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THE HEALTH IMPLICATIONS OF PHOTOCHEMICAL OXIDANT AIR POLLUTION TO YOUR COMMUNITY

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INTRODUCTION

In many communities throughout the country, citizens frequently breathe the air pollutant "photochemical oxidant" in levels which medical research has shown to be potentially dangerous to their health. Levels of this air pollutant in most areas of the country can also cause substantial damage to many forms of vegetation and to a number of valuable materials such as rubber products, painted surfaces, and fabric dyes. Practically no city, town or community of the country fully escapes the effects of photochemical oxidant in the air.

New and expanded efforts are underway to help bring about control of photochemical oxidant and reduce its impact on the general public. However, many people may not fully understand the need for these programs and what can be accomplished through them. This short paper seeks to better clarify the photochemical oxidant situation for State and local government officials such as State legislators, mayors, city councilmen, and community air pollution control officials who have a vital role to play in reducing the health threat from this air pollutant.

BACKGROUND

In 1971 photochemical oxidant was formally recognized by the Environmental Protection Agency as a nationwide air pollution problem. To protect the public from its harmful effects, a national ambient air quality standard was set April 30, of that year. This standard placed a legal limit on the amount of photochemical oxidant that could be present in the air after July 1975 (with some provisions for extending this deadline for two years), based on the best available scientific evidence of health and other adverse effects.

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Since 1971 many problems have been encountered as federal, State, and local governments have attempted to implement air pollution control programs which would ensure that the standard would be met. Even today, there are relatively few places in the country that do not, at least occasionally, experience photochemical oxidant levels in excess of the standard. These problems were expected since the standard was set at a very low concentration level, roughly half of which is often present because of the natural background in many locations. However, medical experts believed that the low concentration was justified based on the available health data and because Congress had stipulated that a national ambient air quality standard must provide protection for all segments of the population and include an adequate margin of safety.

Undoubtedly the standard has become a controversial issue. While very few will disagree that this air pollutant in high concentration levels causes serious adverse health effects, some people have questioned the need for a standard as restrictive as the present one. Likewise, others have questioned the basis on which the current standard was established. Questions such as these have evolved because the data on human health effects from exposure to low levels of photochemical oxidant are very sparse and hence the conclusions to be drawn from these data are somewhat controversial. Therefore, universally acceptable conclusions cannot always be reached over such effects, and one must turn to the wisdom and judgment of qualified experts from the medical sciences to interpret the available data.

In 1974, Congress commissioned the National Academy of Sciences (NAS) to review and update the information on health effects from air pollution, including those effects caused by photochemical oxidant. After reviewing and interpreting the available data, these highly qualified scientists from the various scientific and technical fields concluded:

> In general, the evidence that has been accumulated since the promulgation of the Federal ambient air quality standards by the EPA Administrator on April 30, 1971, supports those standards. Hence on the balance, the (NAS) panels found no substantial basis for changing the standards.[1]

Although the above conclusion applied to all national standards, in specifically addressing photochemical oxidant, the NAS noted that even with the current standard, the risk to the general population may not be negligible, and that there is evidence which suggests that there may not be a completely safe level of this air pollutant for all people. A similar conclusion has more recently been reached by members of the World Health Organization (WHO).[2]

Thus, there are many medical people who are convinced that photochemical oxidant in very low concentration levels can cause substantial health effects to the general public. During the current sessions of Congress in which Clean Air Act amendments were being considered, industry spokesmen presented arguments against the present standard for photochemical oxidant. Senator Domenici appeared to reflect the predominant feelings among members of the Senate and House committees which reported out Clean Air Act amendments when he noted that:

> After listening to testimony from the medical community and reviewing the National Academy of Sciences report, the Senate Public Works Committee turned a deaf ear to industry attacks on the standard.[3]

Unfortunately, it is easy to become so engrossed in the controversy over health effects from low levels of photochemical oxidant, that the real-world situation is overlooked. In many American cities, citizens are frequently exposed to photochemical oxidants--not at levels near the standard where some controversy exists over the health effect--but at levels two to five times higher than the standard where the risk of suffering adverse effects is much higher and better demonstrated.

To put this into better perspective, the numerical value of the photochemical oxidant standard is .08 ppm (parts per million) hourly average, not to be exceeded more than once per year. In somewhat simpler terms this means that: except for one hour each year, the amount of photochemical oxidant in the air (averaged over a one hour period) should not exceed 8 parts oxidant per 100,000,000 parts air. In many American cities, particularly during the summer months, hourly levels of this air pollutant frequently range between .20 ppm and .30 ppm and have exceeded .40 ppm in some places. Thus, while arguments continue over the health effects caused by relatively low levels of photochemical oxidant, millions of Americans are breathing what is considered by many medical experts to be dangerously high levels. The available medical evidence shows that by reducing these high levels, even by relatively small amounts, substantial health benefits can be gained. Furthermore, technology which is reasonable in terms of its economic and social consequences, is available and can be applied to gain many of these benefits. Unfortunately, in the highly populated areas with maximum oxidant levels, there is little "danger" in the forseeable future that oxidant reductions will even approach the .08 ppm national standard that has generated some debate. Thus, that debate is somewhat academic.

BRIEF REVIEW OF HEALTH EFFECTS

Many elected officials may not be fully aware of the health effects which current levels of photochemical oxidant can cause. While a full discussion of all of the health effects data is not attempted in this paper, a brief summary of findings from recent studies conducted by the National Academy of Sciences, the World Health Organization, and other medical institutes should help officials to appreciate the need for reducing elevated levels of photochemical oxidant in their States and communities.

Before going into further detail, a few terms which may be somewhat unfamilar need to be defined. Photochemical oxidant is a group of compounds found as pollutants in the atmosphere all of which are characterized by their oxidizing properties. While there are a large number of compounds which can fall into this group, the one which occurs most abundantly, and for which most is known, is ozone. Another important chemical species measured as oxidant is a group of compounds referred to as PAN (peroxyacyl nitrates).

It is very difficult to obtain an accurate measurement of all the photochemical oxidant compounds in the air. Therefore, most air sampling stations only measure ozone which generally composes over 90% of the total photochemical oxidant in the air. Consequently the terms ozone and photochemical oxidant are sometimes used interchangeably. Many of the health studies, however, have been based on ozone effects rather than on total photochemical oxidant, and in fact, little is known about the health effects of many specific photochemical oxidant compounds other than ozone and PAN. Moreover, some of the other oxidants are stongly suspected to be dangerous to humans.

The two previously referenced reports from the National Academy of Sciences and World Health Organization, along with recent reports from the National Research Council[4] [which is composed of The National Academy of Sciences, National Academy of Engineering and The Institute of Medicine] and the Environmental Health Resource Center of the Illinois Institute for Environmental Quality[5] contain a wealth of medical data showing that health effects can accompany current levels of photochemical oxidant in many American cities. The information below has been extracted from these documents, which are available for those wishing to further explore the health effects of this air pollutant.

It is estimated that between five and ten percent of the general population suffer from some form of chronic disease. As hourly concentrations approach .20 ppm, ozone has been clearly associated with aggravating such diseases as asthma, chronic heart and lung disease, and certain anemias. Some asthma sufferers begin to experience significantly more attacks when hourly levels of ozone are around .15 ppm. People that are very sensitive to air pollution begin to suffer adverse effects at even lower concentrations. It is well documented that people who suffer from cardiopulmonary diseases such as asthma, emphysema, or allergies require many hours to recover from ozone-caused attacks.

Ozone can destroy or weaken red blood cells. For example, increased sphering (shape changing) of red blood cells in humans has been observed after only 30 minutes of exposure to ozone at .25 ppm. Since ozone measurements in the atmosphere are normally reported in terms of an hourly average concentration (rather than 30 minutes) and because similar damage to blood cells in animals has been observed at much lower concentrations, there is evidence that such damage can occur in some humans when hourly ozone levels are considerably below the .25 ppm value. This effect is of particular concern to people who may already have fragile blood cells. In this regard about 12% of the black male population is thought to suffer from G6PD deficiency, a disease which restricts the reproduction of red blood cells. Thus, in such people any cell damaged or destroyed by ozone is not readily replaced by normal body function. Similarly, people who suffer from vitamin E deficiency because of socio-economics, dietary habits, medication, illness, or other reasons, may also suffer additional stresses from breathing ozone.

Although it is often thought that photochemical oxidant affects only the sick or elderly, normal healthy people have also been observed to suffer adverse effects from exposure to this air pollutant. In Japan, during a smog episode in which hourly oxidant (ozone) levels reached .24 ppm, young school children suffered a number of adverse effects including difficulty breathing, nausea, headaches, coughing spells, eye irritation, throat pains, and periods of general ill feeling. This is a level which is reached in many American cities during summer months.

Carefully controlled laboratory experiments in this country have shown that ozone interferes with the normal function of the lung in healthy adults causing such effects as decreased air ventilatory functions, biochemical changes, substantial soreness, coughing, chest tightness, mucous expectoration, wheezing, nausea, pharyngitis, laryngitis and malaise. In normal healthy adults, these observations have not been demonstrated to occur below .25 ppm; however, it must be noted that these are effects when ozone is the only air pollutant present. Members of the National Academy of Sciences[1] point out that some of these effects can be expected to occur in the real world at ozone levels considerably below that observed in the laboratory test. This is because in addition to being a very toxic material, ozone is known to have synergistic properties (i.e., the health effects are much more pronounced when ozone and other common air pollutants are breathed simultaneously than when breathed alone). Thus ozone can aggravate some of the health effects that are actually caused by other air pollutants and can cause the effects to occur at lower levels of these pollutants than would happen if no ozone were present. Likewise, the presence of other air pollutants can synergistically affect the observed health effects noted during pure ozone studies.

A number of medical researchers have demonstrated that the effects of ozone are strongly aggravated during periods of exercise. Thus, while a person may not feel the effects of ozone while sitting or resting, his capability to perform tasks which require exercise can be greatly reduced by ozone. For example, healthy high school athletes have been observed to exhibit a decrease in performance as levels of ozone in the air increase. Statistical analysis of these data shows that this decrease can be detected as ozone levels reach around .12 ppm, and sharply worsen as ozone levels become higher. Thus, high levels of this air pollutant can affect the life style of people, perhaps without their awareness. The National Research Council in its report[(4)] noted that people tend to limit activities which require strenuous exercise when oxidant pollutant is high.

The Occupational Safety and Health Administration (OSHA) has determined that the air in the working environment should not average more than .10 ppm ozone during an 8 hour work day. Normally, OSHA standards are much higher than ambient air standards because the former are designed to protect healthy adult workers rather than the general public. Thus, it is sobering to note that in many American cities, ambient levels of this air pollutant that are breathed by all people, exceed the level that has been determined to be unsafe for normal healthy adult workers.

Other effects that have been observed in healthy humans at ozone levels found in many parts of the country, include increased coughing, irritations of the respiratory system, and decreased visual acuity (especially night vision). At levels even slightly below the current standard, eye irritation can be experienced (not from ozone, but from PAN and other photochemical oxidants) and increased headaches can accompany levels near the current standard.

There are also indirect health effects and direct non-health effects from exposure to photochemical oxidants. One researcher has reported a significant increase in the number of automobile accidents during periods of high levels of photochemical oxidant. The National Academy of Sciences has estimated that damage from this air pollutant to farm crops, forests, and material products can be as much as three billion dollars a year. Such damage is not confined solely to areas surrounded by highly industrial centers, as is evident from reports that the tobacco crop in the relatively rural State of North Carolina has substained several million dollars damage already this year from ozone in the air, much of which is transported from urban areas outside the State.

For obvious reasons, there are limitations to the type of experiments that can be conducted with humans. For example, young children, the elderly, and people with severe chronic illnesses cannot be subjected to experiments which may impair their health. Yet, these groups of people may suffer most from exposure to photochemical oxidants. It is also difficult to obtain a measure of the effects on humans from repeated exposure over a long period of time.

To help answer questions which cannot be answered through human experiments, scientists have tested a variety of animals, in chambers where the levels of ozone can be carefully controlled and maintained for long periods of time. Animal studies are commonly used to indicate likely effects of substances on humans. The results from these studies have created considerable concern among medical experts over exposure to high concentrations of ozone for short periods of time, and exposure to low concentrations for relatively long periods.

At levels and durations of exposure comparable to those experienced in many areas of the country, serious health effects have been observed to occur in animals. Among these are chromosome changes, permanent damage to the elastic recoil properties of lungs, decreased fertility, increased mortality, serious birth defects, and a very disturbing possible link with lung cancer.

Two observations made in animal studies are of vital concern to medical experts. One of these is that ozone appears to much more severely affect very young animals than the adults of the species. This, coupled with recent reports from scientists in Japan that very young human children have been observed to experience lung airway resistance from breathing ozone at .04 ppm, one-half the current U.S. standard, is extremely disturbing because such effects have not been observed in human adults at concentrations this low. The second disturbing observation from animal studies is that in very low concentrations (.08 ppm) for several hours, ozone can reduce the capability of body defenses of animals to fight off infectious bacteria. In this regard, The Illinois Institute for Environmental Quality has concluded:

> Since ozone has recently been shown to predispose the lungs to infection, increase vascular resistance, and affect the young more readily than adults, children must be carefully considered, especially because of their constant outdoor activities.[5]

Medical research has not, as yet, established a direct relationship between the effects observed in animals and the expected effects in humans. In many historical situations, however, the causes and effects of various diseases have been found to be similar in both humans and animals.

Medical experts outside this country have also concluded that levels of photochemical oxidant must be kept low in order to provide protection to the general public. Argentina (.10 ppm), Canada (.08 ppm), Japan (.06 ppm), and Romania (.005 ppm) have established very stringent standards for this air pollutant (averaging time for all the above standards is one hour except Romania which uses a thirty minute average). Other countries can be expected to establish national standards soon in light of work accomplished by the World Health Organization to help them reach such decisions. The chairman of the panel for photochemical oxidant from this organization has reached the following conclusion:

> It is apparent that any primary protection standard between .05 and .10 ppm will provide the narrowest margin of safety against some possible detrimental effects in the more susceptible segments of the population. There would seem to be little justification for exceeding .10 ppm for a primary protection standard, and the fact that the threshold limit value for occupational exposures in the United States is .10 ppm should reinforce the conclusion that this is the upper limit for a primary protection standard for the general population.[2]

THE EFFECT OF REDUCING CURRENT OXIDANT LEVELS

As noted in the reports from the National Academy of Sciences, the National Research Council and World Health Organization, many of the health effects from photochemical oxidant have been found to be dose-response related. This means that at some given level, called the threshold, some people are observed to begin to experience an effect. Then as levels increase above the threshold, the initial sufferers begin to experience more severe effects, while other people begin to feel the symptoms experienced by the initial group at the lower levels. Thus as the levels increase both the severity of the effects and the number of people affected increase.

Ideally, it would be desirable to maintain the level of photochemical oxidant or any other air pollutant well below any identified threshold value. Unfortunately, for many health effects the threshold value of oxidant is not known. From the previous discussion, however, it seems clear that for many of the effects, the threshold is considerably below the levels of photochemical oxidant currently being experienced in many areas of the country. Consequently, by beginning now to reduce the level of photochemical oxidant to which people are exposed, health benefits can be realized, even if the threshold value for every health effect is not reached right away.

An idea of how photochemical oxidant reduction can provide health benefits is contained in a recent report on "Mobile Source Goals Beyond 1980" prepared by a Joint Task Force of the Federal Agencies for the

President's Energy Resources Council.[6] In this report several health effects from photochemical oxidant were studied. Dose-response relationships for six symptoms were developed, which included aggravation of heart and lung disease, aggravation of asthma, incidence of chest pain, headaches, eye irritation, and incidence of coughing spells. From the work by this task force the aggregate effects from these six symptoms were found to be reduced by over 90% in cases where peak photochemical oxidant levels were reduced from .30 ppm to .15 ppm (a 50% improvement in air quality). Thus, in this case, even though the .08 ppm standard would not be met, substantial health benefits could be gained. Since many of the other health effects are probably related in a similar manner and clearly have thresholds below current photochemical oxidant levels, benefits for other than the above six symptoms could also be expected.

The concept that reducing current levels of photochemical oxidant will provide health benefits is not new or unique with this paper. Similar findings have been made by a number of knowledgeable scientists, including members of the National Academy of Sciences,[7] academic scholars,[8,9] and independent panels of medical experts.[10] In general these scientists report that the earlier these reduction programs can begin, and the larger the amount of reduction that can be obtained, the greater will be the health benefits. Similar conclusions have also been reached for reducing material and vegetation damage.

THE FORMATION OF PHOTOCHEMICAL OXIDANT IN THE ATMOSPHERE

The subject of controlling (or reducing the levels of) photochemical oxidant is very technical and has almost developed a language of its own. Yet, to understand the reasons behind various approaches to controlling this air pollutant requires some knowledge of how oxidants are formed in the atmosphere, and why they have become such a nationwide problem.

Photochemical oxidants are usually not emitted directly into the atmosphere by any source, but are formed through chemical reactions between other types of air pollutants, which are sometimes called precursors. These reactions require sunlight as a source of energy. The rate at which photochemical oxidant is formed depends upon the mixture of precursor air pollutants present as well as sunlight intensity. The reactions can be very dynamic in nature. That is, an oxidant can be formed and then react with some other compound to form a new molecule which can later be decomposed to again form oxidant.

This complex atmospheric chemistry occurs as the air mass moves across the country, generally from west to east. In this movement, which sometimes can stagnate for several days at one place, precursor pollutants are added to the air as it passes over sources of these pollutants, most of which are located in the immediate vicinity of urban areas. The net result of this process is that the level of photochemical oxidant present in a given urban area can be influenced by sources of the precursor pollutants in the immediate area, and by sources in other urban areas many miles away over which the air has previously passed.

To complicate matters further, some of the precursors react very rapidly after being emitted into the air, while others can remain in the air for relatively long periods of time before the oxidant forming reactions take place. Consequently, pollutants which enter the air as it passes over a city, can then later lead to high levels of photochemical oxidant in rural areas which may be essentially free of man-made sources of air pollution. Also ozone and other oxidants which form in the air over cities can be entrapped in an inversion layer, transported aloft for many miles, then later be dispersed to the ground at some point many miles downwind. This latter effect was recently demonstrated by the highly publicized da Vinci test conducted in St. Louis. In this test ozone generated over the city became entrapped in an inversion layer. Using a highly instrumented ballon, this pocket of high ozone concentration was tracked as it remained aloft (at about 2500 feet) and moved eastward away from St. Louis. When the inversion layer broke up, the ozone dispersed and caused violations of the standard in the middle of a wheat field 150 miles from St. Louis.

For the above reasons, photochemical oxidant air pollution tends not to be just a localized problem around smoke stacks, but is usually spread across large areas. To control this air pollutant, requires utilization of the factors over which man has some control--that being the manmade precursor pollutants which are emitted into the air and later react to form photochemical oxidant.

The two primary precursor air pollutants which lead to the formation of photochemical oxidant are hydrocarbon compounds and oxides of nitrogen. Historically, the major thrust for controlling photochemical oxidant has been through limiting the amount of hydrocarbon compounds emitted into the air. These compounds are emitted by a large number of diversely located sources including automobile exhaust, gasoline evaporation from handling and storage facilities, petrochemical plants, dry cleaning facilities, degreasing operations, paint shops, solvent facilities, along with many products commonly used in day-to-day living. There are also natural sources of hydrocarbon such as oil seepage, pine trees and rotting foliage.

There has been some implication that controlling manmade hydrocarbon emissions may not be effective in reducing photochemical oxidant levels because the air contains an abundant amount of hydrocarbon which is emitted from natural sources. However, after reviewing the available data, the National Academy of Sciences[14] recently concluded that the evidence indicates that at a maximum, only .05 to .06 ppm of the oxidant found in the air can be attributed to non-manmade (or natural) sources of hydrocarbons.

In laboratories throughout this country and abroad, many tests have been conducted in a device called a "smog chamber" to determine the process by which photochemical oxidant is formed. This device is simply a chamber in which environmental factors such as temperature, sunlight intensity and the amounts of various air pollutants can be carefully controlled to simulate the real-world atmosphere. Results from such tests, which have been conducted in government, university and industry laboratories, have uniformly and consistently revealed that when the mixture of reactive hydrocarbons* and nitrogen oxides is similar to that normally found in the air over major urban areas (that is the ratio of reactive hydrocarbons to nitrogen oxides is less than about 30 to 1) reducing the amount of reactive hydrocarbon present is a very effective means of lowering the amount of photochemical oxidant formed. Where the mixture is similar to that normally found in the air over rural areas (i.e., above ratio greater than about 30 to 1) reducing the amount of hydrocarbon may be somewhat less effective in reducing photochemical oxidant levels.

Results from the "smog chamber" data and well established chemical laws have lead most air pollution control experts to conclude that the most effective means of reducing current levels of oxidants is through controlling the hydrocarbon compounds that are emitted into the air by sources in and around major urban areas. By so doing, the oxidant which is formed over these areas can be reduced as can the oxidant and precursor pollutants that are transported outside the urban area.

Another very important reason for focusing control of hydrocarbon emissions on major urban areas is that oxidant levels are sufficiently high in such areas that current control technology will be effective in reducing these levels. On the other hand, for those areas where oxidant

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* Reactive hydrocarbons are those which react very rapidly in the atmosphere as distinguished from other hydrocarbons which react somewhat slower.

levels are usually relatively low (such as rural areas or isolated small towns), but occasionally may exceed the standard, there is some uncertainty over how effective localized control programs would be.

The California Institute of Technology recently completed a study[11] which shows that over the last ten years, controlling hydrocarbon emissions has proven very effective in reducing the level of photochemical oxidant in the Los Angeles Basin. During this time period the average daily emissions of reactive hydrocarbon in the Basin have been reduced by 18% through various control programs, while over the same time period the average hourly oxidant levels across the Basin were reduced by 19%. Also, it was found that programs to reduce hydrocarbon emissions have been extremely effective in reducing the number of times hourly oxidant levels reach very high values (over .20 ppm). When the data are statistically examined, a clear trend is established which reveals that whenever programs were implemented to reduce hydrocarbon emissions (such as new standards for automobile exhaust) corresponding reductions in the levels of photochemical oxidant were experienced.

It is often argued that trends in Los Angeles may not necessarily represent what can be accomplished at other locations. However, in the San Francisco Bay Area, which has historically experienced considerably lower levels of photochemical than those in Los Angeles, the same type relationship exists between hydrocarbon emission control programs and photochemical oxidant concentrations as noted above for Los Angeles. Although somewhat less convincing because of limited air sampling data and emission inventories, there are strong indications that a number of non-California cities have also experienced reductions in oxidant levels through hydrocarbon emission control program. Sampling data collected in Cincinnati, Denver, Philadelphia, St. Louis, and Washington, D.C. from 1964 through 1973 reveal a general downward trend in the levels of photochemical oxidant. The percentage change in peak concentrations for these cities is not too unlike that found in Los Angeles and San Francisco. Specific emission inventories over the time period are not available for the non-California cities, however, each has experienced some form of hydrocarbon emission control. For example, automobiles produced between 1963 and 1967 emitted 20% less hydorcarbons than pre-1963 models. Likewise, cars produced since 1968 have experienced systematic reductions in hydorcarbon emissions, so that a new 1973 model emitted (on the average) about 68% less hydrocarbons than a pre-1963 model.

Because of growing concern over the repeated number of times ozone watches had to be issued, the State of Illinois recently undertook an independent study to determine the most effective way to control ozone in that State. After a lengthy review of the entire ozone situation, the basic conclusion reached[(12)] was that emphasis should be placed on the reduction of hydrocarbon emissions in urban areas. Similar conclusions have also been reached by other States.

CONTROL PROGRAMS

In a typical urban area, hydrocarbon emissions come from a large number of sources which are usually located somewhat randomly throughout the area. The type of sources are usually quite different in each urban area. For example, in one location oil refineries may produce most of the hydrocarbon emitted into the air, while in another, automobile exhaust may be the largest contributor. Because of the wide differences in types of sources found in various cities it is not possible to outline a single control program which can be used for every city. Rather, it will be necessary to examine each city individually to determine the sources, amounts, and types (fast or slow reacting) of hydrocarbon emissions before an effective control program can be established for that particular city. For this reason, extensive cooperation between governments at all levels will be necessary if the oxidant problem is to be solved. Through effective planning and rational judgment, programs can be developed to reduce the threat of photochemical oxidant to the health and welfare of the nation, without creating chaos in the life style of the general public. The understanding, wisdom and leadership of elected officials are essential in the movement to clean up the air citizens breathe. Without the support of these officials, no air pollution control program can be fully effective.

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