Motor Vehicles, Air Pollution, and Public Health

RICHARD A. PRINDLE, M.D., M.P.H., and CHARLES D. YAFFE, M.S.

The following material is adapted from a statement before the Joint State Government Commission of the General Assembly of the Commonwealth of Pennsylvania, June 8, 1962. The statement was based on a three-part report, "Motor Vehicles, Air Pollution, and Health" (H. Doc. 489), submitted to the U.S. Congress in June 1962. Because of the particular interest of the commission, proportionately more emphasis was given to standards and controls in the statement. Copies of the report are available from the Congress and from the Division of Air Pollution, Public Health Service, Washington 25, D.C.

MOTOR VEHICLES, like the dragons of old, have a foul and fiery breath. From their tailpipes and crankcases these modern monsters spew forth a steady stream of pollutants, visible and invisible, odorous and odorless, into the atmosphere. These emissions are unquestionably obnoxious; whether and to what degree they are also noxious is under intensive study by the Public Health Service.

Before 1955 the Service and other Federal agencies had conducted limited research activities on some aspects of air pollution. With the passage of Public Law 84–159 in 1955, further Federal activity was authorized, and research was centralized in the Public Health Service. Emissions from motor vehicles were investigated as a part of the total air pollution problem, and it was recognized early that these were important contributors, especially in certain areas of the United States. With the passage, in 1960, of Public Law 86–493 (commonly called the Schenck Act, after its sponsor, Congressman Paul F. Schenck of Ohio), added impetus was given to the study of motor vehicle emissions. This act authorized and directed the Surgeon General of the Public Health Service to make a study and report to Congress, by June 1962, from the standpoint of the public health, on the discharge of substances into the atmosphere from the exhaust of motor vehicles.

Dr. Prindle is deputy chief and Mr. Yaffe is staff adviser, Office of the Chief, Division of Air Pollution, Public Health Service.

Production of Emissions

The nature and volume of exhaust emissions discharged by a motor vehicle at any time depend on how it is being driven. In evaluating emissions, four basic driving maneuvers must be considered: (*a*) cruising, uniform speed; (*b*) acceleration, increasing speed; (*c*) deceleration, decreasing speed; and (*d*) idling, standing still with motor running.

The typical U.S. automobile has a four-stroke Otto cycle gasoline engine with four, six, or eight cylinders. Pistons move up and down in these cylinders and transmit their motion by connecting rods to the crankshaft and thence through the transmission to the wheels. A gasoline-air mixture is drawn by a vacuum from the carburetor into each cylinder, where it is compressed and then ignited by an electric spark from the spark plug. The burning gases expand and produce pressures which force the pistons down, driving the crankshaft.

The conflicting requirements for easy starting, fuel economy, power, and the various performance characteristics which the public demands necessitate compromises in the design and the adjustment of the engine. The nature and volume of the exhaust gases are affected by these compromises.

In addition, the nature and composition of the fuel used also affect the nature of these emissions. Fuel is a complex mixture composed almost entirely of hydrocarbons. If these are completely burned in an adequate air supply, the theoretical end products are carbon dioxide and water. Under ordinary driving conditions, the air-to-fuel ratio is such that insufficient oxygen is supplied. The result is emission of substantial amounts of substances other than carbon dioxide and water, including such important compounds as carbon monoxide and numerous partially burned hydrocarbons, in the form of alcohols, aldehydes, ketones, phenols, acids, peroxides, and others. Also, under the conditions of temperature and pressure present, a certain amount of nitrogen and oxygen combine in the cylinder to produce various oxides of nitrogen, which are also important emissions.

The volume of exhaust gases which may be derived varies considerably during the operation of an automobile, ranging from as low as 5 or 6 cubic feet per minute to as much as 200 cubic feet per minute. This tremendous range seriously complicates the task of determining the amounts of contaminants released into the air and adds to the difficulty of designing and developing satisfactory systems for the control of exhaust.

Aside from the exhaust, the crankcase is the other principal source of pollution. Most American automobiles have a system of crankcase ventilation which employs a "road draft tube." With this system, air flowing past the moving vehicle aspirates crankcase fumes through a tube from the crankcase. These fumes are derived principally from fuel-air mixtures which escape past the pistons down into the crankcase. Replacement air is drawn in through the oil filter cap and air inlet. Until recently, this was thought to be only a small proportion of the total emissions produced by a car. More recent evidence has disclosed that between 20 and 40 percent of the total hydrocarbons discharged escape via the crankcase. These "blowby" gases are greatest when the engine is working under a heavy load.

A small additional amount of hydrocarbons, possibly 5 percent of such emissions, may be lost by evaporation from the fuel tank and an equal amount by evaporation from the carburetor, particularly after the engine has stopped and is still warm. Fuel tank evaporative losses are particularly affected by local temperature and humidity conditions.

Magnitude of the Problem

Of approximately 75 million motor vehicles registered in the United States, about 62 million are passenger automobiles. This represents a 2½-fold increase over the 32 million registered in 1942. Judging by projections of expected future economic and population growth, it seems reasonable to forecast 100 million cars, trucks, and buses within the next 10 years.

Motor fuel is consumed at the rate of approximately 60 billion gallons per year. This amounts to about 1 gallon per person per day and represents an average car travel of approximately 10,000 miles per year, using 800 gallons of fuel. In Pennsylvania, for example, 3,625,000 automobiles were registered in 1960. This represents the third largest registration in numbers, exceeded only by the States of California and New York. In the metropolitan area of Philadelphia, there were 473,269 cars, which represents 3,730 cars per square mile, third only to Washington, D. C., with 4,100, and Denver with 3,951. Pittsburgh, because of the larger metropolitan area, and with the same number of cars (474,981), had only 650 cars per square mile. Pennsylvanians used 3,377,892,000 gallons of gasoline in 1960, again exceeded only by California and New York State.

If the research conducted in Los Angeles on the volume of contaminants emitted from automobiles can be extrapolated to other parts of the nation, then we may estimate for Pennsylvania the following annual discharge of contaminants: carbon monoxide, 5 million tons; hydrocarbons, 700,000 tons; nitrogen oxides, about 300,000–6,000,000 tons. These are only a few of the contaminants emitted which may be of considerable significance.

Photochemical Smog

Motor vehicle emissions mix with other pollutants in the atmosphere and may react with these and with each other. Of greater importance is that sunlight plays a significant role in influencing these reactions and in producing changes in the chemical makeup of the atmospheric pollution. It has been demonstrated in the laboratory that hydrocarbon and oxide of nitrogen mixtures, when irradiated by sunlight, produce other compounds, including ozone, related oxygen-carrying compounds known collectively as oxidates, and numerous other chemical substances, including acids and aldehydes. Ultraviolet light from solar radiation can lead to the change of nitrogen dioxide to nitric oxide, along with the release of highly reactive atomic oxygen, part of which forms ozone.

These complex photochemical reactions lead to the production of aerosols, minute particulate substances, which obscure the horizon and decrease visibility. In addition, this change of chemical composition resulting from solar irradiation makes it extremely difficult to assess the individual contributions of various types of engine operation, types of engines, types of fuel, and the numerous other factors which contribute to the total complex. Finally, since many of these compounds produced in the air change further with great rapidity into other compounds, it is difficult to assess which ones adversely affect human health, property, and visibility. From our recent studies, however, we conclude that many of the newly formed compounds are more reactive and more irritating than their "parent" substances.

Biological Effects

Although the adverse effects of air pollution range from economic damage, reduction of visibility, and injurious effects on crops and animals, to illness and death in people, the role of motor vehicles in producing these effects is not fully defined.

The presence in community air of pollutants from motor vehicles has been established. Further, it has been shown that vegetation can be severely damaged by some of these substances, whether they are produced artificially in the laboratory by direct chemical means, in simulated test runs in which automotive exhaust is irradiated by artificial sunlight, or in the ambient atmosphere of urban areas. This damage is found in many areas of the United States. A recent report on this subject, "Air Pollution as It Affects Agriculture in New Jersey," prepared by Robert H. Daines, Ida A. Leone, and Ilene Brennan, of the Department of Plant Pathology of the New Jersey Agriculture Experiment Station at Rutgers University, contains the following statements.

"While injury to vegetation from acid gases appears to be decreasing in New Jersey and 2,4-D herbicides no longer pose a problem, injury from ozone and other oxidants is increasing in frequency by virtue of a greater population concentration. Ozone injury has now reached the point of seriously threatening the commercial production of spinach and possibly endive, chicory, and some varieties of petunias in many areas. Although photochemically produced compounds other than ozone which are responsible for oxidant injury do not at present represent as great a threat to as many crops in New Jersey as ozone, damage has been observed on celery, spinach, and a few greenhouse crops from these compounds. As our population grows further, increase in sources of emission of the constituents responsible for the production of ozone and other oxidants can be expected in urban areas, especially in this age of automobile travel, rendering the air pollution problem especially serious in large cities. . . .

"With the sources of contamination, cars, home, and industrial fires, refineries, etc., being so numerous both in and bordering New Jersey, it is not surprising that test tobacco plants, placed in 14 different locations in New Jersey during the growing season just passed, showed injury from ozone in every location. It appears therefore that this new problem, while being most serious near such cities as Philadelphia and New York, can be expected to affect sensitive plants in all areas of the State."

The problem described in New Jersey can also be expected, of course, to affect sensitive plants in similar areas throughout the country.

Studies on animals have demonstrated that guinea pigs exposed to automotive exhaust, at a concentration several times normal, for 1, 2, and 4 weeks, were especially susceptible to severe pulmonary disease. This came to light accidentally, following an epidemic which produced pneumonia in the test animals. Significantly higher mortality occurred in the animals exposed to irradiated exhaust, comparable to heavy photochemical smog, than in animals exposed to nonirradiated exhaust or in control animals, which had also experienced the epidemic but were exposed only to pure air. This finding parallels the results of another study in which animals exposed for only 2 hours to nitrogen dioxide, at levels similar to those found on occasion in community atmospheres, were much more susceptible to infection from certain pneumonia organisms. This resulted in more serious illness and more deaths among them than in the control animals, which were exposed to the same organisms but otherwise breathed only pure air.

Physiological experiments in which measures were made of respiratory function of laboratory animals, including resistance to breathing, breathing rate, and the depth and pattern of respirations, have shown that the greatest changes occurred in those animals exposed to irradiated exhaust. In general, these changes occurred when the animals were exposed to concentrations two or more times higher than those found in the average community. However, some physiological changes have occurred in animals exposed to concentrations at community levels, and specific pollutants have produced effects at or near these concentrations. This would appear to indicate that the observed maximum levels present in some communities at this time are borderline with respect to causing immediate effects and changes in pulmonary function.

Studies on human beings have been extremely limited, since it is not desirable to expose persons deliberately under laboratory conditions, and since it is extremely difficult to find persons in the normal community who are exposed solely to automotive exhaust; that is, without other prevalent factors, such as cigarette smoke, other air pollutants, and various occupational hazards. In addition, those few groups of persons especially exposed to motor vehicle emissions, such as vehicular tunnel workers, are in situations where the exhaust may not be irradiated by the sunlight, and therefore the supplemental chemical reactions which may be of extra physiological importance to the person may not occur. However, it has been demonstrated that those individuals in the general population who have preexisting pulmonary disease, specifically emphysema, show improvement of various physiological functions when they are protected in specially built rooms provided with protective filtering equipment. When they return to the normal atmosphere of the polluted urban area, their pulmonary function tests show deterioration. Emphysema, a long-term chronic disease of the lungs, causes severe disability and ultimately may lead to death. It has shown an alarming increase in the past 10 years, having risen fivefold nationally as a cause of death.

Cancer

Also of real concern is the possible role of motor vehicle exhaust in the causation of cancer. Of particular interest are cancers of the respiratory system, which, because of its direct exposure to inhaled air, is more likely to be affected by any chemical pollutants in the air.

Statistical studies and epidemiologic surveys of populations have disclosed that cancer of the lung has increased manyfold. As a cause of death in males it has multiplied five times in the past 20 years. Further, it has been shown that many more cases and many more deaths occur in urban areas and that these increase as the size of the city increases.

At the same time, chemical analysis has demonstrated numerous substances in automobile emissions which are known to produce cancers and tumors in animals. Recent studies at the Sloan-Kettering Institute in New York have attempted to assay the quantity and significance of these pollutants in automobile exhaust. However, it has not yet been possible to demonstrate conclusively the association between these pollutants and specific cases of lung cancer in man.

Last year, on the other hand, workers at the University of Southern California produced true cancers in the lungs of mice, similar to those found in human beings. In these experiments, the mice were infected with a viral influenza. After recovery, they were exposed either to clean air or air containing ozonized gasoline. Other laboratory animals, which had not been infected with the influenza, were similarly exposed either to the pure air or the simulated smog. Uninfected animals showed no changes in their lungs. Approximately 8 percent of the animals which had been infected and then exposed only to pure air showed certain changes in the lungs similar to those often found in persons living in urban areas or in heavy smokers. These lesions are thought to be associated with cancer. The striking finding, however, was that 30 percent of the animals which had been infected and then exposed to the simulated smog developed true cancers. Under these conditions, it appears that air pollutants related to vehicular emissions play a role, at least as a co-factor, in the production of lung cancers.

Standards

Complete scientific standards for air pollution control are still to be developed. A few limited standards have been established and these are generally of two types: standards for ambient air quality, designed to provide a safe or comfortable community level; and standards for emissions, designed to control the amounts put into the atmosphere by specific sources. In relation to the motor vehicle, only California has developed standards. Here, air quality standards for the ambient air were established first and then emission standards consistent for their maintenance were set for vehicles.

The California standards were adopted following the enactment in 1959 by the California State Legislature of laws which made it mandatory for the State department of public health to develop such standards for both air quality and motor vehicle exhaust. Standards for several pollutants were adopted by the State board of health on December 4, 1959. These pioneer efforts are tentative and the health department has specifically cautioned that they may be modified or otherwise changed as new information becomes available.

In developing the ambient air standards, California authorities attempted to determine the effects on human health and comfort, on animals and plants, and on visibility, which were likely to occur at various concentrations of contaminants. The standards were not set to establish a fine line of demarcation between good air and bad, but rather to indicate the approximate point at which pollution may have some undesirable effect under certain circumstances.

These standards were devised on the basis of the health effects of pollutants on people, including those who might be most susceptible, such as the aged or the very young, and the kind of effects. These effects included: acute sickness or death; insidious or chronic disease; alteration of important physiological function such as ventilation of the lung, transport of oxygen, or adaptation to dark; untoward symptoms which "might lead a person to seek medical attention and relief"; and discomfort from air pollutants "sufficient to lead individuals to change residence or place of employment." The effects on vegetation were related to acute damage leading to unmarketability; insidious or chronic effects, leading to impaired yield; and alteration of fundamental biochemical processes without overt damage.

On the above bases, a graded set of standards was established, and three levels to correspond to the degree of seriousness were defined as follows:

"Adverse" level. The adverse effects of air pollutants are those likely to lead to untoward symptoms or discomfort. This level is one at which eye irritation occurs and at which costly and undesirable effects occur on biological systems other than humans, such as damage to vegetation; reduction in visibility; or property damage of sufficient magnitude to constitute an economic burden.

"Serious" level. These are levels likely to lead to insidious or chronic disease or to significant alteration of important physiological function in sensitive groups. Such an impairment implies a health risk for persons constituting a sensitive group but not necessarily for persons in good health.

"Emergency" level. This level is one in which pollutants or combinations of pollutants and meteorological factors are likely to lead to acute sickness or death for a sensitive group of people.

It is recognized that standards set for single pollutants are not necessarily applicable to combinations of pollutants. The possibility of such combinations, along with unusual weather conditions or the presence of particulate matter, seriously complicates the task of establishing reasonable levels. For these reasons no single level of a given pollutant, ordinarily without effect at that level, should be interpreted as a guarantee that lower concentrations are safe or free from effect. It is known, for example, that particle size may modify the toxicity of an inhaled particulate, and in some cases, that two or more pollutants may act in conjunction to increase the action of one or the other or both.

Motor vehicle emission standards were derived in California by estimating the degree of control required to achieve the conditions specified by the ambient air standards with respect to expected emissions from all sources in Los Angeles County in 1970. These estimates indicated that an 80 percent reduction in hydrocarbons and a 60 percent reduction in carbon monoxide emitted from motor vehicles would be required. These emissions are to be measured during a specific driving cycle which incorporates 11 different modes for evaluation of specific exhaust emission control devices. These 11 modes were developed to simulate average driving patterns observed in the Los Angeles area. Under these test conditions, the State authorities concluded that the hydrocarbons emitted should be less than 275 parts per million by volume (as hexane) and that the carbon monoxide should not exceed 1.5 percent by volume.

Although nitrogen dioxide is listed in the group of chemicals known as "oxidants" and therefore is included in the ambient air standards, no standard for nitrogen dioxide per se is included yet in the California motor vehicle emission standards.

In December 1960, the California Board of Health adopted a standard for crankcase emissions of hydrocarbons of 0.15 percent by weight of the supplied fuel.

Control of Motor Vehicle Emissions

In considering the control of motor vehicle emissions, attention has been concentrated on two major sources of pollutants, the exhaust and the crankcase. Although schemes have been devised for control of evaporative losses, the consensus to date has been that attention should be focused on the two more significant sources.

For the control of crankcase emissions a simple solution has been devised. This is merely to provide a tube from the crankcase which will return the emissions to the intake of the automobile. Several devices have been marketed; some provide for the reentry of the fumes into the intake manifold and others provide for reentry into the carburetor either before or after the air cleaner. Although there are technical differences in these approaches, the basic pattern is the same; that is, to return the emissions so that they may be burned in the engine. A number of devices which meet the State emission requirements have now been approved by the California board. The Automobile Manufacturers Association has recommended to its member companies that all new cars produced for domestic use be equipped with a crankcase emission control device, beginning with the 1963 models.

Thus, it appears that substantial progress will be made in the control of pollution from the crankcase. The anticipated reduction of total emissions of hydrocarbons, by approximately one-fourth, is a useful first step in the control of air pollution from automobiles, and may be sufficient to postpone in some localities the necessity for additional control methods.

The approaches to control of hydrocarbon and carbon monoxide emissions from the exhaust which currently offer most promise use afterburner devices. Two major types have evolved and presently are under test in California or in development stages by various manufacturers. One uses a catalyst in a muffler-type device to cause the combustion reactions, begun in the engine, to go to completion and result in the ultimate incineration of the partially burned hydrocarbons present in the exhaust. The other device provides a direct flame which will accomplish the same burning process. The California board has decided that any device approved must meet the established emission standards throughout a period of 12,000 miles of driving.

There are numerous difficulties with these devices, including the fact that any afterburner may overheat, with consequent damage to its structure or to a catalyst, if present, when concentrated exhaust mixtures are passed through it; for example, during extended downhill deceleration. One of the problems with the catalytic device has been the "poisoning" of the catalyst caused by lead additives in the gasoline. This results in a shortened lifetime for the catalyst and requires that it be changed or rejuvenated after a period of use. The direct-flame afterburner occasionally requires additional fuel, particularly on starting. It must also withstand higher temperatures. On the other hand, it has the advantage of accomplishing its purpose the moment the engine has started and the flame has been turned on. With the catalytic afterburner, there is frequently a longer waiting period before the catalyst warms up sufficiently to accomplish effective incineration.

At present, no device has been approved by the California board for exhaust control, although four have thus far been selected for 12,000-mile-in-use tests.

Other possibilities for control of exhaust emissions which have not been completely explored include modifications of the engine or of methods of supplying fuel. There is ample justification for believing supplementary devices, such as afterburners, are merely a means of correcting the result of a basic defect. Engine modification or redesign would possibly get to the core of the problem more directly and provide a surer and more positive technique. For this reason the President, in his message on consumer protection, has asked the Secretary of Health, Education, and Welfare and the Secretary of Commerce to meet with the automobile manufacturers to discuss further such approaches which might benefit the nation's health.

Recently, the automotive industry experimented with mechanisms which affect carburetor air-to-fuel ratios and spark advance and retard. These mechanisms are stated to reduce considerably the quantity of emitted hydrocarbons.

Proper engine maintenance can be of substantial assistance in decreasing excessive emissions. Assuring a proper air-to-fuel ratio and providing correctly adjusted and timed ignition spark and properly seated valves help to reduce exhaust emissions. Maintenance of correct piston-and-cylinder tolerances and use of accurately fitted rings will reduce blowby emissions.

A final approach is fuel modification. In Los Angeles County regulation was promulgated which required that gasoline should have a lower content of the chemical hydrocarbon group known as olefins, since there was evidence that these were more reactive and produced more irritating compounds from automobile exhaust. However, there is also evidence that the engine will produce some of these same pollutants, whether or not olefins are present, and reduction of olefins in the original gasoline only results in a partial reduction in the amount emitted. Further, this technique increases other gasoline constituents, such as aromatics, which, while possibly reducing the amount of more photochemically active constituents, may produce more of those which are potentially more hazardous.

Conclusions

1. Although motor vehicles produce a variety of pollutants from four sources, the exhaust and the crankcase are the greatest contributors.

2. Automotive emissions consist principally of carbon monoxide, carbon dioxide, the oxides of nitrogen, and a variety of unburned or partially oxidized hydrocarbons. Some of these substances are rapidly toxic in high concentrations when they are emitted, and there is evidence that some emissions when present in low concentrations over extended periods, may produce adverse effects on biological systems.

3. Some of these emission products, when mixed in the urban atmosphere and irradiated by sunlight, participate in complex chemical reactions which result in the formation of photochemical smog. Many of these substances are more highly reactive chemically and they appear to be more dangerous than the original emissions. These products also may be acutely toxic in high concentrations, and they may be harmful when present in low concentrations for extended periods.

4. In many communities, automotive emissions are already damaging agricultural crops and reducing visibility.

5. Preliminary evidence indicates that current concentrations of automotive emissions in many community atmospheres are borderline in respect to producing adverse effects in man and animals. Concentrations two or three times those found in ambient air have produced adverse and even serious effects in laboratory animals.

6. Some substances in automotive exhaust have produced tumors and cancers in laboratory

animals. Under certain conditions, inhalation of these substances led to cancer. Although the evidence at hand does not provide direct cause-and-effect proof, it does warrant further immediate research.

7. Crankcase emissions, which constitute approximately one-fourth of the total hydrocarbon emissions, can be controlled by existing devices. The Automobile Manufacturers Association has recommended to its member companies that all new cars be equipped with a crankcase emission control, beginning in 1963.

8. Means for control of exhaust emissions are not yet sufficiently developed for general application. Appropriate modification of the engine, fuel, or fuel supply system may be a partial solution.

9. Proper maintenance and operation of motor vehicles can contribute significantly to the reduction of automotive emissions.

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