Aspects of air pollution, and its effect on the respiratory system

Jennifer Randall
University of Northern Iowa

ASPECTS OF AIR POLLUTION, AND ITS EFFECT ON THE RESPIRATORY SYSTEM

Prepared for:
Presidential Scholars Board
15 April 1992

By
Jennifer Randall
Senior, Biology

ABSTRACT

This report centers around one of today's most prominent environmental issues-- air pollution. First, the major pollutants are defined and explained. Chloroflourocarbons, ozone, carbon monoxide, carbon dioxide, methane, sulfur dioxide, nitrogen oxides, and suspended particulate matter all receive attention.

Next, air pollution's effect on the Earth is explained. The "greenhouse effect", global warming, acid rain, and ozone depletion all have an enormous impact on Earth's climate and atmosphere.

The report proceeds on to discuss options for controlling and solving the air pollution problem. Selective catalytic reduction, noncatalytic reduction, tradeable permits-- these three processes are examples of large scale attempts at controlling air pollution. Shorter-lived chloroflourocarbons, renewable resources, and alternative fuel sources may help to approach an actual solution to the pollution problem.

The respiratory system's reactions to air pollution are considered next. The mechanics of breathing are explained first. Carbon monoxide's and ozone's effects on the pulmonary system are examined individually. Asthma and lung cancer are explored next, without specifying given pollutants.

Finally, a political approach to the problem is examined. One national and three international policies and plans are

discussed: The U.S. Clean Air Act revisions, 1990, the Montreal Protocol, 1987, the Large Combustion Plant Directive, 1988, and the United Nations proposal for 1992.

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In the beginning, the earth was a peaceful, self-regulating place. Its ecosystems lived in harmony and a stable balance existed between the land, the oceans, and the skies above.

Then, along came humans. At first, humans did not bother Nature. In fact, they built their own little niche into Life on Earth. As time passed, people became creative and inventive. New technologies and changing lifestyles affected humans-- they got selfish. Humans began to abuse the Earth that had welcomed them and treated them well. Humans littered the land, poisoned the oceans, and polluted the skies.

Now, as the twenty-first century approaches, humans are beginning to face and accept the magnitude of the damage they have done. The trend is reverting back to living in harmony with our Earth. Humans realize that they have a responsibility to repair what damage we can, and to control the existing damaging sources.

This paper centers on one of the Earth's most imminent problems-- air pollution. In many areas of the U.S. and the world, air pollution is not visible to the naked eye. In many other areas, this pollution is evident, and warnings about the air are issued daily. The entire Earth is affected by air pollution, regardless of geographical location. The level of pollution severity may differ, however. As discussed above, a new environmental trend is developing, one which hopes to repair the atmosphere, which has already been corrupted, and to control industrial sources which continue to emit harmful substances.

Before discussing air pollution, however, this report will describe the primary air pollutants themselves. This paper specifically will list 1) the most relevant air pollutants in the atmosphere, 2) how these pollutants affect the Earth, 3) attempts to control air pollution, 4) possible solutions to air pollution, 5) the effect of air pollution on the human respiratory system, and international and national attempts to control these pollutant emissions.

AIR POLLUTANTS IN THE ATMOSPHERE

As industrial demands increase, air pollution in the atmosphere also continues to increase. The total number of different air pollutants is absolutely mind-staggering. Pollutants may be classified as gaseous or particulate. Due to the vast number of pollutants, only the worst ones are described and explained below.

The largest detrimental effects are not seen from individual pollutants. " A recent study by Koenig suggested that pollutants interact synergistically: they are more powerful together than separately" (Read and Read, 1991, p. 36). In this study, a group of asthmatics were exposed to a low level of ozone. This exposure increased their vulnerability to low concentrations of sulfur dioxide (Read and Read, 1991, p. 36). This synergistic effect is of great importance, for ambient air conditions never contain only one pollutant. Thus, pollutant levels may be, and probably are, even more destructive than previously realized.

Chloroflourocarbons

Chloroflourocarbons (CFCs) are defined by Cohn (1987) as " a group of chemical compounds that contain varying members of chlorine, fluorine, carbon, and sometimes, bromine atoms" (p. 647). These chemicals were used in industry as early as 1930. Due to their chemical stability, CFCs are used to make hundreds of useful products from insulating foam to sterilizing or freezing solvents. CFCs are a fairly integral part of U.S. industry, equalling $27 billion yearly in goods and services rendered (Cohn, 1987, p. 647). The world's largest CFC producer, DuPont, alone holds 20-25% of the world market (Cohn, 1987, p. 650).

The problem with CFC's occurs when these chemicals drift into the upper atmosphere (stratosphere). Here, the sun's rays disintegrate these compounds. The chlorine element has an affinity for ozone, the Earth's protective layer in the atmosphere. Chlorine attacks and destroys ozone more quickly than ozone can be regenerated naturally. "This process is gradually depleting the stratosphere's ozone layer" (Cohn, 1987, p.647). The impact of CFC levels is further multiplied because the chlorine stays in the atmosphere, continuing its destructive reactions for 100 years or more (Gibbs and Hogan, 1990, p. 23).

Ozone and Carbon Monoxide

Ozone, O_3, protects the upper atmosphere of the Earth, but serves as a pollutant in the troposphere (the lower 10 km. of atmosphere). Carbon monoxide, CO, is discussed concurrently with O_3 because both pollutants are produced by gasoline powered motor vehicles. "It is estimated that automobiles emit 60% of all manmade, ozone-producing hydrocarbons and 98% of manmade carbon monoxide" (Daggett, 1988, p.27). How these pollutants affect the Earth will be illustrated later. They are also detrimental to human health. "Carbon monoxide impairs normal functioning of the heart and lungs: ozone can cause permanent damage to the respiratory system" (Daggett, 1988, p.27).

Carbon Dioxide

Carbon dioxide, CO_2 , must be considered separately from CO or O_3 due to the recent explosion of media coverage and resulting public alarm about the increases of CO in the atmosphere. CO_2 is a compound vital to life. CO_2 courses through the veins of human bodies every moment, and breathing itself is regulated by the partial pressure of CO_2 in arterial blood (Powers and Howley, 1990, p. 232-233.) However, CO_2 is also a byproduct of burning fossil fuels-- coal, oil, and natural gas. Everyone produces CO_2 . In fact, "the average person in the world delivers 1.1 tons of CO_2 per year into the atmosphere. The average American produces

5 tons per year" (Oman, 1988, p. 116). Industry and modern life as we know it would screech to a halt if fossil fuel burning was prohibited. Yet, resulting CO_2 production also threatens human life. This health situation is the more serious, the threat to life itself. The impact of increasing atmospheric CO_2 levels will be detailed in the upcoming section about the "greenhouse effect."

Methane

Methane, CH_4, is an atmospheric gas emitted primarily from coal mining, waste management, rice cultivation, oil and gas recovery and use, and, yes, even animal husbandry. Methane affects the atmosphere by "absorbing thermal radiation that radiates away from the Earth's surface. One gram of methane in the atmosphere absorbs infrared radiation about 70 times more effectively than CO_2 " (Gibbs and Hogan, 1990, p. 23). Methane, while increasing at a rate of almost one percent per year, still does not affect the atmosphere with the magnitude that CO_2 does. Methane's atmospheric lifetime is only about ten years long, while CO_2 as mentioned above, remains active in the atmosphere for around one hundred years (Gibbs and Hogan, 1990, p. 23)

Sulfur Dioxide and Nitrogen Oxides

Sulfur dioxide (SO_2) and nitrogen oxides (signified by NOx) are additional pollutants that merit comment. Nitrogen oxides chemically react in sunlight to form urban ozone, a pollutant mentioned earlier (Boer, Heggedus, Gouker, and Zak, 1990, p.312). Sulfur dioxide, which like CO is produced by burning fossil fuels, is a major cause of acid rain (Pool, 1991, p.337). SO_2 and NOx emissions also react to form acid aerosols. These acid "colloidal suspensions...form the misty air pollution called 'summer haze'" (Goldsmith, 1990, p. 561). This "summer haze" actually occurs during all seasons, but is most pronounced during the hot, humid days of summer, when temperature enhances the reactions of SO and NOx with the atmosphere (Goldsmith, 1990, p. 561).

Suspended Particulate Matter

Suspended particulate matter (SPM) also negatively affects air quality. Often SPM is of such fine particle size that it is not visible to the naked eye. Other SPM, like dust, can be seen. The variety of SPM is endless. Churg and Wiggs describe a list from their study: "kaolinite, talc, mica, feldspars, and crystalline silica account for about 75 to 85% of the total particles. Included in the miscellaneous group are spinels, calcium compounds (? oxalate or oxide), chlorite and vermiculite, biotite, tin and particles which could not be identified" (1985, p. 367). This list, from one sole study, indicates the wide range of atmospheric SPM.

THE EFFECT OF AIR POLLUTANTS ON EARTH

"Greenhouse Effect" and Global Warming

The "greenhouse effect" is a topic which did not exist fifty years ago and now stands at the forefront of environmental issues. This theory claims that air pollutants, especially CO_2, are forming a shield around the Earth. Visible rays from the sun can filter in, but are then trapped in the atmosphere by the CO_2 shield. Some trapping of this infrared radiation occurs naturally; this is what created the Earth's atmosphere and renders it habitable. Yet, the increase in CO_2 and other pollutants, and the resulting thickening of this shield cause the atmosphere to heat up more than normal. This predicted "global warming" could potentially melt arctic and antarctic ice caps and glaciers, thus raising ocean levels. "The Intergovernmental Panel on Climate Change forecasted last year (1990) that the oceans will rise about 20 cm. [7.9 in.] by the year 2030 and another 45 cm. [17.7 in.] by the year 2100" (Monastersky, 1991, p. 201).

Another result of the melting ice caps has been hypothesized. Methane, CH_4 trapped in the ice sheets would be released into the atmosphere if temperatures increased sufficiently. This CH_4 release would accentuate the greenhouse effect because CH_4 absorbs radiation so effectively (Dr. May, class lecture, March 24, 1992). As the greenhouse effect increases, global warming could potentially become more evident. This temperature increase could increase decomposition in soil, which in turn would increase CO_2 release. This CO release would again increase the greenhouse effect (Dr. May, class lecture, March 24, 1992).

Acid Rain

Acid rain is another hot trans-frontier, international, topic. Acid rain "is a shorthand version of acid deposition--the fallout of acidic material from the atmosphere. It can occur in dry and wet forms" (Park, 1991, p.28). The dry form gradually falls from wind and gravity. The wet form occurs more quickly due to atmospheric precipitation, but wet form usually affects a wider geographic area (Park, 1991, p.28). This acid deposition affects lakes and rivers, destroying fish populations. It "rains" on trees, wiping out huge spans of forests. Acid rain also destroys buildings and other manmade structures, corroding away stone and other building materials. "In the U.S. alone, costs (of acid rain damage) reach an estimated $5 billion annually" (Moore, 1990, p.15).

Ozone Depletion

Ozone depletion has become a prominent issue in the news today. In the early 1970s, it was hypothesized that CFCs drift into the atmosphere, are broken down by ultraviolet (UV) radiation, and destroy the ozone layer. This hypothesis was then confirmed by computer and laboratory research (Cohn, 1987, p. 648). British scientists made some surprising observations in 1984.

> The thinning, or ozone "hole", roughly the size of the continental U.S. begins to develop in August with the onset of the southern spring. It peaks in late September, begins to subside in October, when air currents over the South Pole change, and is gone by late November. In some locations, 50% of the ozone normally present disappears (Cohn, 1987, p. 648).

This stratospheric thinning of Earth's protective later allows more UV radiation to enter the atmosphere. This radiant penetration could have a wide variety of consequences. "Agricultural crops would be scorched, and yields would fall; marine plankton would be seriously affected; human health would suffer (there would be more eye cataracts, more skin cancer, more problems arising from damage to people's body immune systems)" (Park, 1991, p. 27). Obviously, control or reversal of ozone depletion must be achieved as soon as possible.

CONTROLLING AIR POLLUTION

An abrupt end to air pollution production would be ideal. Shutting off every pollution emitter in the world would solve the air quality problem, but industry simply does not work that way. Attempts to control and reduce pollutant emissions have been much more readily considered. Large scale implementation of low emission controls is coming of age. Selective catalytic reduction, nitrogen oxides noncatalytic reductions, and tradeable permits are all gaining popularity as the industrialized population tries to reduce its impact on the environment.

Selective Catalytic Reduction

Selective catalytic reduction (SCR) was first patented in 1959 by a U.S. company. It has recently gained popularity due to "declining costs, growing technical confidence among potential users, and impending legislation" (Boer, Hegedus, Gouker, and Zak, 1990, p. 312). SCR is a process which reacts nitrogen oxides (NOx) with ammonia, forming nitrogen and water. SCR is most often used for oxidation, thus neutralization, of power plant flue gas. The catalyst in this process ensures reaction with NOx only, rather than O_2 also, which is present in flue gas, too. Reaction products are components of everyday air, and the process is 80-90% effective at removing NOx. This is the highest removal percentage seen with today's technology (Boer, Hegedus, Gouker, and Zak, 1990, p. 312). As national and international emission standards become stricter, SCR technology will be the primary NOx neutralizer implemented into large power plants. Its cost effectiveness makes SCR quite appealing to big business, too. "At $400-$700 per ton of NOx removed, SCR compares quite favorably with estimates of $1600 per ton for incremental NOx removal in automobile sources" (Boer, Hegedus, Gouker, and Zak, 1990, p. 318). SCR is so effective and efficient, in fact, that it is not even needed by many emitters, only the very large scale polluters. Most NOx emissions can be adequately handled using noncatalytic measures.

Noncatalytic NOx reductions

Noncatalytic NOx reductions are most often implemented when emissions are in excess, but below 50% excess (Boer, Hegedus, Gouker, and Zak, 1990, p. 318). Two noncatalytic processes will be mentioned here-- one chemical, the other thermal. As with the SCR process, the noncatalytic processes are primarily used to reduce NOx in flue gas which enters the atmosphere. Many NOx reduction chemicals exist. "Urea (H_2NCONH_2) reacts with nitric oxide in the presence of oxygen at roughly 1500-2100 F [815-1150 C] to yield nitrogen gas, carbon dioxide,and water" (Epperly, 1991, p. 429). The reactions are assumed to be as follows:

1) Urea $\longrightarrow$ NH_2 + NCO

2) NH_2 + NO $\longrightarrow$ N_2 + H_2O

3) NCO + NO $\longrightarrow$ N_2 + CO_2 Epperly, 1991, p. 429).

Although many other combinations and temperatures exist, this example was chosen because most combinations originated from this formula.

Thermal deNOx is similar in theory to SCR, reacting nitrous oxide with ammonia to yield nitrogen and water, if used in the presence of oxygen. "Thermal" is the key word here. The process occurs under temperatures between 1650-2010 F [900-1100 C] (Lyon, 1987, p. 231). Due to the likeness in theory and chemical reaction, thermal deNOx can provide NOx reduction comparable to the SCR. Because SCR has large functional volume requirements, though, thermal deNOx can also be used in a wider variety of situations. On two similar oil-and-gas fired boilers, the two processes were compared for cost effectiveness. Both processes yielded similar reduction percentages, thermal deNOx at a capital cost of $0.4 mil., catalytic installation at $2.0 mil. (Lyon, 1987, p. 235).

Tradeable Permits

In the continuing effort to control and reduce air pollution, officials have suggested the use of tradeable permits. This tactic has been successfully used before. "When EPA phased out lead in gasoline, a market in lead allowances saved refiners about $200 mil. a year... savings for sulfur dioxide emissions could be 10 to 15 times as great" (Pool, 1991, p. 337). The system works by requiring purchase of permits for given amounts of pollution emissions. Reducing emissions creates an excess of permits, which can then be sold to others. Costs could also be kept low by keeping emissions low, which reduces the number of permits required (Victor, 1991, p. 453). the tradeable permits approach has two problems, though. First, pollution is seen by many countries as morally indefensible, and second, developing countries may demand the right to more permits because greenhouse gas emission is often a necessary part of standard economic development (Victor, 1991, p. 453). A concern also exists over the finite number of permits. The law of supply and demand could take over, and permit prices could skyrocket (Victor, 1991, p. 453).

SOLUTIONS TO AIR POLLUTION

While this section and the preceding one, "Controlling Air Pollution", may seem synonymous, a difference has been established by the writer of this paper. While a degree of overlap does exist, "Controlling" is seen as leveling out emission totals, ending the increase. Reductions could potentially exist. "Solving" the pollution problem is viewed at a futuristic and also smaller scaled levels. In the future, shorter-lived CFCs may be incorporated into industry. This integration is awaiting final safety, toxicity, and environmental testing (Cohn, 1987, p. 650). Solar, hydro, and nuclear power have all been put into use, and their potential as renewable resources really needs to be tapped in coming years. Transportation may even be "fueled" by alternative fuels, rather than the gas now in use.

Shorter-lived Chloroflourocarbons

As previously explained, the atmospheric lifetime of a broken down chloroflourocarbon (CFC) is one hundred years or more. By shortening that atmospheric lifetime, the long-term effect of CFCs on the ozone could be drastically reduced. CFC-11 and CFC-12 are now prominently used isotopes. Joseph Steed, an environmental manager for DuPont (the largest CFC producer in the world), sees CFC-134a, CFC-123, and CFC-22 as potential shorter-lived replacements of CFC-11 and CFC-12 (Cohn, 1987, p. 650). CFC-22 is already being used in some private and commercial air conditioning systems, but safety, toxicity,and environmental testing must be finalized before its use becomes more widespread or varied (Cohn, 1987, p. 650).

Renewable Resources

Renewable resources, solar, hydro, and nuclear, specifically, may earn deserved respect in the near future. "Sunlight can be converted directly into electric power without the release of carbon dioxide or any other pollutant" (Oman, 1988, p. 117). Aside from the fact that the sun only shines about one third of the time, "the penalty for substituting solar power for coal power is around a 10 times increase in the cost of energy" (Oman, 1988, p. 118). Until coal demand and prices skyrocket, the cost effectiveness of solar power is definitely lacking. And hydro power, though a wonderful source of electricity, is growing limited due to the fact that most desirable hydro sites already have dams (Oman, 1988, p. 118). Nuclear potential is as promising as ever but the public's fear of meltdown must be overcome before nuclear plants will flourish. If this stigma can be minimized, nuclear power could potentially be a determining factor in reducing air pollution. "The predicted year 2000 coal consumption of 985 million tons could be eliminated by generating the power in 360 new nuclear power plants, or by 7.2 plants per state" (Oman, 1988, p. 119).

Alternative Fuels

Four types of alternative fuels, as well as electric cars, have received recent attention for potentially decreasing pollutant emissions. Reformulated gas, methanol, ethanol, and compressed natural gas (CNG) all have emission reducing potential. Reformulated gasolines are such a new concept that ozone-forming potential has not even yet been determined. A 15-20% reduction in 0 -forming potential (as compared with current gasoline) is estimated 20% is the reduction potential for ethanol as well (Chang, Hammerle, Japar, and Salmeen, 1991, p. 1192).

Pure methanol, "Due to large reductions in evaporative and running loss emissions and reductions in tailpipe emissions" (Chang, Hammerle, Japar, and Salmeen, 1991, p. 1192) may achieve reductions from between 25-50%. Methanol mixed with normal gasoline will have much lower yields, but is more practical than pure methanol. Pure methanol is not a workable fuel yet. Safety problems (flame invisibility) and cold engine start problems limit the marketability of this fuel. CNG may be very marketable, on the other hand, because its primary emissions are very unreactive. Its reduction potential may be up to 60% (Chang, Hammerle, Japar, and Salmeen, 1991, p. 1192).

Electric cars, which sound like the answer to our coal- and oil-fired problems, actually may not solve anything. If the electricity to run the car was tapped from a fossil-fuel burning plant, no advantage is gained at all. NOx emissions in fact could potentially increase (Chang, Hammerle, Japar, and Salmeen, 1991, p. 1192). If electric cars gained their energy from a renewable resource, then net energy savings would be seen.

AIR POLLUTION AND ITS EFFECT ON THE HUMAN RESPIRATORY SYSTEM

Researchers in the medical community generally agree with this blanket statement: air pollution negatively affects the respiratory system. Complications arise when researchers attempt to narrow this statement by singling out a specific pollutant at a specific concentration level. Lipfert makes the observation that "direct experiments involving long-term clinical exposures of humans to air pollution are out of the question; analysis must be based on indirect observational studies-- 'natural' experiments" (1985, p. 764-765). This observation has merit, yet, natural experiments yield results affected by numerous outside influences. "The agents measured may be merely indexes of other pollutants or the health effects may be due to the combined action of various compounds" (Ponka, 1990, p. 35). Obviously, limits exist when screening for individual pollutant effects. However, some general conclusions have been reached and definitive data have been collected. Popular data collecting measures include portable personal air samplers, stationary monitor and extrapolating exposure, and biological markers (ex. levels of lead in the blood) (Lioy, 1991, p. 1361). This section will explain the respiration process, how CO and O affect the lungs, and air pollution's effect on asthma and lung cancer.

How Breathing Works

The diaphragm, the flattened, dome-shaped muscle arranged beneath the rib cage and lung cavity, is the primary muscle used in the respiration process. This process is run by the autonomic nervous system, and is thus ordinarily under unconscious control. Normal breathing occurs due to a pressure gradient between the lungs and the outside atmosphere. When the diaphragm contracts, it creates a low pressure environment, relative to the air outside the body. This outside air then rushes into the lungs, along the gradient. Once inside the lungs, air travels down the trachea to the two primary bronchi, which further branch into bronchioles. Lining the trachea, primary bronchi, and upper bronchioles are cilia. these tiny hair-like projections, with the help of a mucus secretion, serve to rid the respiratory branches of foreign particles. Alveoli are found beneath this protective layer. Alveoli, tiny air sacs where gas exchange occurs, are specifically located at the ends of the terminal bronchioles. Alveolar walls, often only one cell thick, are surrounded by tiny blood vessels. When inhaled gases, especially O_2, reach the alveoli, a diffusion gradient transports the gases across alveolar membranes into the bloodstream. Unwanted gases are expelled from the bloodstream in like manner, transported across the alveolar membrane and back up into the lung cavity, where the unwanted gases are exhaled. Exhalation occurs like inhalation, but in reverse. The pressure gradient now favors air diffusion to the outside atmosphere and is facilitated by relaxation of the diaphragm. This is precisely what happens upon exhalation, concluding the explanation of a one-breath cycle (Powers and Howley, 1990, p. 207-211).

How Carbon Monoxide Affects The Lungs

Carbon monoxide (CO) endangers human health because it decreases the efficiency of every breathing cycle.

> Its toxicity is based upon the fact that the oxygen carrying molecule of the blood, hemoglobin, has a high affinity for it. CO occupies oxygen binding sites within the hemoglobin molecule to produce carboxyhemoglobin (CoHb), reducing the oxygen-carrying capacity of the blood (Read and Read, 1991, p. 37).

When the blood carries less oxygen, the brain and other vital organs suffer. Heart disease sufferers may be affected by even low concentrations of CO. Inhaling carbon monoxide while exercising, angina patients studied at the Health Effects Institute of Boston experienced chest pains when CoHb levels reached 2 percent (Read and Read, p. 37).

Effect Of Ozone On The Lungs

Ozone (O_3) also causes negative effects on the lungs' passageways, but in a different manner. Ozone inflames the interior membrane of the respiratory branches, making it more permeable to outside gases. Such inflammation occurs at the Canadian standard of .08 parts per million (ppm) per hour. The current U.S. standard is .12 ppm (Read and Read, !991, p. 36). This discrepancy, while not immediately life-threatening, could lead to long-term health consequences, including chronic bronchitis and an predisposition to pneumonia (Thomas, 1989, p. 252, 1426).

Asthma

Asthma is "paroxysmal dyspnea [labored breathing] accompanied by wheezing caused by a spasm of the bronchial tubes or by a swelling of their mucous membrane" (Thomas, 1989, p. 153). This respiratory affliction is considered independently of a specific pollutant, because asthma is generally affected by many pollutants. Bronchoconstriction, a contraction of the bronchiole walls which makes breathing more difficult, was seen at 0.1 ppm of $SO_{\ }$ in certain asthmatics in one study. The same study got bronchoconstriction from all subjects at 0.5 ppm concentration. The current Occupational Safety and Health Association (OSHA) standard is 5 ppm over a weighted 8 hour period (Goldstein and Weinstein, 1986, p. 332). Particulate air pollution, too, "has been associated with increased asthmatic symptoms and respiratory hospital admissions" (Vedal, Schenker, Munoz, Samet, Batterman, and Speizer, 1987, p. 694). Urban ozone also worsens asthma symptoms, due to reasons explained above. Volatile organic compounds (VOCs) and nitrogen oxides form ozone in the presence of sunlight (Boer, Hegedus, Gouker, and Zak, 1990, p. 312), and are thus indirectly guilty of asthmatic occurrences. Asthmatics obviously cannot safely breathe (ambient) polluted air. National standards currently exceed levels where most asthmatics suffer bronchoconstrictive responses.

One exception to this sobering asthmatic picture: a study done in Los Angeles did show that NO_2 in clean air alone (trials at 0.0, 0.3, and 0.6 ppm) did not elicit a response in moderate to severe asthmatics (Avol, Linn, Peng, Vallencia, Little, and Hackney, 1988, p. 143).

Lung Cancer

Lung cancer also receives individual attention due to the large number of pollutants which contribute to this frightening disease. Suspended particulate matter (SPM) affects lung cancer incidence the most. Not every type of airborne particle causes lung cancer, but even noncarcinogenic (not cancer-causing) particles may increase the rate of lung tumor development if carcinogenic particles are present (Churg and Wiggs, 1985, p. 364). Thus, SPM levels should be kept as low as possible. In 1989, the EPA released a report entitled "Cancer Risk from Outdoor Exposures to Air Toxics". Both gaseous and solid pollutants were considered, 83 pollutants in all. While 30% of these were "proven" carcinogens, an EPA verification agency had not completely reviewed the results before the report's publication (Gray and Graham, 1991, p. 286, 288, 292). Although this oversight taints the data, the report still has value, for it explains the existence of thresholds.

> The mechanisms of chemical carcinogenesis are still unknown, but there is evidence that at least some, if not all, chemicals may have an exposure threshold below which they do not cause cancer. Since the concentrations of outdoor air toxics are frequently in the parts per billion (ppb) range, and may be less than exposure thresholds, the issue of thresholds becomes significant (Gray and Graham, 1991, p. 293).

While the existence of thresholds may provide some level of protection, the sheer number of pollutants, as well as the cancer facilitating effect of particulate matter, shows the imperative nature of reducing air pollution to also reduce incidence of life-threatening lung cancer.

INTERNATIONAL AND NATIONAL ATTEMPTS TO CONTROL OR LIMIT AIR POLLUTANTS

Due to the height and force of the trade winds and the jet streams, Earth's major air currents, air pollution is not location-specific. A large emissions site could conceivably pollute its surroundings for hundreds of square miles. The Organization for Economic Cooperation and Development (OCED) classifies international pollution two ways:

1) upstream-downstream pollution: upstream (or upwind) countries benefit from the natural export downstream (or downwind) of the polluted water (or air), and downstream (or downwind) countries suffer from receiving it.

2) reciprocal pollution: costs and benefits of polluting processes are scattered through a number of

> countries, including the source country or countries (Park, 1991, p.24-25).

Obviously, worldwide cooperation is necessary for any definitive progress against air pollution. Worldwide cooperation begins with individuals, and every day, the general public increases its awareness of air pollution. Since 1970, when the first Clean Air Act was passed, countless efforts to control or reduce air pollution have been and continue to be attempted. These attempts, some more successful than others, occur at every legislative level, from city to county, state to national, national to international. Listed below are four recent attempts to control air pollution, one national and three international, all dated 1987 or later.

Montreal Protocol, 1987

Following the British discovery of the seasonal Antarctic ozone hole (thinning) in 1985, a frantic organizational attempt was made to make concrete and official international efforts to decrease CFC levels. The result of this organizational push was the Montreal Protocol, signed in 1987 by 39 countries. In March of 1989, more nations signed the Protocol (Park, 1991, p.27). These countries agreed to "freeze CFC production at 1986 level, and to decrease production by 20 percent by 1993, and by half by 1999" (Park, 1991, p.27).

Large Combustion Plant Directive, 1988

Not only CFCs were being scrutinized at this time. SO_2 emissions were also recognized as environmentally detrimental. THe European Community thus proceeded to form the Large Combustion Plant Directive. This directive ordered three stages of SO_2 reduction, with deadlines in 1993, 1998, and 2003. Germany, France, Holland, and Belgium entered in enthusiastically, while Britain and the United States grudgingly joined (Park, 1991, p.33). "Britain and the U.S. remain 'dirty old men' in the acid rain debate, refusing to cut down emissions as much and as fast as most other countries think necessary" (Park, 1991, p. 33). Economic and political incentives need to be developed to encourage more widespread cooperation.

U.S. Clean Air Act Revisions, 1990

The U.S. Clean Air Act (CAA) was originally passed in 1970. It was revised in 1977 and revised again in 1990 to accommodate changing environmental conditions. The major goals of the revisions were to prevent accidental spillage of dangerous pollutants, to assure standard compliance for solid waste incinerators, and to regulate levels of existing or new source emissions (Frye, Chadbourne, and Parke, 1991, p.29). The Environmental Protection Agency (EPA) will be required to list major pollutants and allowed levels, indicate potential high risk sources or emitters, approve techniques for emission reduction, standardize permit requirements for emitters, and standardize methods and limits for CAA enforcement (Frye, Chadbourne, and Parke, 1991, p.29-31). "Compliance will generally be required within three years after the standards are established" (Frye, Chadbourne, and Parke, 1991, p.29). Of course, some exceptions and time extensions apply to these new standards, and a few years will pass before this system is in place and running smoothly, but these revisions, if enforced properly, will provide a drastic reduction in pollutant emissions.

United Nations Proposal, 1992

In February, 1991, 101 countries met to discuss the state of atmospheric warming, and the state of the air on Earth. The leaders at this meeting hoped to organize a climate treaty which would be ready to sign in June, 1992. Although progress was slow at best, and no written document produced, this conference was seen as a positive sign. Representatives from both industrialized and non-industrialized countries were present. Such collaboration is essential. If progress is to occur in non-industrialized countries, as well it should, the industrial powers must be willing to foot the bill for some emission control technology to be put into use in these less developed countries (Monastersky, 1991, p.200).

CONCLUSION

Since the beginning of Life on Earth, symbiotic and cooperative relationships have existed. In this modern age of ever-changing technology, industry, and lifestyles, humans need to realize that the Earth truly is not theirs for the taking. This realization is slowly becoming the prevalent opinion, and not a moment too soon.

With pollutants like chloroflourocarbons, ozone, carbon monoxide, carbon dioxide, sulfur dioxide, and nitrogen oxides increasing in the stratosphere, it is only a matter of time before such environmental abuse overloads the atmosphere. The delicate balance of Nature seemingly has already been altered. The "greenhouse effect", global warming, acid rain, and ozone depletion are just four examples of how abuse of the Earth can potentially bring about its demise.

Controlling air pollution, and potentially even solving the problem with such methods as shorter-lived cfcs, renewable resources, or alternative fuels could abate any public fears about losing the atmosphere or suffering in terms of health. CO and O_3 have life endangering effects on the respiratory system. Asthma and lung cancer are two respiratory diseases which are directly affected by air pollution. The need for eradication or at least reduction of air pollution is obvious.

Luckily, worldwide organizations and plans have been introduced in attempts to slow, stop, ar even reverse the negative effects that air pollution has caused. The Montreal Protocol, the Large Combustion Plant directive, the changes in the U.S. Clean Air Act, and the U.N. conference involving 101 countries are all indicators that with such cooperation, the world's nations may truly be capable of air pollution control.

The end or even "middle" of the road to control and reduce air pollutants is yet far away. "The World Health Organization estimates that fully 70 percent of the globe's urban population breathes air made unhealthy by high levels of smog, sulfur dioxide, nitrogen oxides, and other pollutants" (Moore, 1990, p.14). Yet, the inhabitants of Earth seem to be on the road to control, and this does seem promising.

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Jennifer Randall