THE AIR POLLUTION PROBLEM

by L. A. DuBRIDGE

ONE OF OUR BIGGEST HANDICAPS in the fight for clean air in Los Angeles has been the fact that our air pollution is called "smog." The term "smog" originated in certain midwestern and eastern cities where —twenty years or more ago—on damp, foggy winter days a black pall of soft-coal smoke settled over the city, blanking out the sun and literally turning day into night. Those black, sulfurous clouds were a mixture of coal smoke and fog, and the name "smog" was a natural one.

The cure for that kind of smog, although it was not easy, was obvious—namely, stop the smoke! That is, stop burning soft coal or else put in smoke eliminators. And so in St. Louis, Pittsburgh and other cities the factories put in eliminators and better combustion controls; the apartment houses and private homes switched from soft coal to hard coal or to oil or gas. And presto! The smog stopped!

But Los Angeles begins where Pittsburgh and St. Louis left off. We have not burned soft coal here for fifty years. Our worst smoggy days are like bright, clear sunshine compared to a good old-fashioned St. Louis smog. Even today there is plenty of air pollution in every major city in the nation.

The Los Angeles air pollution problem is more serious than some, not because we are "dirtier" than other cities, but only because Mother Nature, in providing us such a nice climate, failed to provide southern California with adequate ventilation. Hence, we must be much cleaner than anyone else needs to be.

Because old-fashioned eastern smog was largely caused by one thing—namely, soft coal—we in the West also, at first, looked for a simple single cause for our trouble. In 1942-45 everyone was sure that the wartime synthetic rubber plants were the major culprit. Possibly, then, they were. But by 1945 they were cleaned up or shut down, yet the air pollution persisted. Then we went after sulfur. Expensive equipment was built to remove sulfur from the stack gases of refineries and other industrial plants. This too was probably a good thing to do, but the pollution problem persisted. Nor did the elimination of many of the principal sources of visible smoke and fumes solve the problem.

Finally, the time came when a few people realized that we had a really tough problem on our hands in Los Angeles and that someone had better do some good solid research to find out just what *were* the objectionable pollutants in Los Angeles air and where they were coming from.

Eight years ago the newly organized Air Pollution Control District began its research program. About the same time the oil industry—the most frequently blamed culprit—started more research. Two years ago the Air Pollution Foundation began an independent research program, and today a very substantial attack on the problem is under way in many laboratories. Nevertheless, we are still not spending half as much as we should on research. We are still trying to solve a billion-dollar problem with peanuts!

The very first results of this research revealed the complexity of the problem. It soon became evident that there were *many* components of air pollution—and that some of them at least had no relation at all to visible smoke. They came from invisible vapors of unburned gasoline and other petroleum products. But these invisible and supposedly innocent vapors, once trapped under the southern California inversion layer, went through a chemical change—a complex series of changes, in fact—in which one essential contributor was (of all things) our good friend, California sunshine! It was found that smoggy air contains peroxides of these gasoline and other organic substances. It also contains ozone and nitrogen oxides, in addition to the usual smoke and dust of a metropolitan area.

Air pollution in Los Angeles is thus many things—many things going into the atmosphere and there reacting with each other and with the air itself, and with sunshine, in complex ways. The cities of the East today face this same problem—that is, "oil smog" has replaced "coal smog." The cleanliness of the air in various

Some plain words about smog—what it is, where it comes from, who's to blame and what we can do about it—by the new chairman of the Board of the Air Pollution Foundation

communities at various times is mostly a matter of how good is the ventilation.

Clearly, there was a whole series of new questions to be answered about this new kind of smog. First we must ask what are the most objectionable effects of air pollution. Eye irritation? Bad smell? Bad taste? Low visibility? Rubber cracking? What causes each of these? Are many compounds involved? Or only a few? Or only one? Through which chemical reactions are the harmful materials produced? From what raw materials? What catalysts, if any, participate in the reactions? Can *they* be controlled? How? How much will it cost to reduce the emission of various materials? To what levels *can* each be reduced? To what levels must it be reduced to make our air tolerably clean?

These are questions whose answers were *all unknown* a few years ago. Indeed we did not know enough *then* even to *ask* some of them. Many of the answers are unknown today. But today every one of these questions is under intensive study; some can now be answered. That is itself tremendous progress.

Let us turn first to the question, "What are the objectionable effects of air pollution?" It is not difficult to prepare a list. The principal items are (1) reduced visibility, (2) eye irritation, (3) damage to plants, (4) the cracking of rubber, (5) a pungent odor, (6) a general physical discomfort on the part of many people who are especially sensitive. In addition, there may be longer-term health effects which we do not understand, but no specific hazard attributable to air pollution has yet been established.

Now if one stops to think about it, it is rather amazing that there are so many diverse effects produced by impure air. One can think of many things in the air which would cause reduced visibility but which would not have a bad smell, which would not crack rubber, damage plants, or produce eye irritation. Conversely, there are many things which could produce a bad smell and eye irritation which would not reduce visibility. Yet our general observation is that all these effects are observed together on smoggy days. The first question which arises, therefore, is whether all of these effects are due to a single substance or whether they are due to several substances which happen to appear together.

In the last two years careful measurements have shown that actually the degree of eye irritation, of visibility reduction and of plant damage do not, in fact, all rise and fall together. On some days, or on certain hours of a single day, the relative intensity of these phenomena may very considerably. An obvious example is when a dense sea fog rolls in and mixes with the man-made smog. On such days the visibility becomes very low indeed, although the smell and eye irritation may not be too objectionable. It now seems clear that the different objectionable results of smog are produced by several different contaminants in the atmosphere—not all by a single substance.

If this is the case, one might think that the next step would be to determine all the foreign substances in the air and then find out which ones produce which effects. This is not so easy as it sounds for there are literally hundreds of compounds and materials present in our atmosphere, mostly in very tiny quantities, many of them far below any possibility of noticeable effects. At the same time, one of the grave difficulties of the air pollution problem is that certain substances need be present only to the extent of a few parts in one hundred million in order to have detectable or even objectionable effects. In fact, the identification and measurement of such tiny concentrations of material is, in itself, a great achievement in analytical chemistry. Newly developed instruments are now automatically recording, day and night, the concentrations of some of these materials.

Today we have a pretty fair picture of the pollutants in the air which seem to be causing the principal objectionable characteristics of smog.

In the first place, we find particulate matter—that is, finely divided solid particles of smoke, ashes, dust, and similar substances, plus tiny liquid droplets, both of water and of different kinds of organic substances.

We then find an array of gaseous compounds, particularly the following: (1) vapors of gasoline and oil (known chemically as hydrocarbon vapors); (2) nitrogen compounds, particularly nitrogen oxides (formed principally in combustion processes from the nitrogen in ordinary air); (3) ozone (a compound whose molecules consist of three oxygen atoms, whereas the ordinary oxygen in our atmosphere has two oxygen atoms per molecule); (4) oxides of hydrocarbons (that is, gasoline and oil molecules to which one or more atoms of oxygen have been attached); and (5) sulfur compounds, especially sulfur oxides (formed principally in the burning of fuels which contain small quantities of sulfur).

If we consider the particulate matter first, we quickly recognize that it is the principal factor in the reduction of visibility. Reduced visibility is caused by the scattering of light from tiny individual solid or liquid particles suspended in the atmosphere. It is not caused by gaseous materials. These particles can consist either of actual solid particles, as of smoke or dust; or of liquid droplets as in the case of a fog; or of liquid droplets condensed on solid particles.

The solid particulate matter is easiest to see and to control. Clouds of smoke or dust coming from industrial plants or from backyard incinerators are readily detectable. The Los Angeles Air Pollution Control District has made giant strides in reducing the amount of smoke and dust being emitted by industrial plants, and it will not be long before solid particulate matter from this source will be reduced to a fraction of what it was a few years ago. For many plants, the combustion right now is just about as clean as engineering science knows how to make it. And yet that is not good enough! More research to develop techniques of smoke reduction is needed.

Backyard incinerators

The Air Pollution Control District has also taken important steps toward the elimination of the backyard incinerator which remains today as the most important source of solid particulate matter in our atmosphere. Throwing smoke, ashes and dust into the air from a million and a half backyard incinerators is a dirty, filthy custom and it should have been stopped long ago. I am not saying that the incinerators are the *sole* cause of air pollution, but they do project over a hundred tons of "dirt" into the atmosphere each day and when this is eliminated we will have purer, cleaner air in the Los Angeles basin.

To reduce the smoggy haze caused by tiny droplets of organic materials is not so easy. Clearly, we must control the sources of these organic materials. Some of these materials are emitted originally as gases or vapors, but later are transformed into liquid droplets.

This brings us to the gaseous components of polluted air. As a result of work in many scientific laboratories in the past few years, it appears now that the principal offensive gases in our atmosphere are oxides of hydrocarbons, oxides of nitrogen and ozone. Though these are not the only atmospheric pollutants, they seem to be the ones principally responsible for eye irritation, for plant damage and for the cracking of rubber. Where do these gaseous compounds come from?

Nitrogen oxide, whose role in the air pollution problem was almost unrecognized a few years ago, is produced in nearly every combustion process. Wherever oil, gas, coal, wood, trash, or anything else is being burned, some of the nitrogen in the air is combined with oxygen to form nitrogen oxides. The nitrogen oxides are gases which are quite invisible and, therefore, not all the sources can necessarily be located by going around looking for smoke clouds. In fact, it is unfortunately necessary to report that no way of reducing the emission of nitrogen oxides into our atmosphere has yet been invented. Since combustion is the basis of any industrial society, since combustion occurs in every home, apartment building, power plant and factory, it is clear that strenuous efforts to develop methods of reducing the emission of nitrogen oxides are called for.

Oxides of hydrocarbons

The situation is somewhat similar in the case of the oxides of hydrocarbons. It is these substances which are the principal causes of eye irritation and plant damage. These hydrocarbon oxides are formed in the atmosphere itself where unburned hydrocarbons, in the presence of sunshine and nitric oxide, combine with the oxygen of the air. Since, obviously, we in southern California can't eliminate either sunshine or air, the only way of reducing the oxides of hydrocarbons is to reduce the emission of hydrocarbons and nitric oxide.

Now hydrocarbon vapors—that is, vapors of gasoline, oil and other organic materials—are also normally quite invisible. Hence, again, the sources of these vapors cannot be observed by visual means. We do know, however, that any process involving the burning of gasoline, oil, natural gas or other petroleum products results in the emission into the air of a certain percentage of unburned vapors. In addition, wherever volatile gasoline or other petroleum products are exposed to the air (as in storage tanks or filling stations) there is a certain amount of evaporation into the air.

It is to find methods of reducing the emission of these hydrocarbons into the atmosphere that the most strenuous efforts, both in research and in enforcement, are now focused. The problem is a terribly difficult and complex one. We can say, however, that industry in recent years has taken important strides in reducing the escape of hydrocarbon vapors from its plants. To reduce the contribution of the automobile is the next stage of the problem.

The third objectionable impurity in the air which I have mentioned is ozone. Ozone is not produced in combustion processes at all, but is formed entirely in the atmosphere from air and sunshine with the catalytic assistance of nitrogen oxides, hydrocarbons or other organic materials. We know that clean, pure desert air at sea level contains no appreciable quantities of ozone. On a smoggy day in Los Angeles, however, ozone occurs in amounts ranging up to six- or eight-tenths of a part per million.

It seems clear that ozone is the principal contributor to the cracking of rubber. *Yet no person or company is guilty of putting ozone into the air!* Naturally, therefore, the Air Pollution Control District faces a dilemma. Ozone is a bad air contaminant, but nobody is contaminating the air with ozone. Like the hydrocarbon peroxides, it is a compound formed in the atmosphere as a result of the action of sunshine plus oxygen plus some other impurities.

Several years ago it was shown in laboratory experiments (by Dr. Haagen-Smit of Caltech) that hydrocarbon vapors plus nitrogen oxides plus light will form ozone and peroxides. It is now clear that the major problem is to find ways of reducing the amount of these substances which enter our atmosphere. But these substances are found in every combustion process. And we can't stop combustion and still have an industrial community.

Does this mean that the problem is a hopeless one? Certainly not! It does, however, mean that the problem is not going to be solved next week by pushing a button or by putting somebody in jail, or firing somebody from his job, or even by holding mass meetings of indignant citizens. What are the ways by which the pollution nuisance will be reduced?

Change of climate

First, let us dispose of one class of remedies which keep cropping up; namely, those which involve changing the climate of the Los Angeles area or producing better ventilation. All such schemes, involving blowers or fans or heaters or smokestacks, can be seen in perspective if we remember simply that the total mass of the air which lies over the Los Angeles basin between sea level and about 500 feet is approximately one-quarter of a billion tons. In other words, the weight of the air which we have to deal with is twice the weight of all the steel produced in the United States in a whole year.

Now if we had 250 million tons of steel sitting in downtown Los Angeles and we had to transport it 50 miles out into the desert twice a day, we would recognize that we had quite a job on our hands. A quarter billion tons of steel, incidentally, would be a pile 1000 feet long, 1000 feet wide and 1000 feet high. Moving this steel would actually be easier than moving air, because at least you could load it on freight cars and haul it away! But to move the air in the Los Angeles basin rapidly enough to change it, say, twice a day would require more power (whether it be in the form of heat, electricity, sunshine or gasoline engines) than all the electric power generated in the United States.

In other words, we are not going to get rid of the Los Angeles smog by blowing it away! What should we do?

First we need more research. We cannot eliminate combustion itself, but we can find ways to make combustion more complete so that smoke and unburned hydrocarbon vapors do not escape. If smoke and hydrocarbons were *completely* burned, the products would be simply water vapor and carbon dioxide which are quite harmless.

In larger power plants the combustion is already quite complete. Industrial companies are very anxious to prevent valuable unburned fuel from escaping up the stacks. But some smoke does escape and a considerable quantity of nitrogen oxide escapes. It is very important to find ways of converting these nitrogen oxides back to nitrogen and oxygen before they escape. There is, doubtless, some catalytic process which will do this, but no practical method has been found.

The principal source of smog

The two million automobiles of Los Angeles are pumping into the air 1200 tons of unburned gasoline plus 300 tons of nitrogen oxide each day. This is four times as much hydrocarbon as comes from industrial sources and is 50 percent more nitrogen oxide. The laboratories of the automobile industry are working hard on methods to improve the combustion of the gasoline. No satisfactory device for this purpose has, however, yet been produced, and there is certainly a year or more of development and test work still ahead before one can be adopted and placed on the market. A nitrogen oxide eliminator is still further away. No one knows how much either device will cost. Certainly the total job of equipping two million cars will take both time and money. The thing to remember is that you and I and the other two million car owners are the principal source of smog—and we are going to have to pay to get it eliminated. Still worse, we are going to have to wait patiently until the engineering research required to develop the necessary devices has been completed.

In the meantime, we can do three things: (1) Eliminate the backyard incinerators which produce many hundreds of tons of smoke, dirt, organic materials and nitrogen oxides; (2) support the research programs of the Air Pollution Foundation which are seeking to find new methods of reducing air pollution; (3) support the Air Pollution Control District in both its research and enforcement activities.

Finally, we can cease quarreling among ourselves about who causes the most smog. We all cause smog, and not until we all stop our contribution will our air be tolerably clean. It cost $\frac{3}{4}$ of a billion dollars to get an adequate supply of pure water in southern California. We should be willing to pay as much for pure air.