# Overview of Transportation and Stationary-Source Control Options

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An introduction to the subject of cost-effectiveness in selecting air-pollution control options is provided by offering an overview of control options for both stationary and mobile sources of air pollution and by identifying some historical obstacles to comparative analysis. After the traditional stationary-source control options presented in the U.S. Environmental Protection Agency guideline document Control Techniques for Volatile Organic Emissions from Stationary Sources are summarized, mobile-source control options, including transportation control measures, are described and grouped by applying the stationary-source categorization scheme. Some cost-effectiveness analysis problems common in evaluating both transportation and stationary-source controls are identified and the institutional obstacles that continue to inhibit effective comparative analysis and problem solving are noted.

In this paper, some background information on stationary-source and mobile-source control options is presented, and some of the historical problems--both institutional and analytical--that have impeded previous comparative assessments of these measures are addressed.

Although the costs and effects of transportation projects and programs are familiar, emission-reduction techniques for nontransportation sources are less well known. Therefore, this discussion will initially focus on stationary sources and their control and then relate these techniques to emission reduction from transportation measures.

The discussion will focus on emissions of volatile organic compounds, or VOC emissions. This term is similar to the description of the principal precursor to ozone but slightly more accurate than the term hydrocarbons. It should be remembered, however, that transportation sources are also the major source of carbon monoxide and nitrogen oxides in urban areas and at street level a major source of particulate matter. These facts become of interest when one discusses the multiple effects of a given control measure.

For the past 10 yr, the national amount of VOC emissions has not changed significantly; it has hovered around 30 million tons/yr. Nevertheless, mobile-source emissions have declined despite growth in travel because of the Federal Motor Vehicle Control Program, and stationary-source emissions have increased despite controls on some categories of sources (1). Major efforts by the U.S. Environmental Protection Agency (EPA), state and local air-pollution-control agencies, and industry over the past 3 yr should produce some decline in stationary emissions over the next few years.

When we look at national VOC emissions for 1977, for example, we find that highway vehicles contributed 10.3 million tons; total mobile sources, including highway, rail, ships, and aircraft, bring the total to 11.9 million tons out of a total of 30.1 million tons (2). From the transportation professional's point of view, contributing approximately one-third of the emissions is certainly significant, but should not the environmental agencies be focusing on the other two-thirds?

First of all, when we look at urban areas, the mobile-source contribution is slightly higher than one-third--typically 40-50 percent. Second, stationary sources are not homogeneous nor do they represent even a few homogeneous sources susceptible to one or even a few control techniques. There are dozens of major source categories (hundreds of smaller categories) and dozens of control techniques. It could be argued that there is more in common between a gasoline tank truck on the road (a mobile source) and the vapors emitted when it loads and unloads its gasoline (a stationary source) than there is between a dry cleaner and an oil refinery or between automobile painting and drug manufacturing, all of which are stationary sources.

I find the distinction between mobile and stationary somewhat arbitrary; but, more important, it can be misleading when used in a rationale for controlling air pollution. An emissions inventory serves two principal purposes: it tells us where emissions are coming from, and when multiplied by a control efficiency, it helps us determine potential emission reductions. By itself, an inventory does not tell us which sources to control. Control efficiency, cost-effectiveness, and political feasibility are far more important factors in making that decision.

## STATIONARY-SOURCE CONTROL OPTIONS

Now let us look at the major approaches to stationary-source control and some of their applications (2). The three general methods employed commercially to control VOC emissions are

1. Installation of add-on control equipment to recover or destroy the organic vapors,
2. Substitution of less photochemically reactive materials in the process, and
3. Incorporation of process or material changes or both that reduce or eliminate vapor emissions.

### Add-on Controls

The first general category can be further subdivided into five categories of techniques: incineration, adsorption, absorption, condensation, and flaring.

#### Incineration

Incineration is the technique most universally applicable to sources of volatile organics. Therefore, I will spend more time on this technique and discuss the others only briefly. There are two basic approaches to incineration--thermal afterburners and catalytic afterburners. Boilers can sometimes be used as thermal afterburners if the temperature, turbulence, and flame contact are adequate to burn the contaminate.

#### Thermal Afterburners

For the use of thermal afterburners, the concentrations of vapors and air must be within the limits of flammability--which, of course, vary by pollutant. Additional fuel, such as natural gas, liquid propane gas (LPG), distillate, or residual oil, is usually used. Heat recovery offers a way to reduce the afterburner energy requirements but at the expense of increased capital equipment costs.

## Catalytic Afterburners

A catalytic afterburner initiates and promotes oxidation at a significantly lower temperature than a thermal afterburner. However, contact time is critical to ensure maximum oxidation, and a variety of substances in the pollutant stream can poison the catalyst and make it useless. Compared with those of thermal afterburners, fuel costs of catalytic afterburners are lower, but savings from heat recovery are lower also.

### *Applications*

Incineration has been successfully applied to aluminum-chip dryers, petroleum processing and marketing operations, animal-blood dryers, automotive-brakeshoe debonding ovens, foundry-core ovens, meat smokehouses, paint-baking ovens, varnish cookers, paper printing and impregnating installations, pharmaceutical manufacturing plants, sewage-disposal plants, chemical-processing plants, and textile-finishing plants.

### *Efficiencies and Cost Factors*

Control efficiencies have been more than 95 percent where applicable and when properly designed and operated. Capital costs and operating costs can vary widely, depending on

1. The nature of contaminants in the waste gas,
2. The concentration of organics in the gas,
3. The gas volume flow rate,
4. The fuel used for the afterburner,
5. Design problems, and
6. The degree of heat recovery.

### *Problems*

In addition to the need of the thermal afterburner for energy, its use of fuel oil can be a source of pollution itself. If we assume that there is no sulfur in the off-gas, use of distillate oil in a typical afterburner can emit an $SO_2$ concentration of 50 ppm. In addition, nitrogen-containing compounds may be oxidized to $NO_x$, which increases those emissions. Due to the abundance of nitrogen in air, no nitrogen compounds need to be in the fuel or VOC stream to produce $NO_x$ emissions. $NO_x$ emissions will result from all combustion processes. The estimated $NO_x$ concentration for effluent from noncatalytic afterburners fired with natural gas is 40-50 ppm. Incineration of any halogen-containing compound will cause acid formation; a scrubber following the incinerator may be required.

In catalytic incineration, the regeneration or replacement of the catalyst can present a secondary pollution problem. When the catalyst needs to be completely replaced, the used catalyst is treated as solid waste, and an acceptable means for disposal must be found. If the catalyst can be reused, the cleaning or reactivation process requires proper disposal of any waste material.

## Adsorption

Adsorption is the process by which components of a gas are retained on the surface of granular solids. The adsorbent particles of the solids are highly porous and have a large surface-to-volume ratio. Gas molecules penetrate pores of the material and contact the large surface area available for adsorption. Organic vapors retained on the adsorbent are subsequently desorbed. Both the vapors and the adsorbent are recovered and may be reused.

### *Applications*

Activated carbon is the most widely used adsorbent. It selectively adsorbs organic vapors from gases, even in the presence of water. Other adsorbents, such as silica gel and alumina, can remove organic solvents but are not widely used because of their affinity for water. Processes that can be controlled by adsorption include dry cleaning, degreasing, paint spraying, tank dipping, solvent extracting, metal-foil coating, fabric impregnation, and manufacturing of plastics, chemicals, pharmaceuticals, rubber, linoleum, and transparent wrap.

### *Efficiencies and Cost Factors*

Initially, adsorption is rapid and removes essentially 100 percent of the VOC from the vapor. The efficiency declines as the adsorbent becomes saturated. Therefore, most systems are designed to require adsorbent regeneration or replacement as soon as the efficiency drops below 100 percent.

In addition to the characteristics of the particular operation affecting the capital and operating costs of this technique, if the absorbent is regenerated, there may be recovery costs. When recovered organics are credited at their market value, the adsorption operation can show a net return on investment. However, if more than one solvent is being recovered, product separation is usually not worth the cost. If cost recovery is not profitable, incineration of the recovered solvent is performed.

### *Problems*

There is some air and water pollution from an adsorption system. Loss of organic solvent with wastewater, oxidation-product emissions with incineration, and solid-waste disposal are possible, depending on the system used.

## Absorption

Absorption is the process in which certain constituents of a gas stream are selectively transferred to a liquid solvent. Absorption may be purely physical, in which the solute simply dissolves in the absorbent, or chemical, in which the solute chemically reacts with the absorbent or with reagents dissolved in the absorbent.

The generally low concentrations of exhausted organics require long contact times and large quantities of absorbent for adequate emission control. Absorption is therefore less desirable than adsorption or incineration, unless the absorbent is easily regenerated or the solution can be used as a process make-up stream. Absorption may be best suited for use in conjunction with other control methods such as incineration or adsorption to achieve the prescribed degree of emission removal.

### *Applications*

Although absorption has been used primarily to control inorganic rather than organic vapors, it has been used to control organic vapors and particulate matter in surface-coating operations, waste handling and treatment plants, degreasing operations, asphalt-batch plants, ceramic-tile manufacturing plants, coffee roasters, chromium-plating units, petroleum coker units, fish-meal systems, smoke generators, and varnish and resin cookers.

*Problems*

Adverse environmental effects resulting from the operation of an absorber include improper disposal of the organic-laden liquid effluent, undesired emissions from the incineration of the regenerated waste gas, loss of absorbent to the atmosphere, and increased water use.

### Condensation

Condensation is usually applied in combination with other air pollution control systems. Condensers located upstream of afterburners, carbon beds, or absorbers can reduce the total load entering the more expensive control equipment. When used alone as in gasoline vapor control in bulk terminals, refrigeration is the usual means of achieving the low temperatures necessary for condensation.

*Applications*

The predominant application of the condensation technique is with the recovery of gasoline vapors at bulk gasoline terminals. Removal efficiencies depend on the hydrocarbon concentration of the inlet vapors but are greater than 96 percent for the removal of saturated hydrocarbons.

*Cost Factors*

For the primary application of this technique, bulk gasoline terminals, high flow rates can offset both operating and capital costs, which results in a net savings through vapor recovery. In most other applications, however, condensation systems are uneconomical as the sole means of emission control unless the gas contains high concentrations of valuable and recoverable organic vapors.

*Problems*

A condenser will create few secondary environmental problems when the condensation process is considered by itself. However, condensation is rarely used alone as a control method.

### Flaring

Flares are most commonly used as safety devices to incinerate waste gases from petroleum refining and petrochemical manufacturing operations. Flares are preferred when gas streams are disposed of that have sufficient heat value to attain the combustion temperature without the use of supplemental fuel. Flares are also preferred when gases that have little recovery value are disposed of or for gases containing contaminants that make recovery unprofitable.

Although capital and operating costs tend to be lower because the gas is sufficiently volatile to sustain combustion, there are costs and problems with flaring in addition to its limited application. Smokeless operation of a flare usually requires a supply of steam or air to ensure complete combustion. Also, the operation of a flare affects the environment in the following areas: chemical and oxidation emissions (including $SO_x$ and $NO_x$ emissions), particulate emissions, thermal and visible radiation, and noise.

## SUBSTITUTION OF LESS-REACTIVE SUBSTANCES

The second general category of stationary VOC control is to substitute less photochemically reactive materials for highly reactive ones. This approach is not so popular today as it was several years ago for two reasons: first, even less-reactive materials react during a multiday stagnation and, second, of the small number of VOCs that have only negligible photochemical reactivity, all but one--benzaldehyde--are suspected carcinogens, teratogens, or mutagens.

## PROCESS OPERATION AND MATERIAL CHANGES

Process operation and material changes are the most diverse options available for control of organic emissions. In general there are three types of possible changes: (a) material substitutions, in which alternative materials are used in the process or products of the process are reformulated; (b) process changes, in which certain operations of the process are modified; and (c) housekeeping and maintenance procedure changes.

Material substitutions are intended to reduce volatile organic emissions by replacing materials used in the process with less-volatile or nonreactive compounds. For example, organic emissions from surface-coating operations can be significantly reduced by replacing conventional organic solvent-borne coatings with water-borne high solids or powder coatings. Water-borne coatings can be applied with most of the same methods used for organic solvent-borne coatings. Water-borne spray-coating solvent does contain 20 to 30 percent organic solvent; thus, VOC emissions cannot be completely eliminated.

Process changes reduce organic vapor emissions by using raw materials more effectively. For example, organic emissions from surface coating can be reduced by adopting more efficient coating methods or by changing curing techniques. Electrostatic spray coating and ultraviolet curing reduce emissions by limiting solvent contact with air.

Finally, improved maintenance procedures and good housekeeping reduce volatile organic emissions by preventing leaks and spillage and by improving product yield.

## MOBILE-SOURCE CONTROL OPTIONS

Interestingly, two of the three general categories of stationary-source control options can be related to mobile-source control. The first category, the installation of add-on control equipment, clearly describes the oxidizing catalyst and exhaust gas recirculation options used on automobiles.

The third category, incorporation of process and material changes that reduce or eliminate vapor emissions, may require some imagination, but I believe it is also analogous to mobile-source control. The use of diesel engines and the incorporation of computer control of engines can be seen as process changes that reduce VOC and CO emissions. What I find interesting about such process changes relative to the discussion of cost-effectiveness analysis is the difficulty in assigning that portion of the cost of the process change to one benefit, such as VOC emission reduction. Should the cost of a diesel engine (or the entire car) be related to the VOC reduction benefit? What about CO? And is not the primary reason for buying a diesel the savings in energy cost?

In advocating a relaxation in automobile emission standards, General Motors admitted that even though the new computer control technology would not be needed to meet the relaxed emissions standards, they might keep it on some cars to enhance performance (and sales). Should the entire cost of this technology, then, be assigned to air-quality improve-

ment? If not, what portion should be? What portion of the cost should be attributed to other effects?

These problems become more critical when one stretches the process-change analogy to other transportation measures. Encouraging modal shifts from automobile to transit by enhancing public transportation travel or increasing the costs of automobile travel can be seen as a process change. Under the right circumstances and properly planned, public transportation or ridesharing can be less-polluting alternatives (or travel processes) when compared with land use patterns, and right-of-way modifications can make pedestrian and bicycle travel a zero-polluting substitute for vehicular travel. The substitute for transportation traditionally offered is communications. I believe there are limits to the capability of communications to substitute for transportation and face-to-face interaction, but I also believe that more substitution is possible than we are currently exercising.

Specific transportation measures have been included in state air-quality plans or are under consideration by metropolitan planning organizations for inclusion in the 1982 air-quality plans. All nonattainment areas with populations greater than 200,000 submitted transportation measures in their 1979 state air-quality implementation plans. Of the 49 areas receiving an extension of the CO or ozone attainment date, 36 included transit improvements, 31 included carpool and vanpool programs, 27 included bicycle incentive measures, 25 included traffic-flow improvements, 18 included exclusive lanes for high-occupancy vehicles, 11 included work rescheduling, 10 included parking management programs, and 8 included automobile-restricted zones.

In addition to those measures that represent modal substitution, the above list of transportation control measures also includes what the stationary-source control engineer might term process-efficiency improvements and what the transportation planner refers to as transportation systems management, such as signalization and other measures designed to improve the efficiency of the existing transportation system.

## THE TECHNICAL PROBLEM

The technical problem with analyzing the cost-effectiveness of process changes is relating specific costs to specific effects. All the transportation measures included in the 1979 air-quality plans were found acceptable because the transportation, energy, and perhaps political benefits outweighed the costs. None were determined to have only an air-quality benefit; most were not originally proposed for their air-quality benefits.

Should the entire cost of a measure be assigned to the effect of immediate analytical concern? Should the costs be allocated to each effect? If so, how? Or should all the effects (positive and negative) except the one of immediate concern be summed and then substracted from the costs and a net cost-effectiveness approach be used? Would this approach be meaningful if there were a net benefit assigned to the effect?

## THE INSTITUTIONAL PROBLEM

In addition to the technical problem of analyzing cost-effectiveness, there is the institutional problem. This is an important problem, too, and I could spend considerable time on it; but for now, I will just highlight the issues. Until 1970, transportation planning and air pollution control were two separate worlds: there was little or no professional interaction, little sharing of analytical approaches, little in common in terms of institutional arrangements. When they were brought together during the 1970s, there was little understanding of these differences and a limited desire in both spheres to alter historical approaches and institutions.

Transportation decision making is far more complex institutionally than air pollution control, both in numbers of institutions and in their relationships to one another. In transportation, political costs can be more decisive than dollar costs, and thousands of people are routinely and directly affected by transportation decisions. Pollution control decisions generally have affected individual industries or groups of industries; the public is indirectly affected by these decisions. Transportation decisions have to be accepted or at least tolerated; they are not subject to enforcement actions, as are most pollution control decisions. Finally, the focus of pollution control has been by definition narrower than that of transportation. Of necessity, transportation has moved toward being multiobjective.

As a consequence of all these institutional factors, communication and mutual understanding between air pollution control and transportation decision makers have been limited. I believe that before agreement can be reached on applying analytical approaches and ultimately on the appropriate responsibilities for transportation and stationary sources in reducing air pollution, greater understanding is needed between the two professions and by responsible decision makers.

## REFERENCES

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