 assessment, the animal study conducted by the National Toxicology Program, the epidemiological study sponsored by the Chemical Manufacturers Association, and a review of the California Department of Health Services' benzene assessment. On the basis of the internal report, EPA increased its benzene unit risk factor by 18 percent, or from 22 to 26 leukemia cases per 1,000 people exposed.

The internal report stated that while an animal study was incorporated into the evaluation, human epidemiological data still carried considerable weight in EPA's reassessment process. In response to the conclusions of the California benzene study, officials from the Carcinogen Assessment Group told us that when human exposure data are available, animal data should be used to confirm human data results. The group disagrees with using animal data as an upper limit for risk because the available human data do not indicate the various cancers found in animals; EPA's purpose is to protect public health, and health assessments based on available human studies are preferred.

In June 1984—prior to the work conducted on the internal report—the Chairman of EPA's Carcinogen Assessment Group had directed the group to reevaluate benzene carcinogenicity. The chairman was interested in reviewing the quality of the updated data on epidemiology, toxicology, and mutagenicity because so much time had elapsed and many inquiries had been made since the 1979 assessment. Included among these was a benzene study conducted by the National Institute of Occupational Safety and Health. The study was released to EPA in August 1985 and is a follow-up to one of the three studies upon which the original EPA benzene unit risk factor was based.

As a result, EPA plans to reevaluate all recent data on benzene health risks, including studies that have become available since the Natural Resources Defense Council's petition. EPA's final report is scheduled for publication by December 1985. In September 1985 EPA officials told us that EPA will request that the Science Advisory Board review the EPA analysis of the new benzene health data after the December 1985 report is released.

EPA's Benzene Exposure Estimates Are Based on Uncertain and Limited Data

In developing its quantitative risk assessment, EPA combines its health data with exposure data generated from emission and population information and modeling techniques. EPA's emission and population data used in its benzene decision were not always accurate. EPA's modeling of benzene health and exposure data was based on several assumptions that add to the uncertainty of the benzene risk assessment numbers.

EPA's Verification of Emission Data Is Limited

EPA conducted limited verification of the benzene emission data it received from industry. According to EPA officials in the Chemicals and Petroleum and the Standards Development Branches, the extent of verification is generally limited to the review and judgment of EPA's engineers and follow-up telephone calls, if deemed necessary. Occasional site visits and some contractual monitoring are being conducted. However, according to an official in EPA's Office of Air Quality Planning and Standards, site visits and monitoring for verification of emissions data have been minimal because of limited resources.

Section 114 of the Clean Air Act authorizes EPA to secure information needed in the development of emission standards. Among other things, section 114 authorizes EPA to make inspections, conduct tests, examine records, and require owners and operators of emission sources to submit information requested by EPA to develop such standards.

Between 1977 and 1980, EPA sent letters to industries inquiring about the types of information described above. EPA's Office of Air Quality Planning and Standards reviewed the industry-furnished information such as emission data and control technology designs, and followed up, if deemed necessary, by telephone. According to EPA officials, EPA engineers also compared plant designs and emissions data to determine the reasonableness of the data reported by industry. EPA did not conduct routine site visits but made them occasionally to (1) verify the data reported by industry, (2) identify potential monitoring emissions test sites, and (3) facilitate communication between EPA and plant personnel. EPA uses contractors to monitor emissions at some plants; the visits usually last a few days.

We reviewed EPA files to determine the extent that EPA requested information and made site visits for the four benzene standards which were proposed in 1980 and 1981. The number of letters requesting information and site visits are shown in table 2.2.

Table 2.2: EPA Letters Sent to Industries Requesting Information for Four Source Categories

Source category	Number of facilities	Number of EPA letters requesting information[a]	Number of EPA letters requesting plant visits[b]
Maleic anhydride	10	20	8
Ethylbenzene/ Styrene	13	31	7
Benzene storage	143	100	1
Benzene fugitives	250	15	11

[a]Some letters were sent to plants more than one time, such as follow-up requests for additional data or clarification of previously provided information.

[b]Because the letters sometimes requested information from more than one plant, these 27 letters requested visits to 46 plants.

From our review of EPA files and visits to several plants affected by EPA proposed standards, we identified instances where data were not current or were based on assumptions. For example:

- EPA's emissions data for maleic anhydride plants were not current. EPA's 1984 documentation supporting its decision to withdraw its proposed maleic anhydride standard indicated that EPA based its decision on emission data from three maleic anhydride plants. However, we found that one of the plants had stopped using benzene in its production process in July 1983 and another plant stopped manufacturing maleic anhydride in May 1984. Because only one plant was using benzene when EPA published its final withdrawal notice in June 1984, EPA's emission data were inaccurate. EPA officials told us that they were aware that one of the plants had closed but were reluctant to reflect it in EPA's emission data because they had not verified the closure and wanted to be conservative in their risk calculations. EPA did not know that the second plant stopped using benzene until the company notified them in July 1984.
- EPA used assumptions to develop its emission estimate for benzene storage. After proposing its standard in 1980, EPA revised its emission estimates on the basis of an industry-sponsored study that provided more representative emission data than EPA's original estimates. The study indicated an 18- to 98-percent benzene emissions reduction from EPA's original storage estimates, depending on the controls used. On the basis of the study, EPA estimated a 70-percent emissions reduction from its proposed estimates and lowered its health risk estimates over 85 percent. EPA assumed that industry had made extensive use of the controls. EPA did not verify this against actual storage tank controls nor the extent that controls are being used. According to an official of the Standards Development Branch, verifying these estimates would have been expensive, and EPA believed that the data gathered before the standard

was prepared were sufficient to enable EPA to make its decision. He stated that many of the plants had the same type of controls used in the study.

EPA also used inconsistent methods when comparing benzene emission and risk data for the five source categories in its December 1983 decision. EPA grouped emission data for coke by-product recovery plants differently from other benzene source categories. A typical industrial plant with benzene emissions contains several benzene sources—storage tanks, fugitive sources (pipes, valves, etc.), and process vents. For the ethylbenzene/styrene and maleic anhydride chemical plants, EPA divided these sources into components and developed risk numbers for each component (for example, emissions from all maleic anhydride plant process vents were grouped together to be used in risk numbers for maleic anhydride process vents; all benzene emissions from storage tanks and fugitive sources at maleic anhydride plants were grouped separately). However, for coke by-product recovery plants, EPA combined the emissions from all sources at the plant, including process, storage, and fugitive, to develop its quantitative risk number. In other words, the risk numbers for coke by-product recovery plants contained emission data from all benzene sources in the plant. EPA evaluated the risks of the chemical plant sources with those of the coke by-product recovery plants on an equal basis despite the fact that risk estimates for each source category did not represent equally weighted combinations.

EPA officials agreed that dividing the emission sources for maleic anhydride and ethylbenzene/styrene plants may have underestimated the risk to these persons relative to persons exposed to emission from coke by-product recovery plants. They told us that grouping the benzene emissions at the chemical plants would not have signficantly increased their calculations of risk to the public.

EPA Did Not Use Current Census Data to Determine Affected Population

EPA uses census data to assist in determining the exposure and risk of populations in the vicinity of plants that use benzene and other air toxics. In 1980-81, when EPA proposed standards for maleic anhydride, ethylbenzene/styrene, benzene storage, and fugitive emissions, it used 1978 census estimates projected from actual 1970 census data. However, when EPA made its decision in December 1983 to withdraw three of the proposed standards, it did not update population exposure estimates with actual 1980 census information. Rather, EPA relied on estimates based on 1970 census data. As a result, EPA's population risk computations were not current. For example, the population risk near a plant in a high-growth area may be understated because the more current census data were not used. In contrast, the risk to the population near a plant in an area with a declining population may be overstated. An engineer in EPA's Standards Development Branch stated that officials in his branch were unaware that the 1980 data were available. He stated, however, that including the updated data would not have made a significant difference in the risk numbers. EPA officials told us that they have since updated their estimates with 1980 census data and that, while they do not believe it makes a significant difference in EPA's benzene decision, they believe it improves the public's perception of the reliability of EPA's estimates.

Because of the cost involved, EPA does not routinely conduct site visits to identify the actual exposed population surrounding plants or to determine the actual population characteristics. Therefore, EPA may be uncertain whether the plants are near businesses, residences, schools, and so forth, which may also affect the risk factors.

Topographical maps are another resource available for verifying population estimates. The maps show industrial, residential, and commercial areas near emission sources. EPA sometimes utilizes these maps to better estimate precise locations of emission sources and the population exposed to emission sources of hazardous air pollutants. EPA did not use this resource for developing benzene exposure data for its December 1983 decision because it considered its modeling data sufficient for estimation purposes. However, in September 1985 EPA officials told us that they had recently used topographical maps in reviewing the EPA proposed standard for coke by-product recovery plants. They told us that the maps improved their accuracy and that EPA plans to use them more extensively in the future.

Limitations in EPA's Models

According to EPA documentation, although the general population is exposed to a complex mixture of potentially toxic agents, it is not possible to directly link actual human cancers with ambient air exposure to chemicals, such as benzene. EPA, therefore, relies on mathematical modeling techniques to estimate human health risks. EPA uses a Human Exposure Model [7] to incorporate health and environmental data in order to generate quantitative risk assessments for toxic pollutants. An EPA contractor developed two versions of the model for EPA—a simplified

[7]The Human Exposure Model is a dispersion model that EPA uses to combine health and exposure data to estimate risk to the population near emission points.

national exposure model and a more complex site-specific model. For its December 1983 decision, EPA used the simplified model, which incorporates the unit risk factor with data gathered from industrial emissions, census, and meteorological sources. An engineer in EPA's Pollutant Assessment Branch told us that risk estimates derived from the simplified model approach are not precise. The simplified model is more limited than the complex model in that it cannot incorporate more detailed data and, therefore, can generate only a rough estimate of actual risk for residents near a source.

EPA's Human Exposure Model has several limitations. Both versions of the model assume that (1) people are exposed for 70 years, (2) the population is immobile, (3) sensitive populations are not represented, (4) the terrain is flat, (5) the emissions are constant, and (6) exposure occurs at computer-generated "population centroids" [8] rather than precise locations. At the time EPA generated its risk numbers for benzene source categories, the population centroids were dispersed throughout a 20-kilometer radius from the emissions source in order to calculate the exposure risks. The population centroid does not measure the actual number of people exposed.

EPA acknowledges the limitations of its modeling process and is planning to improve various aspects of the exposure model. Before withdrawing the proposed benzene standards in 1984, EPA did not rerun its models to get updated estimates of risks because it did not identify any significant emission changes from the industry. Therefore, the withdrawal decision in 1984 was based on the modeling assessment primarily using exposure and health data developed in 1980-81. Since making its decision to withdraw proposed standards on three source categories, EPA updated census information, extended the total exposure distance radius to 50 kilometers, and included the updated 1985 unit risk factor in its model. According to an engineer in EPA's Pollutant Assessment Branch, EPA can improve its model by accounting for potentially sensitive groups, population, mobility, and terrain differences. EPA had a contractor evaluate the feasibility of making these improvements. EPA officials told us in September 1985 that they had decided to improve the model but had not yet determined the extent to which the improvements would be made. They expected to make a final decision on this issue in late 1985.

[8]Population centroids are computer-generated points around an emission source that estimate exposure risks on the basis of census data and emission concentration levels.

Importance of Accurate Data in Risk Assessments

EPA recognizes that for hazardous air pollutants, such as benzene, the amount of uncertainty in its quantitative risk assessment is large. According to EPA's options paper for coke oven emissions, this uncertainty for hazardous air pollutants may be in the range of 2 orders of magnitude [9] or greater. EPA officials believe, however, that there is as much data from which to perform a risk assessment on benzene as on any chemical and that the uncertainty in its benzene risk numbers—though not quantifiable—is not as great as for other chemicals.

As discussed above, EPA has made or is planning to make several improvements to the components of its benzene risk assessments. These include updating its census data, revising its unit risk factor, and planning to improve its dispersion modeling. According to the Chief of EPA's Pollutant Assessment Branch, some of these improvements may have little impact on the benzene risk assessment numbers. He stated that these improvements generally resulted in increasing the risk estimates because of the 18-percent increase in the benzene unit risk factor. He noted that these increases were not significant enough for EPA to change the decisions it announced on the five source categories in December 1983.

However, EPA agrees that it is important to have risk assessment numbers that are as scientifically accurate and up-to-date as possible to ensure they are valid, given the uncertainty in the process. EPA officials also believe it is important to use current and accurate data in risk assessments to ensure public comfort with and acceptance of these numbers.

The quantitative risk assessment numbers EPA uses to help support decisions on hazardous air pollutants, such as benzene, are developed by the Pollutant Assessment Branch in EPA's Office of Air Quality Planning and Standards. The branch uses inputs on emission data developed by the Office's Emission Standards and Engineering Division and combines them with other data to obtain the exposure assessments. The branch then combines this information with the unit risk factor and the exposure data in the human exposure model to determine the quantitative risk assessment numbers for each source category.

The Chief of the Pollutant Assessment Branch told us in October 1985 that EPA does not have any written guidance detailing how it develops

[9] For example, a risk of 50 persons contracting leukemia with a range of 2 orders of magnitude of uncertainty could range from 0.5 to 5,000 persons.

quantitative risk assessment numbers for hazardous air pollutants. He stated, however, that he is planning to compile an operating manual in fiscal year 1986 that will, among other things, clarify EPA and Pollutant Assessment Branch procedures on reviewing health data, developing exposure assessments, coordinating with other EPA offices, and developing quantitative risk assessments. We believe that when the Pollutant Assessment Branch develops this operating manual, it should include the requirement that EPA staff utilize the most current and accurate data possible when developing risk assessments.

We also noted that EPA's Federal Register notices and other public documentation related to its December 1983 benzene decisions generally did not contain statements qualifying the extent to which current or accurate data were excluded from its benzene risk numbers. For example, EPA's 1984 Federal Register notices for the five source categories did not clarify the extent to which current census data were used in the benzene risk assessments. In only one case—the June 1984 final notice to withdraw proposed standards for three source categories—did EPA include a statement to the effect that recent benzene health data were not included in its benzene decision. Whenever EPA is not including current or verified data in its risk assessments, it would be appropriate to clarify this in its public presentation of the assessment numbers.

States Plan No Action on Withdrawn Source Categories

EPA has decided that certain benzene source categories (e.g., maleic anhydride) do not pose a significant risk to the public and should not therefore be regulated at the federal level. For these source categories, we wanted to determine (1) whether the states with those sources planned to take action in the absence of EPA regulations and (2) what assistance EPA has provided to these states. We contacted air toxic program officials in five states with maleic anhydride and ethylbenzene/styrene plants—Indiana, Louisiana, Missouri, Pennsylvania, and Texas—to discuss EPA's decision to withdraw the proposed standards for those source categories and whether the state officials planned any further action. According to the state air toxic program officials, the five states have taken no actions to develop regulatory programs for the withdrawn source categories nor do they anticipate regulating them in the future. State officials from four states said that they have no plans to regulate these source categories because of inadequate resources. The air program official for the fifth state said it would not be cost effective to regulate the benzene emissions for the one plant in his state. However, officials from four states said they would consider regulating withdrawn source categories if EPA were to provide funding, personnel, and technical and scientific support.

The state officials expressed some concern over EPA's withdrawal of the proposed standards. For example, one state official said that it would be difficult for the states to effectively enforce any state regulation for the withdrawn source categories because of EPA's determination that the benzene risks are not significant.

EPA's assistance to the states has generally been limited to disseminating information such as risk assessments, health data, and control techniques through the National Air Toxics Clearinghouse it established in 1984. EPA is also developing courses to assist states in regulating hazardous chemicals such as conducting risk assessments.

EPA also has a pilot program in which it is working with several states to establish a state-operated regulation program for the chemical acrylonitrile. If this program is successful, EPA will expand it to other chemicals. In September 1985 EPA officials told us that they are considering expanding the acrylonitrile project to benzene source categories. The officials told us that EPA may provide support to the states that want to regulate certain benzene source categories (e.g., ethylbenzene/styrene) that EPA has decided not to regulate at the federal level.

Conclusions

Uncertainty was associated with each component of EPA's benzene risk assessment used in its December 1983 decision. For example, EPA's health data were based on epidemiological studies from employment records of workers exposed to benzene in the 1940's and 1950's. The workers' actual exposure levels are unknown, so EPA had to estimate the exposure levels. EPA also used assumptions in generating benzene emission and population data and in the mathematical model it used to combine these factors and calculate benzene risk numbers. Combining each component in the modeling process can compound the uncertainty in EPA's benzene risk assessment.

EPA did not always use current, accurate, or verified data in generating its benzene risk assessment. For example, when EPA determined in 1983 which source categories it would regulate, it based its decision on 1970 census data estimates instead of 1980 census data. EPA officials told us they were not aware that the more recent data were available in 1983.

Because quantitative risk assessment numbers play a key role in EPA's decision making, it is important that the numbers be based on current and accurate information.

EPA acknowledges the uncertainty associated with its risk assessments for hazardous air pollutants, such as benzene. EPA believes, however, that given the uncertainties, the benzene risk numbers represent a reasonable approach to quantitatively evaluating the impact of benzene exposure on public health.

EPA's Pollutant Assessment Branch—the office responsible for developing exposure estimates and calculating the quantitative risk numbers for air toxics—is planning to compile an operating manual that will provide written guidance on what kinds of information should be included in the quantitative risk assessments.

Recommendation

To improve the risk assessments for hazardous air pollutants, such as benzene, we recommend that the Administrator, Environmental Protection Agency, direct that the proposed Operating Manual for the EPA Pollutant Assessment Branch include a requirement that, to the extent possible, current and verified data be used in developing quantitative risk assessments or that an explanation be included in the assessment as to why those data are not being used.

EPA and State Efforts to Control Automobile Refueling Emissions

EPA's decision on how best to control automobile refueling emissions will be the culmination of over 13 years of studying the issue. Since 1973 EPA has been examining the use of technology on gasoline pumps (called stage II controls) to control ozone. The Clean Air Act Amendments of 1977 required EPA to examine technology on automobiles (called onboard controls) as an alternative to stage II to control vapors from automobile refueling. The decision became more complicated in 1979 when EPA identified automobile refueling and other segments of the gasoline-marketing network as benzene source categories, indicating that such controls may reduce exposure to a hazardous air pollutant as well as reduce ozone levels. In 1981 EPA announced it would not require onboard technology to control automobile refueling vapors. However, in 1983 EPA began reevaluating automobile refueling controls and plans to make a decision in late 1985 or early 1986 as to whether onboard or stage II controls should be implemented.

In the absence of an EPA decision on the issue, California and the District of Columbia have implemented stage II programs to help reduce ozone levels. Several other states have also considered implementing stage II programs for ozone control. However, most state air pollution control officials are reluctant to implement stage II controls without EPA guidance because, among other things, such controls are perceived as being difficult for the public to use and are opposed by petroleum lobby groups.

Since 1978 states have repeatedly asked EPA to make a decision on automobile refueling controls. If EPA or the states decide to implement such controls, this will assist them in reducing ozone levels. However, because of the leadtime required before they can be implemented, automobile refueling controls will not have a significant impact on states' ability to obtain ozone standards by the congressionally mandated deadline.

Control Options for Gasoline Marketing

The gasoline-marketing network comprises several sectors of gasoline transportation, from delivery of gasoline to bulk terminals to refueling automobiles at service stations. EPA refers to emissions from all of these steps except automobile refueling as stage I emissions. See appendix III for a description of stage I controls in the United States. Stage II and onboard controls are options for controlling emissions from automobile refueling.

Stage II Controls

The final step in the gasoline-marketing network is automobile refueling. At this step, the general public is exposed directly to emissions from gasoline vapor. When an individual refuels an automobile, he or she is exposed to gasoline vapor displaced from the fuel tank by incoming gasoline liquid. EPA refers to systems on service station equipment designed to control the vapor as stage II controls. These controls have been in use in the District of Columbia and 26 California counties since the 1970's.

Three types of stage II systems are currently being used in the United States—the vapor balance, the vacuum assist, and the hybrid system. An explanation of each of these systems is provided in appendix IV. The balance system is the simplest of the three systems and is in use at about 80 percent of the California stations with stage II controls and every station except one in the District of Columbia.

EPA estimates that stage II systems can control gasoline refueling vapor at a 95-percent efficiency level. EPA assumes that the actual in-use efficiency of the systems will be lower.

Onboard Controls

An alternative to stage II for controlling refueling emissions from motor vehicle fuel tanks is a vapor control system that could be designed into new model automobiles and light duty trucks. EPA refers to this alternative as onboard controls. The onboard vapor control system includes a sealed fill pipe and enlargement of the carbon canister that has been required on automobiles produced since 1971. While refueling a car with onboard controls, displaced vapor is trapped in the tank by the sealed fill pipe and absorbed by the enlarged carbon canister. (See app. V for an explanation of onboard technology.) When the car is driven, the vapor is purged from the canister to the carburetor for combustion. As explained below, the enlarged canister will also reduce evaporative emissions as well as the refueling emissions.

Prototype onboard systems have been tested but are not currently being used in automobiles. EPA has determined that the onboard system is about 98-percent efficient in controlling automobile refueling emissions. As with stage II, EPA assumes that during actual use, the onboard systems would not always achieve that level of efficiency.

Status of Automobile Refueling Vapor Controls

In 1973 EPA identified stage II as an ozone control technology for eight states and was about to issue standards requiring its use when the Clean Air Act Amendments were passed in 1977. As required by the amendments, EPA began studying onboard controls as an alternative to stage II but has yet to make a decision on which alternative is more effective to control gasoline vapor emitted during automobile refueling.

History of EPA's Actions on Automobile Refueling Controls

On November 6, 1973, EPA issued a notice in the Federal Register identifying stage II technology as one of several options for reducing hydrocarbon emissions. According to the notice, EPA's action was prompted by difficulties encountered by states in attaining air pollution standards by the deadline set in the Clean Air Act of 1970. EPA's November notice stated that stage II is one of the most cost-effective methods of hydrocarbon control and, on the basis of estimates at that time, could be implemented in 28 months (for 80-percent control) to 39 months (for 90-percent control). Between November 6 and December 12, 1973, EPA approved air pollution control plans, which included stage II controls for all or part of eight states—California, Colorado, the District of Columbia, Maryland, Massachusetts, New Jersey, Texas, and Virginia.

Over the next 3-1/2 years, EPA revised the compliance dates and reproposed the stage II regulations. For example, on February 8, 1974, EPA delayed compliance deadlines in response to comments that the schedules issued in the 1973 plans were unrealistically short. On May 31, 1977, EPA published an order stating that final standards would be issued in the near future and deferring the compliance deadlines for the states.

In August 1977 the Congress passed the Clean Air Act Amendments, which delayed the deadlines for ozone attainment until as late as December 31, 1982, with a possible 5-year extension to 1987. The amendments also included sections requiring EPA to reexamine its position on the gasoline vapor-recovery issue. Section 202(a)(6) of the amended act requires EPA to determine the feasibility and desirability of requiring onboard controls to avoid the necessity of stage II controls. In making a determination, EPA is to consider such factors as fuel economy, economic costs, and administrative burdens. Section 324 limits the applicability of any EPA stage II regulations by exempting an independent marketer of gasoline with monthly sales of less than 50,000 gallons and by providing a 3-year phase-in period implementation schedule for stage II controls for other independent marketers.

As required by the act, EPA began studying onboard technology as an alternative to stage II controls. EPA also began examining stage II and onboard technologies as methods for controlling nationwide benzene emissions. EPA considered making a decision on the issue but, because of the 1980 elections, delayed the decision. According to the former EPA Assistant Administrator for Air, Noise and Radiation, EPA postponed the decision for the incoming administrator because EPA had reservations concerning the analysis and had a short time frame in which to address these reservations.

After the change in administrations in 1981, EPA announced on April 13, 1981, a reduction in motor vehicle industry regulations, as part of the Vice President's governmentwide regulatory reform effort. As part of this effort, EPA stated that onboard controls would not be required and that a justification of this decision would be provided by June 1981. However, EPA neither issued a justification for the decision nor took any action on stage II controls because, according to EPA officials, automobile refueling controls became a low priority.

EPA did not take any further action on refueling emissions until new health data became available and a lawsuit was filed against EPA. In 1982 the American Petroleum Institute forwarded to EPA a study indicating that exposure to gasoline vapor may have adverse health effects. In July 1983 two environmental groups filed suit to force EPA to take action on benzene source categories, including gasoline marketing.

As a result, EPA began reexamining refueling emissions and issued two documents—a June 1984 review of public health risk from gasoline-marketing emissions and a July 1984 document outlining several regulatory strategies for gasoline marketing. EPA received public comments on the documents and is planning to issue a decision on how best to control emissions from gasoline marketing in late 1985 or early 1986.

State Activity on Stage II Controls

In the absence of an EPA decision on how best to control automobile refueling emissions, some states have taken action on stage II controls. In 1971 the San Diego County Air Pollution Control District began a stage II program that predated EPA's actions on the issue. The San Francisco Bay Area Air Pollution Control District followed suit in 1973, and by the late 1970's, 26 California counties and the District of Columbia had implemented stage II programs. Also, Bernadillo County in New Mexico enacted stage II regulations in June 1975. However, because the county meets the ozone standard, it has no plans to implement the regulations unless its ozone air quality degrades to nonattainment status.

Other states have considered implementing stage II controls. In their 1982 State Implementation Plans, seven states—Illinois, Maryland, New Jersey, New York, Ohio, Pennsylvania, and Virginia—agreed to consider stage II vapor recovery technology as a method of controlling ozone. Of the seven, New Jersey held hearings on proposed stage II regulations in September 1985 and, as of October 1985, was evaluating public comments received at the hearings. The New Jersey Department of Environmental Protection has written EPA stating that the New Jersey stage II program would be a short-term option to achieve the ozone standard; the Department has urged EPA to immediately mandate nationwide onboard controls as a long-term strategy to control air toxics and ozone. The Executive Director of the Virginia State Air Pollution Control Board told us that his state also favors a nationwide onboard program. State law prohibits Illinois from implementing stage II controls until EPA determines that such controls are required for compliance with the Clean Air Act. According to the Acting Manager of the Illinois Division of Air Pollution Control, petroleum interests (oil companies and gasoline marketers) in his state lobbied strongly for this law. New York is studying the issue and considering regulations but plans to take no action on stage II until EPA makes a decision on the issue. Pennsylvania and Ohio air pollution control officials told us in October 1985 that they had no plans to pursue stage II controls.

Alabama held a hearing in June 1985 to consider stage II regulations for ozone nonattainment areas. Missouri is considering implementing stage II controls in St. Louis. Vermont is in attainment with the ozone standard but as of August 1985, was planning to hold hearings to consider stage II to control benzene emissions. California is considering expanding the scope of its stage II program beyond the current 26 counties in order to reduce public exposure to benzene emissions.

Officials from most states are not confident, however, that they can implement stage II controls without EPA support. Stage II controls are perceived as difficult for the public to use and, therefore, politically unpopular with state legislators. Furthermore, they are strongly opposed by petroleum interests in the states. For example, the Director of the Massachusetts Division of Air Quality Control, told us that it would be politically difficult to implement stage II controls in his state without EPA's first issuing a decision or guidance document. He noted that the difficulty arises from having to convince gasoline retailers to incur costs for stage II controls and to justify a program that is not being imposed nationwide.

The Assistant Section Leader for Air Quality and Nuclear Energy of the Louisiana Department of Environmental Quality told us that bills have been introduced in the state legislature to require stage II controls but none have passed. A Louisiana state legislator who introduced the bills told us that the oil industry lobbied strongly against the bills, arguing that (1) the controls would be costly and (2) a state decision may be premature because EPA will soon make a decision on the issue.

EPA officials agree with state officials that a vapor-recovery decision is likely to be met with public opposition. Because they would be responsible for implementation costs, oil and gas interests oppose stage II controls, and the automobile manufacturers oppose onboard regulations. The Director of EPA's Office of Policy Analysis (responsible for studying vapor recovery after the 1977 amendments) told us that because of the political opposition associated with vapor-recovery controls, the states want EPA to impose controls on them.

The Executive Secretary of the State and Territorial Air Pollution Program Administrators [1] explained that stage II controls are politically difficult for states to implement, especially without EPA guidance. He stated that state air pollution control officials need EPA to issue a control technique guideline document or some other document mandating stage II controls for nonattainment areas. Such a federal mandate would provide the state air pollution officials with a stronger mechanism to obtain action from their respective governors and state legislatures.

The states encounter other problems that make it difficult to implement stage II controls before EPA makes a decision. For example, in its 1984 draft revision to its state implementation plan, Arizona acknowledged that it would not meet the ozone standard for Maricopa County without stage II or onboard controls. The draft plan noted that Arizona was reluctant to implement stage II controls for several reasons. For example, if EPA decided to require onboard controls after the state had implemented stage II controls, needless costs for the stage II systems would have been incurred. The draft Arizona plan also indicated that if EPA decided to require onboard controls after a state had implemented stage II controls, the two control systems may not be compatible.

[1] This is the national association of state air quality officials in the 54 states and territories of the United States.

States Have Repeatedly Requested a Vapor-Recovery Decision From EPA

States have repeatedly asked EPA for a refueling vapor recovery control decision, and on several occasions between 1978 and 1981, EPA responded that a decision was pending. For example, in response to a letter from the Council of the District of Columbia concerning refueling vapor recovery, the EPA Administrator stated on July 6, 1978, that a decision concerning onboard and stage II control was scheduled for mid-1978. When this deadline passed, the District of Columbia government again requested EPA to explain EPA's position on refueling vapor-recovery controls. On December 28, 1978, the EPA Assistant Administrator for Air, Noise and Radiation, responded that EPA's evaluation of alternative control techniques for vehicle refueling losses would be complete in about 1 month. When no determination was made, the Mayor of the District of Columbia requested that EPA make a decision on refueling vapor controls. The EPA Administrator responded on May 14, 1979, that a decision regarding onboard and stage II controls was forthcoming early that summer.

In a September 27, 1979, letter the Administrator for Air Quality Programs in Maryland requested EPA to indicate when a decision on vapor-recovery controls would be expected. EPA's Director of the Office of Policy Analysis responded that EPA hoped to reach a decision by the end of February 1980. As stated earlier, in April 1981 EPA published a decision that it would not require onboard controls and took no action on stage II controls.

On June 21, 1982, the State and Territorial Air Pollution Program Administrators passed a resolution requesting EPA to take action on stage II controls. The resolution noted that stage II vapor recovery has been successfully implemented in California and the District of Columbia and that such controls would reduce public exposure to benzene as well as limit emissions of volatile organic compounds. [2] The administrators resolved that EPA should review stage II vapor recovery and publish a Control Technique Guideline Document to assist the states in defining reasonably available control technology for controlling of motor vehicle refueling emissions.

When EPA took no action, the same organization passed another vapor control resolution in June 1985. The administrators resolved that EPA

[2] A volatile organic compound is any organic compound which reacts in the presence of ultraviolet radiation to form photochemical oxidants. The oxidants are a major portion of the air pollution commonly known as smog or ozone.

should (1) specify stage II vapor recovery as reasonably available control technology for all ozone nonattainment areas which need stage II to meet the 1987 deadline, (2) establish a national summertime limit on gasoline volatility, and (3) require onboard evaporative control technology.

Some States Are Not Expected to Attain the Ozone Standard by 1987

According to EPA's November 1985 estimates, 32 areas in 26 states will not meet the December 31, 1987, ozone attainment deadline. If EPA or the states had implemented automobile vapor-recovery controls in the late 1970's or early 1980's, states may have had a better opportunity to comply with the 1987 deadline because such controls can result in a significant reduction of hydrocarbons. For example, EPA estimated in July 1985 that refueling vapor controls could result in 100 percent of the needed reduction in Baltimore, Maryland, and 17 percent of the needed reduction in the New York metropolitan area to bring them into attainment with the ozone standard.

Other states could have followed California and the District of Columbia in establishing stage II programs without EPA guidance. Furthermore, if EPA had taken action to implement onboard or stage II controls in the 1970's or early 1980's, such action may have had an impact on the 1987 ozone deadlines. Even with the long time frame involved in implementing onboard controls to the point where automobile fleet turnover results in significant emissions reduction, an EPA decision in the late 1970's or early 1980's could have helped reduce ozone levels by the 1987 deadline. If EPA decides in late 1985 or early 1986 to implement onboard controls, EPA estimates that the technology could not be initially installed on automobiles until 1988 models are manufactured. As a result, the decision will have no impact on states' ability to comply with the 1987 ozone attainment deadline. Similarly, an EPA decision to support stage II controls will have little or no impact on the states' ability to comply with the 1987 deadline because of the leadtimes involved. EPA estimated that, as of October 1985, stage II standards could be issued no sooner than November 1986 and that controls would not be fully installed for another 6 years. EPA estimated that it would take about 1 year beyond November 1986 for the various states to put together a proposal, hold public hearings, and issue final stage II regulations.

EPA has established a Volatile Organic Compound Task Force to collect information on options for those areas projected to be in nonattainment by the 1987 deadline. In late 1985 the task force will present the EPA Administrator with a series of briefings on the options it develops.

Conclusions

The gasoline-marketing network comprises several sectors of gasoline transportation from delivery of gasoline to bulk terminals to refueling automobiles at service stations. EPA has issued guidance for controlling all sectors of gasoline marketing except automobile refueling.

EPA has been studying stage II refueling vapor technology since 1973 for ozone control and 1979 for benzene control. EPA has been examining onboard technology as an option to stage II since the 1977 Amendments to the Clean Air Act mandated EPA to do so.

Since 1978 states have repeatedly asked EPA to make a decision on this issue. EPA is planning to make a decision on gasoline refueling controls by late 1985 or early 1986. However, because of the necessary implementation leadtimes, the decision will come too late to have a significant impact on ozone levels by 1987.

Issues Affecting EPA's Decision to Regulate Gasoline Vapor

EPA officials told us that EPA plans to make a decision by late 1985 or early 1986 on how best to control gasoline vapor emitted during automobile refueling. They believe this will be a potentially controversial decision that could affect the automobile and/or the petroleum industry.

EPA is considering several key factors in making its decisions to control gasoline vapor from automobile refueling. Recent health studies indicate that gasoline vapor—apart from its benzene component—may be carcinogenic. This could change EPA's estimates of the level of individual risk and may affect EPA's refueling vapor control decision. The availability and reliability of the options also affect EPA's decision. Stage II technology has been in place in two states since the 1970's while onboard systems have been demonstrated only on prototype vehicles. EPA assumes, however, that the reliability of onboard systems will be greater than that for stage II systems.

EPA is also analyzing the cost-effectiveness of the various automobile refueling options. Several uncertainties, including onboard and stage II performance and durability, affect the cost-effectiveness estimates that EPA has calculated. In its cost-effectiveness analysis, EPA has not used a range of values to reflect many of these uncertainties because EPA officials believe a range would obscure the comparison of alternatives.

Health Data Concerning Carcinogenicity of Gasoline Vapor Affect EPA's Decision

One of the issues affecting EPA's decision regarding vapor recovery controls is the potential carcinogenicity of gasoline vapor. Prior to 1983, EPA's examination of regulatory strategies concerning vapor recovery focused on controlling the benzene component of gasoline and/or reducing ozone in the atmosphere. However, in 1984 EPA began examining the health effects of gasoline vapor—apart from its benzene component—and the ramifications those health effects may have on the vapor recovery issue.

EPA's analysis of the health effects associated with gasoline vapor is important to EPA's decision regarding vapor recovery control. According to EPA officials, if EPA determines that public exposure to gasoline vapor is a serious problem, it may want to implement nationwide controls. EPA could determine, for example, that the benzene component of gasoline vapor does not present a significant health risk but that the carcinogenicity of gasoline vapor is significant enough to warrant national controls. EPA could then include gasoline vapor on its list of hazardous air pollutants under Section 112 of the Clean Air Act and establish national standards for refueling vapor. Given EPA's experience with delays under

Section 112,[1] this process could be time consuming and could slow the implementation of vapor recovery controls. If EPA determines that neither benzene nor gasoline vapor presents a health threat during automobile refueling, it may still want to regulate gasoline vapor to control smog in ozone nonattainment areas.

In early 1984 the American Petroleum Institute forwarded to EPA an Institute-sponsored animal inhalation study on gasoline vapor. In June 1984 EPA issued a draft staff paper summarizing its evaluation of the study and other epidemiological and animal studies. The staff paper concluded that unleaded gasoline should be classified as a probable human carcinogen. EPA primarily based its staff paper on the American Petroleum Institute's study, which reported that a wholly vaporized (complete evaporation of a liquid to a gas) unleaded gasoline mixture caused certain cancers in two rodent species. The EPA staff paper reported a significant response in animals for carcinogenicity and developed a human risk factor on the basis of its finding. Although EPA reported the epidemiological data to be inadequate because of insufficient documentation of exposures and employment histories, it believed these studies nevertheless indicated scattered reports of kidney cancer.

In July 1984 the Environmental Health Committee of EPA's Science Advisory Board met to review and solicit public comments on the staff paper. After reviewing the staff paper and obtaining public comments, the Science Advisory Board issued a report in October 1984 to the EPA Administrator summarizing its review. The Science Advisory Board's report concluded that

- the American Petroleum Institute's inhalation study of wholly vaporized unleaded gasoline was well designed and properly conducted,
- wholly vaporized unleaded gasoline vapor should be classified as a probable human carcinogen, and
- EPA underrepresented the analysis of the degree of uncertainty in assessing human health impacts. EPA needs to more clearly demonstrate how the calculation of population exposures are utilized in developing risk estimates.

In its January 1985 reply to the Science Advisory Board report, EPA acknowledged the uncertainty in its quantitative risk analysis and agreed to address some of the specific uncertainties listed in the report.

[1] We discussed these delays in our report, Delays in EPA's Regulation of Hazardous Air Pollutants (GAO/RCED-83-199, Aug. 26, 1983).

However, EPA judged that in instances where data were lacking, the standard assumptions common to other risk assessments must still be used.

In September 1985 the Health Effects Institute—a research organization funded equally by EPA and the automobile industry—published a review of the scientific uncertanties surrounding gasoline vapor carcinogenicity. The report concluded that possible carcinogenicity of gasoline vapor to humans cannot be dismissed but it is not possible to draw accurate conclusions concerning the degree of human risk.

EPA plans to complete a final report on gasoline vapor in late 1985. Depending on the report's conclusions, EPA could decide to identify gasoline vapor as a hazardous air pollutant.

Reliability and Availability of Technologies Affect EPA Decision

Another consideration in EPA's decision regarding refueling vapor recovery controls is the reliability and availability of the alternative technologies. Stage II controls have been in use in California and the District of Columbia since the 1970's. Enforcement programs are in place in both states, though they differ in scope and strategy. Onboard technology is not currently in use but has been demonstrated in EPA's Mobile Source Laboratory. EPA's estimates as of July 1985 of onboard in-use reliability were high but may not have taken into account problems with evaporative canisters.

Stage II Technology

Evidence of the reliability and availability of stage II refueling vapor-recovery equipment can be drawn from experience in the 26 counties of California and the District of Columbia, where stage II systems have been required since the early 1970's. Currently, about 14,000 service stations in California and about 250 in the District of Columbia have stage II systems in place. This number represents about 7 percent of the national total of public gasoline-dispensing outlets.

California

Currently, two manufacturers of each type of stage II equipment have had their design certified by the California Air Resources Board (CARB). In order to be certified, the equipment must meet durability requirements, it must control at least 95 percent of refueling vapors during in-use testing, and it must pass tests for frequency of fuel spillage. These requirements were developed to correct deficiencies in the early versions of stage II equipment.

According to CARB officials, a result of these requirements and certain mandated equipment modifications is that the in-use performance of stage II systems has improved in recent years. The number of customer complaints about stage II equipment has decreased over time. CARB's latest report to the state legislature, in 1983, reported 2,533 complaints over an 11-month period, a rate of about 1 complaint per 200,000 vehicle refuelings. Fuel spillage was the most common complaint.

CARB's 1983 report to the legislature estimated that the in-use control efficiency of stage II systems is approximately 80 to 92 percent. This value includes the impact of equipment defects on efficiency. EPA's analysis estimates control efficiency of 62 to 86 percent, depending on enforcement effort. The latter value corresponds to an enforcement effort like that undertaken by California. CARB's Director of Engineering told us that recent improvements in stage II equipment and new CARB requirements should result in further improvements in performance and in ease of use.

California's stage II enforcement is overseen by the state's Air Resources Board and implemented by regional Air Quality Management Districts. District inspectors are empowered to prohibit use of gasoline pump nozzles and assess fines (up to $1,000/day) if previously discovered defects have not been repaired. The state now requires these districts to visit each dispenser of fuel above a specified volume at least once a year. The San Diego district requires inspections three times a year for commercial and once a year for noncommercial facilities. The Director of Engineering for this district told us that its enforcement program was financed entirely from permit fees (about $50 per nozzle per year) charged to dispensing outlets. Other districts also charge fees, but not all costs are covered by them.

District of Columbia

Stage II systems in the District of Columbia must be certified at efficiency levels established by the California Air Resources Board. District regulations allow each station to maintain one nozzle of its choice without stage II controls. District Air Pollution Control officials told us that the District's enforcement program was minimal until 1985, when it increased its inspection and legal staff. They now plan to inspect every station annually and estimate the cost of each inspection to be $10 to $15 per station.

The District is empowered to issue fines of up to $5,000 per violation per day for noncompliance with stage II regulations. In 1985 the District obtained its first two convictions for service station owners in noncompliance, and as of October 1985, it had 15 cases pending.

Onboard Technology

EPA's evaluation of the feasibility of onboard control technology is based partly on testing of prototype onboard equipment, and partly on the similarity of the onboard system to the evaporative emissions control systems installed on new vehicles since 1971. In its July 1984 strategies document, EPA considered an onboard prototype that was developed and tested by the American Petroleum Institute in 1978. On the basis of that testing, EPA estimates that onboard systems would be capable of 92-percent in-use control efficiency, and would function for the average lifetime of a passenger vehicle. EPA officials stated that their judgment on durability did not reflect testing over long periods of time or actual testing up to 100,000 miles on any vehicle (the average life of a passenger car).

Since publication of the strategies document, EPA had developed a different prototype onboard system with a liquid seal rather than a mechanical seal. (See app. V.) EPA believes the liquid seal system is superior to the earlier version. EPA estimates that this onboard system will have a 95-percent in-use control efficiency, including the effects of deliberate tampering with the equipment by vehicle owners. As of September 1985, EPA had not performed extensive durability testing of onboard systems. EPA officials believe that the only significant uncertainty about the durability of onboard systems concerns the effect of alcohol-blend fuels on the carbon in the canisters. EPA had asked a contractor to examine this issue but, as of August 1985, did not have data on it yet. Officials in EPA's Office of Mobile Sources told us that onboard technology would be a high-efficiency technology that would require minimal enforcement resources to maintain.

The California Air Resources Board believes that EPA's estimate of onboard system control efficiency may be overly optimistic, given that the system has not yet been demonstrated on an in-use vehicle fleet. CARB also noted that evaporative emissions canisters have not succeeded in controlling all of the evaporative emissions, which may be due to flaws in the system. Thus, EPA's assumptions that onboard systems will be effective because they are an extension of evaporative emissions systems does not seem appropriate, according to CARB. The engineering project manager at EPA's Office of Mobile Sources acknowledged that evaporative canisters do not always meet performance standards when tested on in-use vehicles. He stated that this occurs because of the increased volatility of in-use fuel relative to the volatility of fuel used to design and test the canisters.

Other potential performance problems were raised by members of the Motor Vehicle Manufacturers Association. They argued that onboard systems might affect vehicles' ability to meet exhaust emissions standards, because the fuel system would be required to process the additional fuel from vapor recovery. The Association argued that such effects will not be known until EPA specifies a final test procedure for onboard systems. EPA does not anticipate increased exhaust emissions because of the addition of onboard systems based on analysis of their prototype system.

EPA Is Analyzing the Cost-Effectiveness of Refueling Emission Control Alternatives

In developing information to support a regulatory decision, EPA is estimating the cost-effectiveness of alternative strategies for controlling emissions from the vehicle refueling stage of gasoline marketing. EPA published preliminary estimates in July 1984 and, as of August 1985, was revising the estimates in response to comments by various groups, including industry and state and local governments. Because EPA is continuing to examine this issue before making a final decision, EPA's assumptions and estimates may change. In this report, we review EPA's analysis as of its July 1985 draft options paper to the EPA Administrator.

Uncertainties in Cost-Effectiveness Estimates Should Be Displayed in EPA's Decision Document

In a 1984 report to the Congress,[2] we discussed the need for EPA to present ranges of estimates in its cost analyses when the estimates are uncertain. We noted that presenting the underlying uncertainty is important because, among other things, it indicates the degree of precision that can be attached to the estimates, and it provides guidance to the decision maker for planning future research efforts to sharpen the accuracy of the estimates. We recommended that EPA prominently present the ranges of uncertainty associated with cost and benefit estimates as well as the sources of uncertainty. EPA agreed with the recommendation and included it in its final Regulatory Impact Analysis guidelines issued in 1984.

[2] Cost-Benefit Analysis Can Be Useful in Assessing Environmental Regulations, Despite Limitations (GAO/RCED-84-62, Apr. 2, 1984).

EPA has not presented most of its cost-effectiveness estimates for vehicle-refueling control options with ranges to reflect the underlying uncertainty. In the 1984 strategies document, none of the cost-effectiveness estimates in the executive summary were presented with ranges. In the July 1985 options paper, EPA only presented ranges reflecting uncertainty about (1) stage II control efficiency due to varying enforcement efforts and (2) the time needed to implement stage II as a nationwide strategy. Several other uncertainties affect the cost-effectiveness estimates of both stage II and onboard systems, but were not presented as ranges in EPA's analysis. These include the cost of alternative technologies, control system performance and durability, and the length of implementation schedules for both options.

Control Costs

EPA's estimates of stage II costs in its 1984 strategies document were based on data generated in 1978. In responding to that document, several commenters noted that stage II technology had changed considerably in that time period. EPA reanalyzed these costs and incorporated more up-to-date information on the basis of systems currently in use.

At least two factors make the total cost of a stage II regulation difficult to estimate. One is that the future population of gasoline stations is not known with certainty. EPA's 1985 analysis assumes that the number will decline in proportion to the volume of gasoline dispensed. The decline is consistent with the trend in recent years, but the actual rate of decline is uncertain.

A second source of uncertainty affecting stage II costs is the size exemption policy that will apply to the regulation. Size exemptions refer to a level of business below which a service station would be exempted from having to install stage II equipment because of the economic hardship it would impose. The size exemption policy specified by section 324 of the Clean Air Act relates to the use of stage II as an ozone control measure. This section states, for example, that automobile refueling vapor recovery regulations shall not apply to any independent small business gasoline outlets having monthly sales of less than 50,000 gallons. However, state air quality authorities may choose to require a lower (more stringent) exemption level if they prefer. In California, for example, exemption levels are below those specified in section 324; EPA allows this because it results in stricter levels of control. EPA calculations indicate that the lower the exemption level size is, the higher (more expensive) the cost-effectiveness value is for stage II systems. An official in EPA's Office of General Counsel told us that, as of October 15, 1985, EPA had not made a decision as to whether section 324 guidelines on size exemptions apply if stage II is required to control benzene or other hazardous pollutants regulated under section 112 of the act. As a result, the actual exemption policy by EPA and the states is unclear, adding to the uncertainty of the analysis.

EPA's estimates of onboard system costs are based on analysis of the components of a prototype system it has designed. EPA's July 1985 draft options paper estimated the cost of an onboard system to be about $22 per vehicle. In comments on the 1984 strategies document, automobile manufacturers stated that EPA's cost estimates were very uncertain, given that final test specifications have not been established and hence the final configuration of the equipment is unknown. Their estimates of onboard costs were higher than EPA's, ranging from $30 per vehicle (General Motors) to $85 per vehicle (Chrysler).

Performance and Durability

EPA's cost-effectiveness analysis assumes that onboard equipment will be 95-percent efficient for controlling emissions and that the only reduction of efficiency in use would be due to tampering by a small percentage of vehicle owners. EPA also assumes that the onboard system will last for the life of the vehicle.

Commenters on EPA's 1984 strategies document raised some questions about these assumptions. One automobile manufacturer noted that evaporative emissions canisters currently on cars have failed to control all of the evaporative emissions. According to EPA officials, this failure is the result of the higher volatility of in-use fuel than the fuel on which the evaporative canisters were tested.

EPA told us that there may be other reasons for this "excess," including inadequate capability of the fuel system to process all of the vapors, and also the possible deterioration of the carbon in the canisters. The San Diego Air Pollution Control District reported in its comments that it found deterioration of the absorptive capacity of similar carbon canisters in the early years of the stage II program.

As of October 1985, EPA had not conducted any on-road testing to verify the durabilty of onboard systems. No vehicles have been equipped with the current prototype and driven 100,000 miles, the number of miles EPA assumes corresponds to the lifetime of a passenger car.

EPA's analysis does include ranges to reflect uncertainty about stage II control effectiveness owing to varying enforcement efforts across jurisdictions. The comments by the California Air Resources Board emphasized that a thorough enforcement effort is essential to ensure the adequate performance of stage II systems. EPA assumes that enforcement effort will vary from state to state, and that in-use stage II control efficiency will range from 62 to 86 percent, depending on the level of enforcement.

Refueling Vapor Recovery Options Implementation Schedule

EPA has estimated the implementation time required for both stage II and onboard controls. The shortest implementation period would be for stage II in ozone nonattainment areas only, which EPA estimates would be fully installed 6 years after promulgation, projected to be November 1986 at the earliest. Stage II nationwide, would take longer to promulgate (until 1989) plus another 3 to 7 years to fully install. A nationwide strategy could be based on plans to control benzene, gasoline vapor, or both as hazardous air pollutants. Onboard controls would take the longest time to implement fully. EPA assumes that onboard final standards can be issued in 1986 and that systems would begin being installed on 1988 model vehicles. EPA estimates that 90 percent of the vehicle fleet would be controlled 10 years after initial installation and that the entire fleet would be controlled 15 to 20 years after initial installation.

EPA received differing reactions to its assumptions about stage II and onboard implementation timetables. The American Petroleum Institute commented that lack of a sufficient number of construction contractors capable of installing stage II equipment could slow implementation. EPA incorporated this comment by including the 7-year estimate as the upper bound in the range cited above. The California Air Resources Board commented that a 3-year timetable for stage II implementation seemed reasonable, given that the technology is currently commercially available. The board believes that EPA's assumed lead-time prior to initial installation of onboard systems (2 years), is probably too optimistic, given the difficulties California has experienced in the past trying to get auto manufacturers to install new pollution control equipment. CARB thought a minimum of 4 years lead-time was appropriate.

Inconvenience Costs

Another source of uncertainty in EPA's analysis is the inclusion of "inconvenience costs" of stage II systems. This refers to the amount of money customers would be willing to pay to avoid the necessity of using stage II nozzles, which are generally more cumbersome than conventional gas pump nozzles. EPA is considering conducting a survey of California residents who use stage II equipment to generate empirical estimates of these costs. According to an economist in EPA's Office of Program Planning and Evaluation, the results of this survey will probably not be available in time to support EPA's decision on vehicle refueling emission controls. EPA's July 1985 draft options paper instead includes inconvenience costs in a sensitivity analysis of stage II's cost-effectiveness. EPA does not present estimates of the effects of inconvenience costs on stage II's cost-effectiveness, but it reports that stage II cost-effectiveness values could double if an inconvenience cost of 2 to 2-1/2 cents per fillup is assumed. Depending on the time period over which the strategies are compared, this would either make stage II and onboard controls equally cost-effective, or make stage II less cost-effective than onboard controls. In both cases stage II was more cost-effective without the inclusion of the inconvenience costs.

Actual inconvenience values are uncertain. The inconvenience of stage II varies with the type of equipment; vacuum assist systems, for example, are lighter and easier to use than balance systems. Also, the latest versions of both systems' nozzles are more convenient than earlier versions. One model we examined is virtually indistinguishable from conventional nozzles in weight and bulkiness. In addition, consumers' concerns about inconvenience could depend on their understanding of the role of stage II equipment. The manner in which EPA's survey questions are asked to determine these costs is also important to the outcome.

Ranges Will Represent Uncertainty

EPA officials told us that EPA generally relies on point estimates rather than ranges when presenting results of its automobile refueling cost-effectiveness estimates because presenting ranges would obscure the differences between alternatives. They said EPA prefers to use its best estimates for each alternative, and to describe uncertainties qualitatively rather than quantitatively.

Unless EPA presents the uncertainties associated with its cost-effectiveness estimates, the differences between competing alternatives may be exaggerated. For example, according to EPA calculations in the 1984 strategies document, the ranking of alternative strategies by cost-effectiveness ratios was changed by assuming different values for the estimated cost-per-vehicle of onboard systems. Stage II became more cost-effective when the higher of two possible costs values was assumed.

EPA's selective presentation of uncertainty in its automobile refueling analysis may create misleading impressions. When EPA presented the estimates of stage II control efficiency as uncertain in its draft July 1985 options paper, but presented the control efficiency of onboard systems as certain, it gives the impression that more is known about the latter technology than about the former. However, stage II is a technology currently in use at thousands of service stations, whereas onboard is a prototype technology. Thus, a misleading impression may be created by not presenting uncertainties associated with each option.

We believe that EPA's qualitative description of uncertainties in its cost-effectiveness analysis will have some benefits. However, we believe that a quantitative presentation of ranges, when available, provides a more accurate indication of the uncertainties and will serve to identify the most uncertain components of the cost-effectiveness estimation. We do not believe the inclusion of ranges in EPA's presentation should require additional time or resources prior to making its decision because EPA has, in many cases, generated ranges of estimates in the process of developing the point estimates it has reported.

EPA's Presentation of Cost-Effectiveness Ratios

According to EPA's guidelines for performing Regulatory Impact Analyses, situations may arise where a cost-benefit analysis of regulatory alternatives is not possible owing to the difficulty of estimating benefits. In those instances EPA recommends that a cost-effectiveness analysis be conducted instead. However, as the guidelines point out, cost-effectiveness analysis by itself does not necessarily reveal the level of control of a pollutant that results in maximum net social benefits (the difference between social benefits and social costs) as would be the case in a properly conducted cost-benefit analysis. Rather, the guidelines state that a cost-effectiveness analysis can only indicate the most efficient way of achieving a predetermined objective, such as avoiding a specific level of pollutant emissions. Consequently, when using cost-effectiveness analysis to compare control options, EPA's guidelines recommend that EPA present the degree to which each option contributes to achieving applicable air quality goals.

Two air quality goals are identified in EPA's analysis of automobile refueling control options. One goal is to reduce benzene emissions, which EPA has determined to cause adverse health effects. The other goal is to lower ozone concentrations in certain areas to meet the ambient air quality standard. EPA has determined that adverse health effects and other problems are associated with ozone levels above this standard.

In evaluating its control options, EPA calculated two types of cost-effectiveness ratios, corresponding to the two air quality goals. To measure cost-effectiveness of benzene emission control strategies, EPA calculated "dollars-per-cancer-incidence-avoided." To do so, EPA estimated the number of cancer incidences avoided because of benzene emission reductions and divided this into the cost of reducing those emissions with each option.

To measure the cost-effectiveness of ozone control strategies, EPA presented ratios in terms of dollars-per-megagram of volatile organic compound emissions reduced. These are the emissions that lead to ozone formation. EPA did not calculate the number of health effects associated with these emissions, because of the difficulty of estimating these effects. However, these cost-effectiveness ratios, as calculated, cannot be used to determine the most efficient way of achieving the ozone air quality standard because the value of each megagram of reduction is not necessarily the same for all options. This is because some options reduce emissions in ozone nonattainment areas only, while others reduce emissions nationwide. The reduction of volatile organic compound emissions in ozone nonattainment areas is more important than in attainment areas because EPA has determined that adverse health effects occur at the high levels of ozone in the former, but not necessarily at the lower levels in the latter. As a result, volatile organic compound reductions due to nonattainment area options are not directly comparable with those of nationwide options.

One method EPA could use to compare ozone reduction options on an even basis would be to show the extent to which each option contributes to achieving the ozone air quality standard. EPA could do this by presenting in its analysis (1) emission reduction estimates in nonattainment areas needed to meet ozone standards and (2) emission reductions in nonattainment areas associated with each option to compare with this goal. If EPA presented this information, then the cost-effectiveness ratios could be used to select the option(s) which achieve(s) the desired reductions at the lowest cost. Ranking options by cost-effectiveness ratios without this information could lead to the selection of an option that is cost effective but one that does not achieve the desired air quality goal. Presenting the information about the contribution of each control option to achieving the ozone standard should not require delays in EPA's decision-making process. For example, EPA already has estimates of the emission reductions in nonattainment areas associated with each option. This information was used in calculating some of the cost-effectiveness ratios EPA presented. In addition, EPA has some information, provided by states that contain ozone nonattainment areas, on the emission reductions needed in those areas to meet the ozone standard. Using these types of information, EPA could calculate the contribution of each option toward the ozone attainment goal.

EPA officials agreed that cost-effectiveness analysis alone should not be used to compare ozone reductions achieved by nationwide and nonattainment area strategies. They said that the EPA Administrator would be considering the ozone control benefits of each control option in his decision on vehicle refueling. In addition, they said they would try to incorporate information about the benefits of the different regulatory options into their document to support EPA's final decision.

Economic Impacts of Automobile Refueling Options

EPA has estimated the unit cost and quantity impacts of automobile refueling emission control options. According to an official in EPA's Office of Air Quality Planning and Standards, EPA's estimates of the unit cost increase associated with stage II controls would be 0.16 cents (or about 0.14 percent) out of a base price of $1.19 per gallon of gasoline. EPA estimated that stage II controls would result in a reduction of about 832 million gallons (or about 0.08 percent) of gasoline sold per year out of a total of 1,096 billion gallons per year.

EPA also estimated the possible economic impacts of a stage II regulation on service stations. In its July 1985 draft options paper, EPA estimated that 190 service stations (or about 0.11 percent of the projected 1988 service station population of 173,000) would close as a result of a nationwide stage II regulation. EPA did not estimate the impact of a stage II regulation for nonattainment areas only because it did not have information on local market conditions. EPA documentation shows that unit cost impacts of a stage II regulation would be greater for small-volume service stations than for large ones, even when size exemptions are permitted for the smallest ones. As a result, EPA believes a stage II regulation would probably lead to a population of fewer and larger service stations. In this regard, EPA points out, it would amplify a well-established historical trend away from smaller stations to larger, more cost-effective facilities.

On the basis of a reanalysis as of July 1985 conducted by EPA's Office of Mobile Sources, the short-term costs for EPA's onboard design were estimated at an average of about $22 per vehicle, decreasing to $18 over time. EPA estimated that the impact of these price increases would be a reduction in sales of 26,200 (or 0.2 percent) of the 13.1 million passenger vehicles and 8,200 (or 0.2 percent) of the 4.1 million light-duty trucks.

Other Options That Could Affect Automobile Refueling

EPA's Office of Mobile Sources is studying two options that relate to its decision on how best to regulate automobile refueling. These include enlarging evaporative canisters on automobiles and controlling gasoline volatility.

EPA is studying the option of requiring the automotive industry to enlarge evaporative canisters to control evaporative emissions. While this option would not control refueling emissions, EPA data indicate that it would be less expensive and a more cost-effective way to control hydrocarbons than onboard or stage II.

EPA is also considering placing limitations on gasoline reid vapor pressure, a measure of gasoline volatility. Automobile gasolines are classified by five volatility classes. Low volatility gasoline is suitable for use in the highest temperature and highest altitude areas of the country in the summer. Highest volatility gasoline is suitable for use in the coldest regions in winter. According to EPA, reid vapor pressure ranges from 7 to 16 pounds per square inch, the average being 10 in summer and 12.5 in winter.

Average reid vapor pressure has been increasing since the 1970's. Petroleum refiners have added more butane and pentane liquid to gasoline because they are cheaper substitutes for gasoline and serve as octane boosters. By controlling gasoline reid vapor pressure, EPA could reduce the emission factor associated with evaporative and automobile refueling emissions. For example, if EPA limited gasoline reid vapor pressure to 9 pounds per square inch during the summer months (when smog is the worst) the amount of smog-creating pollution from evaporative and refueling emissions would be reduced.

According to EPA officials, these options could be implemented in concert with automobile refueling alternatives. For example, EPA could require onboard controls and impose a limit on gasoline reid vapor pressure. As of October 1985, EPA was studying controls on reid vapor pressure and evaporative canisters and was planning to make a decision on these issues sometime in late 1985.

Conclusions

EPA is considering regulating refueling emissions for several reasons—to control the hazardous air pollutant, benzene; to control the suspected carcinogen, gasoline vapor; and/or to control hydrocarbons, which contribute to ozone and smog formation. According to EPA officials, if, in studying refueling emissions, EPA decides to regulate benzene or gasoline vapor, it would consider implementing nationwide controls. If, however, EPA decides to regulate refueling emissions for ozone control purposes, it may implement controls only in those areas with smog problems (i.e., those areas considered in nonattainment with the ozone standard).

EPA's options for refueling controls include

- implementing a stage II program either nationally or in ozone nonattainment areas only and/or
- requiring a nationwide onboard program.

These options could be used with a combination of other alternatives, including expanding stage I controls nationwide; increasing the size of the evaporative canister currently on automobiles and/or controlling the volatility of gasoline.

In making its decision, EPA is considering several factors including health data, reliability and availability of the technologies, and the cost-effectiveness of each option. Recent information available to EPA, for example, indicates that gasoline vapor—apart from its benzene component—may be carcinogenic. Therefore, if EPA decides the risk from this vapor is significant, it could require national controls. Conversely, if EPA believes the risk to the public is minimal, it could require controls only in those areas where states are having difficulty in attaining the ozone standard.

Several other factors affect EPA's refueling vapor control decision. For example, stage II is a proven technology that has been in use in California and the District of Columbia since the 1970's. Onboard controls have been demonstrated in prototype vehicles. In addition, stage II controls can be implemented faster than onboard controls. EPA estimates the lead time for implementation to be similar for the two options. However, because the effectiveness of onboard controls depends on automobile fleet turnover, EPA estimates that stage II could be fully implemented 3 to 10 years before onboard controls.

The efficiency of both options depends on how they are enforced. EPA estimates the enforcement resources required to maintain stage II systems to be significant. EPA also estimates that the in-use efficiency of stage II will range from 62 to 86 percent, depending on the degree of enforcement. EPA estimates enforcement resources for onboard controls to be minimal. However, EPA may have overestimated the in-use efficiency of onboard controls because the evaporative canisters have not always been performing at the expected efficiency.

EPA and states anticipate that because of the heavier or bulkier nozzles, stage II controls will generate public resistance. EPA also expects intense opposition to onboard controls from automobile manufacturers and to stage II controls from oil companies and gasoline dealers.

EPA is also examining the cost-effectiveness of each option. Several uncertainties are involved in this cost-effectiveness analysis, including the cost, performance, and implementation schedule of the options. EPA's analysis, however, does not always provide a range of values to reflect these uncertainties, as recommended in its Regulatory Impact Analysis Guidelines. Instead, EPA's analysis primarily relies on point estimates, rather than ranges because EPA officials believe that presenting ranges would obscure the differences between alternatives. EPA has chosen to describe the uncertainties qualitatively rather than quantitatively. Because they do not always include ranges, EPA's cost-effectiveness numbers for each option do not indicate the degree of precision that can be attached to the estimates, and they may exaggerate the differences between the options.

Furthermore, EPA should use caution in interpreting the results of its cost-effectiveness analysis of automobile refueling control options. The options should be compared in terms of the extent to which each contributes to desired air quality goals, as well as in terms of their cost-effectiveness ratios.

Recommendation

To improve EPA's cost-effectiveness analysis used to help determine the best alternative for controlling automobile refueling vapor emissions, we recommend that the Administrator, Environmental Protection Agency, direct that a range values be provided to reflect the various uncertainties inherent in its cost-effectiveness analysis.

EPA's In-House and Contractual Expenditures for Controlling Benzene Under Section 112 of the Clean Air Act

Table I.1: Total EPA Expenditures on Benzene Standards, Fiscal Years 1977-85

	In-House	External	Total
Office of Air Quality Planning and Standards	$ 2,355,180	$ 3,713,138	**$ 6,068,318**
Office of Research and Development	9,900	54,253	**64,153**
Total	**$ 2,365,080**	**$ 3,767,391**	**$ 6,132,471**

Source: EPA.

Table I.2: Contractors Used by EPA's Office of Research and Development to Regulate Benzene Emissions for Fiscal Years 1977-85 (As of June 1985)

Contractor	Contract purpose	Time frame (fiscal year)	Cost
Life Systems, Inc.	Review of benzene epidemiology studies	1984	$ 5,259
	Technical support of health assessment document on benzene (toxicology)	1985	$ 31,446
	Technical support of health assessment document on benzene (epidemiology)	1985	$ 17,548

Source: EPA.

Table I.3: Contractors Used by EPA's Office of Air Quality Planning and Standards to Regulate Benzene Emissions (As of May 1985)

Contractor	Contract purpose	Time frame (fiscal year)	Cost
Energy and Environmental Analysis	Regulatory development- ethylbenzene/styrene	1977-81	$380,000
	Economic analysis	1979-81	30,969
	Health appendix for ethylbenzene/styrene	1980	3,000
JACA	Economic analysis	1979-81	104,385
Pacific Environmental Services	Regulatory development- fugitive emissions	1977-84	415,000
	Gasoline-marketing studies	1983-85	436,000[a]
PEDCO Environmental, Inc.	Atmospheric assessment	1977-78	53,750
Radian Corporation	Assessment of selected stationary source categories of benzene	1983	41,300
	Chemical manufacturing categories	1984	12,250
Research Triangle Institute	Regulatory development- maleic anhydride	1977-84	460,000
	Economic analysis	1979-81	31,500
	Health appendices for benzene storage and fugitive emissions documents	1980	9,034
	Regulatory development- coke by-product	1980-84	865,000[a]
	Regulatory development- ethylbenzene/styrene	1981-84	135,000
	Economic analysis	1983-85	126,000
Stanford Research Institute	Exposure estimates around storage tanks	1980	9,950
TRW-Radian Corporation	Regulatory development- storage	1977-84	600,000

[a]To date.

Status of EPA's Regulation of Benzene Source Categories

As can be seen on table II.1, EPA has identified 18 stationary and mobile source categories of benzene emissions (including the 12 priority categories it identified in 1979). It plans to regulate two of these categories and is studying options that could affect seven others. EPA has decided it will not regulate the other benzene source categories because it believes the risks to the public health are not significant or it does not have sufficient information to make a decision.

Plans to Control Some Source Categories of Benzene Emissions

EPA issued a final standard for fugitive emissions and proposed a standard for coke by-product recovery plants in June 1984. EPA is currently assessing options for controlling benzene emissions from the gasoline-marketing network. Also, EPA is controlling some benzene emissions through other air regulations designed to control volatile organic compounds.

Benzene Fugitive Emissions

EPA issued final standards for fugitive emissions on June 6, 1984. The standard applies to service equipment (such as valves, pumps, and compressors) containing materials with a benzene concentration of 10 percent or more. The standard affects equipment in more than 200 units such as petroleum refineries and pharmaceutical and chemical industries. The standard requires industry to conduct periodic inspections, usually monthly, of the equipment for benzene leaks. Additionally, it requires that initial repairs on the equipment (valves, pumps, and compressors) be attempted within 5 days and repairs be completed within 15 days.

Table II.1: EPA's Estimates of Benzene Emissions As of May 1985

Source category	Benzene emissions (Mg/yr)	Percentage of total emissions	Status of EPA's actions
Fugitive emissions	7,900	3.1	Standard issued
Coke by-product recovery plants	26,800	10.6	Standard proposed
Maleic anhydride production	60	•	Proposal withdrawn
Ethylbenzene/Styrene production	155	.1	Proposal withdrawn
Benzene storage tanks	1,290	.5	Proposal withdrawn
Gasoline marketing:			
Stage I	3,274[a]	1.3	Proposal under study
Auto refueling	2,726	1.1	Proposal under study
Linear alkylbenzene production	260	.1	Proposal under study
Nitrobenzene production	240	.1	Proposal under study
Chlorobenzene production	110	•	Proposal under study
Ethylene production	480	.2	Proposal under study
Automobiles:			
Evaporation	36,509	14.4	Proposal under study
Exhaust	173,419	68.4	No action
Cumene production	Trace[b]	•	No action
Cyclohexane production	Trace[b]	•	No action
Benzene handling (barge loading)	360	.1	No action
Solvent use	Trace[c]	•	No action
Waste disposal	d	•	No action
Total	**253,583**	**100.0**	

[a]Includes bulk terminals, bulk plants, and service station storage tanks.

[b]Both cumene and cyclohexane processes occur at elevated temperatures and pressures. No process emissions would be expected during normal operations.

[c]A 1978 telephone survey showed 1,800 Mg/yr. Limited follow-up in 1983 indicated significant decreases in use. Category not included in percent of emissions calculation.

[d]Not available.

Source: EPA.

EPA's proposal identified 13 industry process components as potential sources of fugitive emissions. However, 3 of the 13 components—cooling towers, wastewater separators, and process unit turnarounds—were excluded from the standard because data were not available to indicate the extent of benzene emissions or technology to control emissions. A fourth component, agitators, was also excluded because EPA did not consider it a significant source of benzene emissions. EPA also stated that standards could be proposed in the future if information became available showing the extent of emissions from these sources. EPA has made no decision relative to proposing standards to control these emissions, although it has collected some benzene emission data on these components. According to officials in the Standards Development Branch of EPA's Office of Air Quality Planning and Standards, the emissions from these components do not appear significant and, therefore, EPA is placing a low priority on regulating these emissions.

Coke By-Product Recovery Plants

On June 6, 1984, EPA proposed a standard that would reduce benzene emissions from more than 20 emission points at coke by-product recovery plants [1] that would be affected by the standards. EPA estimated that the standard would reduce benzene emissions from these plants by 89 percent. EPA has slipped the date for issuing a final standard from the fall of 1985 to March 1986 in order to analyze the public comments it received.

EPA initially estimated the annualized cost of the standard would be a savings to the industry. However, after receiving numerous comments from the coke industry and reanalyzing the cost data, EPA officials stated that their cost estimates were too low.

The proposed standard identifies specific types of equipment for the plants to use in controlling emissions. Industry officials prefer that EPA set the standard with a specific level of control and allow the industry to select and use the most appropriate control to meet this level. According to EPA, the specific types of controls emphasized in the proposed standard were identified as effective and thus EPA used them for its initial cost estimates. EPA does not consider these as the only controls that

[1] Coke by-product recovery is related to the steel industry. Coal is heated to produce coke in order to convert iron ore to iron. The capture and refinement of the gases from the coking process is actually a separate industry known as coke by-product recovery.

industry can use. EPA officials stated that EPA will approve any technology that industry demonstrates as effective in controlling benzene emissions.

Gasoline Marketing and Evaporative Emissions

EPA is currently assessing its options for controlling benzene and/or hydrocarbon emissions at various points within the gasoline-marketing and distribution network. As part of this assessment, EPA is also reviewing options for reducing automobile fuel system evaporative emissions. EPA estimates that about 3 percent of total benzene emissons are from gasoline marketing and 14 percent are from automobile fuel system evaporation. EPA's options for controlling gasoline-marketing emissions are discussed in chapter 4.

Volatile Organic Compounds Regulations

Benzene is one of the chemicals that EPA classifies as a volatile organic compound. Thus, EPA, controls some benzene emissions through various volatile organic compound regulations designed to ensure that the ozone standard is met. For example, EPA's volatile organic compound emission standard for petroleum refinery wastewater systems requires the refineries to control emissions from several points within the wastewater system. EPA has issued several additional regulations to control volatile organic compound emissions from other sources that contribute to ozone and smog formation.

EPA Withdrew Three Proposed Benzene Standards

In 1979 EPA prioritized the major source categories of benzene emissions and selected several for regulatory action. Between April and December 1980, EPA issued proposed standards for three source categories—maleic anhydride, ethylbenzene/styrene, and benzene storage tanks. By May 1983 EPA recognized that the amount of benzene emissions from these sources had decreased because of plant closures and the installation of additional emission controls. According to internal EPA documents, EPA was still planning to issue the three proposed standards because control technologies were readily available at reasonable cost to further reduce benzene emissions. However, as discussed in chapter 2, EPA reexamined the proposed standards and announced in December 1983 its intentions to withdraw these proposed standards. EPA issued a proposed withdrawal notice in March 1984, and on June 6, 1984, withdrew the three proposed standards.

EPA's basis for withdrawing the three proposed standards was that public risk from benzene emissions had declined significantly since the standards had been proposed. The following are the specific reasons for withdrawing the proposed standards:

1. Maleic anhydride production: In April 1980 EPA identified 10 maleic anhydride plants that used benzene in their production processes. However, by 1984 EPA data showed that only three plants were using benzene. EPA cited the closure of some maleic anhydride plants, the discontinued use of benzene in the production process by other plants, and the installation of emission controls as its reasons for withdrawing the standard. The small reduction in the health risks achievable with additional controls was also cited by EPA. As of August 1985, only one maleic anhydride plant used benzene in its production process.

2. Ethylbenzene/Styrene production: In August 1980 EPA identified 17 ethylbenzene/styrene plants that used benzene in their production processes. After proposing the standard in 1980, EPA reduced its estimates of the amount of benzene emitted from ethylbenzene/styrene process vents. The study indicated that industry flares destroyed benzene at a 98-percent efficiency rate, compared with the 60-percent efficiency rate EPA used at proposal. EPA cited the broad use of controls, the relatively small amount of emissions, the low health risks, and the small reduction in health risk that would be achieved with additional controls as reasons for withdrawing the standard. As of August 1985, EPA officials were not aware of any changes in the amount of emissions or the number of ethylbenzene/styrene plants since the withdrawal of the proposed standard.

3. Benzene storage tanks: In December 1980 EPA estimated that 143 petroleum and chemical plants would be affected by the proposed benzene storage tank standard. As of March 1984, 126 plants would have been affected by the standard. EPA's reasons for withdrawing the proposed standard were the extensive number of controls in use, the relatively small amount of emissions, the small health risk, and the inability to reduce health risks significantly with additional controls. As of August 1985, EPA was not aware of any change in the status of this emission category since the withdrawal of the proposed standard.

EPA Plans Not to Regulate Four Benzene Source Categories

Because it believes the health risks are not significant enough to warrant imposing national emission standards, EPA plans not to regulate the process vents for four other benzene source categories—linear alkylbenzene, nitrobenzene, chlorobenzene, and ethylene. However, as of September 1985, EPA was examing the possibility of referring these source categories to the states for regulation. According to an EPA decision memorandum, benzene emission data provided by industry were used in determining the low health risk for those four source categories. EPA's rationale for relying upon the data was that even with the uncertainty of the estimates, the emissions were not significant enough to affect its decision. Officials in EPA's Office of Air Quality Planning and Standards also cited the fact that the estimated cancer incidence rates for these categories are lower than the rates for the three source categories for which EPA withdrew proposed standards. EPA also believes that the benzene fugitive emission standards issued in June 1984—though not affecting process emissions—reduced some of the emissions from these plant sites.

EPA Has Taken No Action to Control Other Sources of Benzene Emissions

EPA is not considering controls for several of the benzene source categories, including automobile exhaust, benzene handling, and some chemical processes. EPA states that the lack of reasonable technology for some sources and the insignificant amounts of benzene emissions for other sources do not warrant EPA's regulating them.

Automobile Exhaust Emissions

EPA estimates that benzene emissions from automobile exhaust account for more than 173,000 megagrams per year, or about 68 percent of all benzene emissions. According to a project manager in EPA's Office of Mobile Sources, EPA has no plans to reduce the benzene component of automobile exhaust emissions. He noted that the catalytic converter regulations and inspection and maintenance programs, [2] which are aimed at reducing hydrocarbons in automobile exhaust, also control some benzene emissions. EPA estimates a 60-percent reduction in total hydrocarbons since 1970 and projects that, because of the growing use of the catalytic converter and the inspection and maintenance programs, benzene exhaust emissions will be reduced another 60 percent by the year 2000. According to the EPA official, EPA currently has no further plans to

[2] We reviewed EPA's Inspection and Maintenance Program in our report, Vehicle Emissions Inspection and Maintenance Program Is Behind Schedule (GAO/RCED-85-22, Jan. 16, 1985).

require additional controls for automobile exhaust because no other technology will reduce benzene emissions.

In 1979 EPA examined the feasibility of removing benzene from gasoline and determined that this option was not reasonable because of the excessive cost and limited benefits. Since the catalytic converter on automobiles already provided some control for benzene emissions, EPA took no further action.

Benzene Handling

Benzene is emitted while being transferred between barges and storage terminals. However, when EPA originally examined this source category in 1979, it determined that no safe technology was available to control these emissions.

In September 1984 EPA identified new technology that may be considered safe and effective in controlling emissions during the transfer of benzene between barges and terminals. An official of the Pollution Assessment Branch, Office of Air Quality Planning and Standards, stated that EPA plans to examine this technology further and consider proposing a standard to control these benzene emissions. However, as of June 1985, EPA had taken no further action on this because of anticipated problems with retrofitting barges with the controls. Furthermore, EPA had not developed a schedule for making a decision on regulating benzene handling.

Cumene and Cyclohexane Production

EPA identified two additional source categories—cumene and cyclohexane production—for which it reports only trace amounts of benzene emissions. The Stanford Research Institute 1983 Chemical Economics Handbook shows that the use of benzene in the production of cumene was projected to increase significantly between 1981 and 1986. According to EPA, the increased use of cumene would still result in only trace amounts of benzene because no process vent emissions occur at the elevated temperature of normal production. Therefore, EPA has no plans to regulate benzene emitted from the cumene production process.

Cyclohexane is another source category that EPA officials say has only trace amounts of benzene emissions because of the elevated temperatures at which it is produced. As with cumene, EPA has no plans to regulate benzene emitted from the cyclohexane production process.

Solvent Use and Waste Disposal

EPA officials told us they have incomplete information for two other benzene source categories—solvent use and waste disposal. However, because the available data indicate insignificant or unknown amounts of benzene emissions for these categories, EPA has no plans to regulate either source category.

Description of Stage I Controls in the United States

The gasoline-marketing network comprises several segments of gasoline transportation, as shown in figure III.1. Gasoline is delivered to bulk terminal storage tanks from petroleum refineries by pipeline, barge, or ship. Gasoline from the storage tanks is loaded into tank trucks or railcars and then delivered to smaller, intermediate storage facilities, known as bulk plants, or delivered directly to service stations. The gasoline delivered to bulk plants is again transferred into tank trucks and delivered to service stations or other users, such as farmers. EPA refers to emissions from transfer operations at bulk terminals at service stations as "stage I" emissions.

As shown in table III.1, EPA has prepared control technique guideline documents for every sector of the gasoline-marketing industry that results in stage I emissions. The purpose of these documents is to outline what EPA defines as reasonably available control technology for limiting emissions from stage I sources. States with ozone nonattainment areas are required to adopt regulations consistent with the control technique guideline recommendations to help them meet the ozone air quality standard.

Once the EPA recommendations are adopted, the state requires industry to control emissions to the level prescribed in the control technique guideline. For example, on the basis of guideline, stage I controls at service stations contain gasoline vapor within the station's underground tank for transfer to empty tank trucks returning to the bulk terminal or bulk plant.

Figure III.1: Gasoline Marketing in the United States

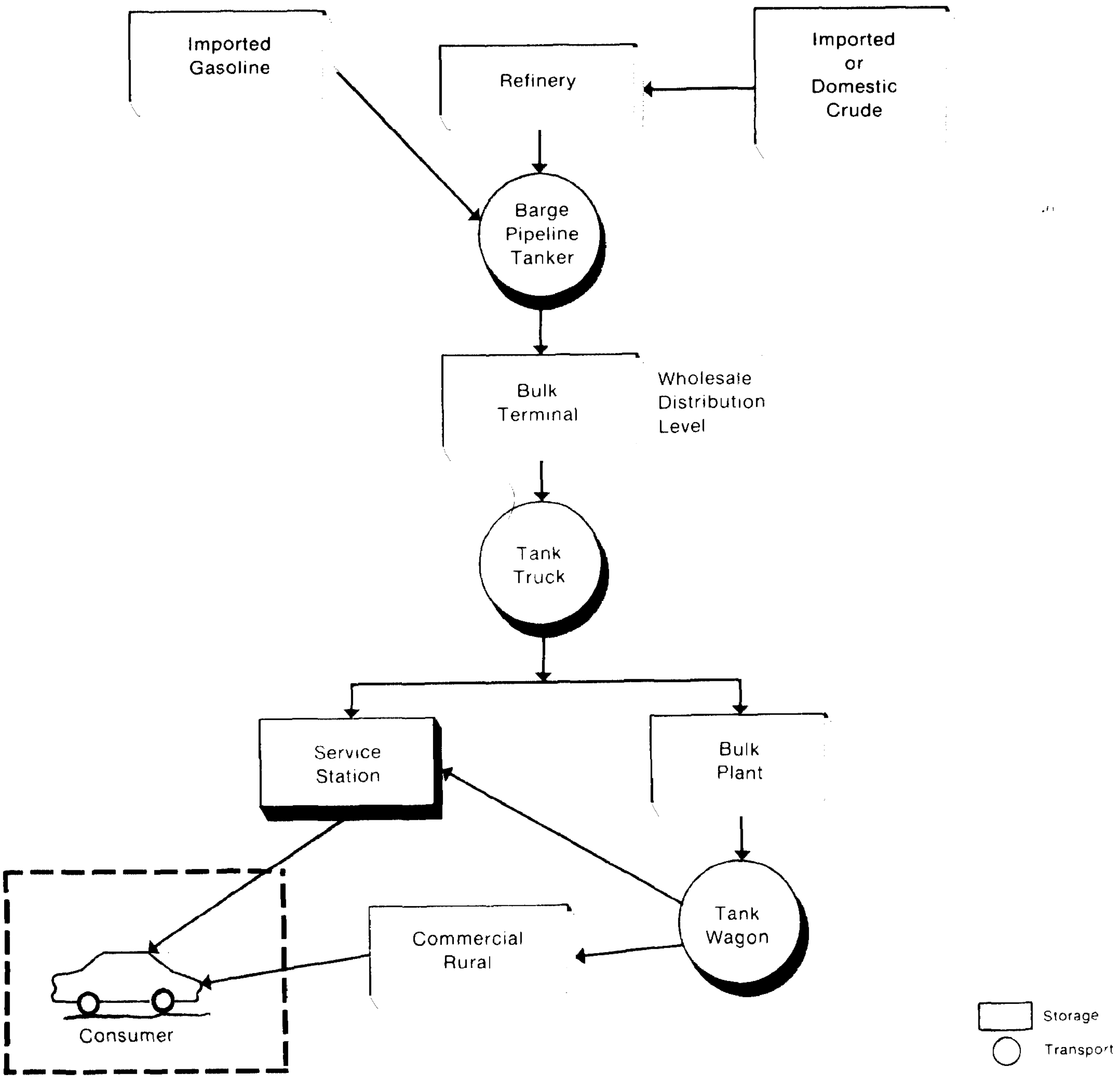


Table III.1: EPA's Control Technique Guidelines for Stage I Emissions

Source of volatile organic compound[a]	Date Issued
Service stations underground tanks[b]	Nov. 1975
Bulk plants	Oct. 1977
Storage of petroleum liquid in fixed roof tanks	Dec. 1977
Bulk gasoline plants	Dec. 1977
Leaks from gasoline tank trucks and vapor collection systems	Dec. 1978

[a]A volatile organic compound is any organic compound that reacts in the presence of ultraviolet radiation to form photochemical oxidants. The oxidants are a major portion of the air pollution commonly known as smog or ozone.

[b]EPA issued criteria for stage I vapor control systems at service stations, but not in the form of a control technique guideline.

A national patchwork of stage I controls is in effect in the United States. States with an ozone problem decided whether it would implement each set of stage I controls statewide or in nonattainment areas only. Other states without an ozone problem did not implement the controls at all. For example, 12 states have implemented statewide stage I controls for bulk plants; 16 states have these controls in nonattainment areas, and 22 states have no such controls.

EPA estimates that stage I control systems are in place at about two-thirds of the bulk terminals and at about half of the bulk plants operating in the United States. EPA also estimates that stage I controls are in use at about half of the nation's service stations. If EPA determines that the gasoline-marketing network should be regulated to reduce human health risk from exposure to benzene, EPA may extend the stage I controls to a nationwide basis to protect those people outside of ozone nonattainment areas.

Description of Stage II Refueling Vapor-Control Systems

Three types of stage II systems are being used in the United States: the vapor balance, the vacuum assist, and the hybrid.

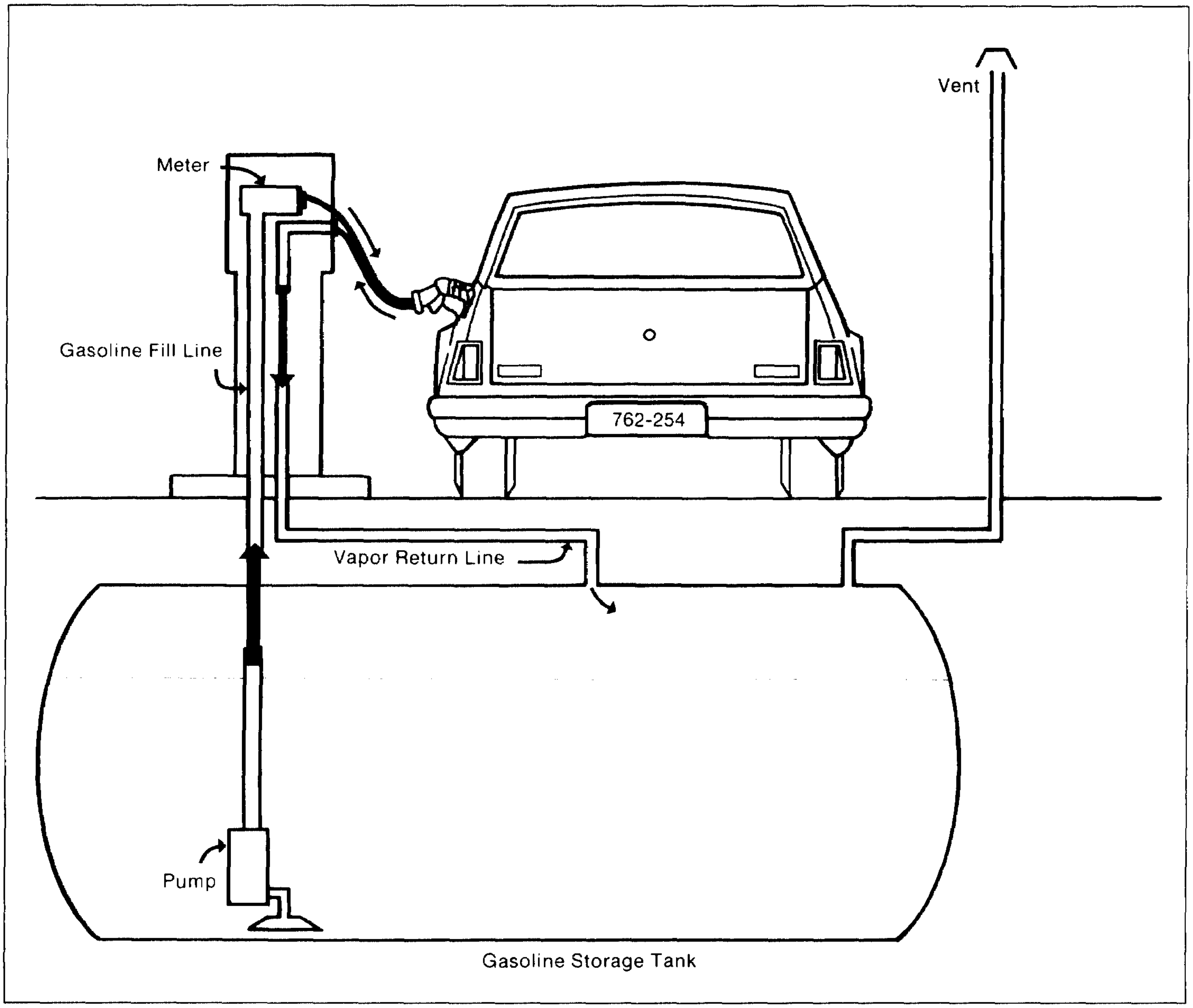
Vapor Balance System

The simplest of the stage II systems is the vapor-balance system. While refueling with this system in place, gasoline vapor displaced in the automobile fuel tank by incoming gasoline is prevented from escaping to the atmosphere at the fillneck/nozzle interface by a flexible rubber bellows. The bellows fits over a standard nozzle and is attached to either (1) a second hose similar to the one through which the gasoline is dispensed or (2) a coaxial hose that dispenses gasoline in the center and returns vapors between the inner and outer hose. The hose is connected to piping that vents the vapor to the underground tank.

The effectiveness of the balance system depends on a tight seal between the bellows and fillpipe. The system's vapor-recovery efficiency is impaired if a tight seal is not maintained.

The balance-system nozzle is heavier and somewhat more difficult to use than the other stage II alternatives. The system is less expensive to install than the alternatives and is in place in 80 percent of the California stage II stations and all but one station in the District of Columbia.

Figure IV.1: Stage II Vapor-Recovery Balance System



Vacuum-Assist System

The vacuum-assist system differs from the balance system in that a vacuum pump is needed to provide extra vapor suction at the nozzle/fillneck interface. This vacuum, which keeps gasoline vapor from escaping, makes it unnecessary to have as tight an interface as is necessary with the balance system. Consequently, the bellows does not need to cover the interface as it does with a balance system.

The vacuum draws the gasoline vapor/air mixture into the underground storage tank at a rate greater than the tank can accommodate. As a result, the vacuum-assist system requires some venting of excess vapor from the storage tank to the ambient air. This, in turn, requires some secondary processing, such as incineration, to reduce the vapor.

The vacuum-assist system is in place at about 10 percent of the stage II stations in California. Its nozzle is lighter than that of the balance system, and maintenance costs are generally lower because a tear in the bellows does not greatly affect the system's effectiveness.

One station in the District of Columbia is operating a vacuum-assist, vapor-recovery system without a bellows. The system operates in the same manner as the vacuum assist described above. However, the nozzle looks and weighs the same as a conventional gasoline nozzle. The system meets the vapor-recovery efficiency criterion, according to air pollution control officials in the District of Columbia.

Hybrid System

The hybrid system enhances vapor recovery at the nozzle/fillneck interface by vacuum, but keeps that vacuum low enough so that a minimal level of excess vapor/air is returned to the underground storage tank. In this system, a small amount of liquid gasoline pumped from the storage tank is routed to a restricting nozzle called an "aspirator." This generates a small vacuum, which draws vapor into the gasoline nozzle bellows. Because the vacuum is small, very little or no excess air (unlike the vacuum-assist system described above) is drawn into the underground storage tank. As a result, a great displacement of vapor from the storage tank does not occur, and a secondary processor, such as an incinerator, is unnecessary.

Description of Onboard System

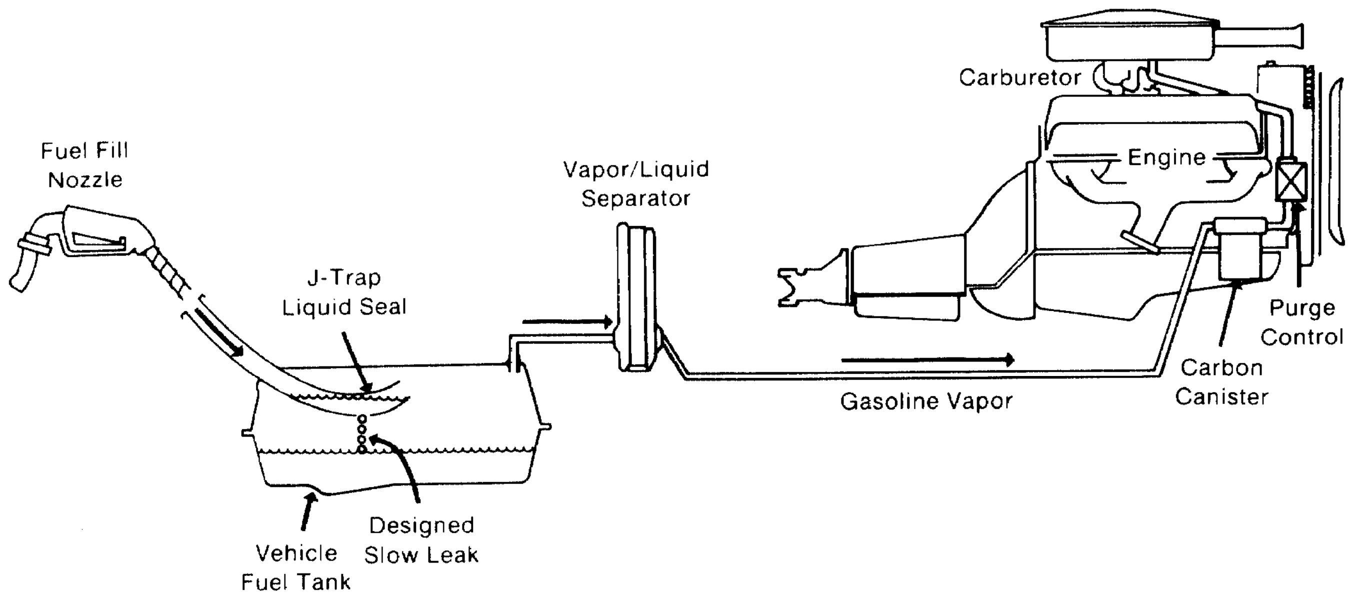
The present evaporative emissions control system reduces evaporative emissions from the fuel tank and the carburetor. The onboard system would be an expansion of this system, requiring (1) the addition of a seal to prevent vapor from escaping into the atmosphere from the gasoline pump nozzle/fill pipe interface during refueling and (2) an enlargement of the evaporative canister used to capture excess vapor from the gasoline tank.

The seal ensures that vapor flows into the carbon canister and is not lost to the atmosphere. EPA has considered using either a mechanical or liquid seal. A mechanical seal is a mechanism located in the automobile fill pipe at the nozzle/fill pipe interface. A trap door opens when the gasoline pump dispensing nozzle is placed in the fill pipe and closes as the nozzle is being removed. The door traps the vapor inside the fuel tank and prevents it from escaping into the air.

Because of safety concerns raised by the Ford Motor Company, EPA developed a liquid seal as an option to the mechanical seal system. EPA considers two options workable for a liquid seal—a "J" tube system and a submerged fill system. With the J tube system, the fill pipe is curved much like the piping below a sink. As shown in figure V.1, when gasoline is pumped into the tank, a liquid seal is formed in the curved section of the piping trapping the vapor inside the tank.

With the submerged fill system, the fill pipe descends to a level just above the fuel tank floor. During refueling, gasoline is introduced below the liquid surface in the tank, which acts as a seal to prevent vapor from escaping. The submerged fill system prevents splashing and, therefore, decreases vapor creation.

Figure V.1: Onboard Vapor-Control System



Vapor displaced from the fuel tank during refueling is blocked by the seal from escaping through the fill pipe and flows into a canister filled with activated carbon. The canister size required is estimated to be about two or three times the size of canisters used for evaporative emissions in automobiles manufactured after 1971. The enlargement is needed to capture the excess vapor that is currently emitted through the fill pipe during refueling. The carbon is regenerated when the vehicle is in operation with air drawn through the canister to remove the gasoline vapor. The air/vapor mixture is burned in the engine.

Glossary

Carcinogenic	Cancer producing
Control technique guideline	EPA's methodology for defining reasonably available control technology that can be applied to existing facilities that emit significant quantities of air pollutants.
Coke by-product recovery plants	Coke is one of the basic materials used to convert iron ore to iron. The coke-forming process also produces a variety of chemicals. These chemicals are recovered by the coke by-product recovery plant.
Epidemiology	The study of the relationships of the various factors determining the frequency and distribution of diseases in a human community.
Ethylbenzene/Styrene	Ethylbenzene is a chemical produced as an intermediate step in the formation of styrene. Styrene derivatives are used in the production of plastics, rubbers (such as tires and disposable serviceware), and packaging.
Ethylene dibromide	Formed when ethylene is mixed with bromine. It is a constituent of leaded gasoline and is being studied by EPA as a potential carcinogen.
Ethylene dichloride	Formed by ethylene and chlorine. It is another leaded gasoline constituent that EPA is studying for its potential carcinogenicity.
Fugitive emissions	Emissions from sources such as valves, pumps, flanges, and other pieces of equipment that develop leaks or equipment that vent benzene vapors directly to the atmosphere.
Hydrocarbons	Chemical compounds containing only carbon and hydrogen elements. These compounds are constituents of petrochemicals, which contribute to smog formation.
Maleic anhydride	Benzene combines with air at high temperatures to form maleic anhydride. The product is used in producing materials such as polyester resins (plastics for automobiles, pipes, and building panels), agricultural chemicals, and lubricants.
Mutagenicity	The property of being able to induce genetic mutation (change genetic material).
Ozone	The primary constituent of smog. It is formed by the chemical reaction of hydrocarbons and nitrogen oxides in the presence of sunlight. Ozone originates mainly from emissions produced by motor vehicles, combustion of fossil fuels, and industrial processes.
Risk assessment	An analytical tool used to evaluate the relationship between exposure to toxic substances and the potential occurrence of disease.
Toxicology	The scientific study of poisons, their actions, their detection, and the treatment of the conditions produced by them.
Volatile organic compounds	Emissions that react in the atmosphere to produce ozone and other constituents of smog.

Requests for copies of GAO reports should be sent to:

U.S. General Accounting Office
Post Office Box 6015
Gaithersburg, Maryland 20877

Telephone 202-275-6241

The first five copies of each report are free. Additional copies are $2.00 each.

There is a 25% discount on orders for 100 or more copies mailed to a single address.

Orders must be prepaid by cash or by check or money order made out to the Superintendent of Documents.

33254

United States
General Accounting Office
Washington, D.C. 20548

Official Business
Penalty for Private Use $300

Bulk Rate
Postage & Fees Paid
GAO
Permit No. G100