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Atmospheric Changes and Energy Loss Due to Industrial and Residential Combustion of Hydrocarbon Fuels

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Introduction

As many as thirty-seven (37) known metallic and gaseous particulates and matter make up air pollution. [1] But the detection of the components of air pollution varies according to the geographic region studied the and the thoroughness of the testing. Areas of high population and industry lend themselves to excellent findings with relative ease, but areas that are remote from pollution sources are more difficult to investigate and make source detection more complicated to conduct accurately. For the purpose of this study the areas of the northeast United States and southern Canada are the areas whose reports will be used and the data used will relate to pollution which is attributed to emissions from coal industries. Coal is the United States most abundant natural fuel source and data concerning gaseous emissions and heat energy production is most readily available. Although coal is the primary energy source of this discussion, additional data on oil and nuclear fuel is included so that a comparative analysis and greater discussion can be pursued.

Lesson 1

(1) The Public Acceptance of the Risk of Hazards in the Energy Industry
(2) Major Sources of Air Pollution

The major industrial hazards associated with the use of any of the hydrocarbon fuels (coal, oil, and gas) come in the actual retrieval of the fuel and its refinement and transport to the consumer and, then, in the actual usage of the fuel in the combustion process.

The primary cause of air pollution is from the combustion of the hydrocarbon fuels. It has had very grave health effects on the population in heavily industrialized areas. There has also been well-documented damage done to buildings, statues, fabrics, vegetation and water supplies. Not until recent years has there been strong enough public opinion to warrant the enactment of legislature to control pollution and to take measures to protect the environment. The lack of early controls may be due to public acceptance of the secondary “mals” of an industrialized society. Bronchitis, asthma and emphysema are only a few of the health problems attributed to air pollution and can be added to a much longer list of health problems of industrialized society. (Appendix 1)

Many see the secondary harmful effects of industry as “the price to pay for progress.” The intellectualizing process of risk assessment and acceptance has been evaluated by social psychologists. [2] Those who study public reaction to potentially hazardous conditions find reactions favorable if the hazardous conditions have been present over a period of time (longevity factor) and if the hazards are not omnipresent because of constant news media coverage. There have been definite predictable public outcries to well-publicized catastrophic events involving the nuclear powered energy plants (Three Mile Island) and relatively little concern about the long-term accumulative risks of air pollution. [3]

The emissions causing pollution arise from power-generating plants, residential and commercial buildings, industrial facilities, petroleum refineries, chemical plants and automobiles. These sources are all powered by fossil fuels of nuclear energy. The hydrocarbon or fossil fuels all have the carbon-hydrogen bond. This study concentrates on coal.

Generally speaking, of late, air pollution has caused concern because the increase in population and the resultant decrease of land per capita has had a directly proportionate relationship with the consumption of the fossil fuels. In turn, the increase in consumption has caused a proportionate increase in air pollution. Specific areas have had a high-incident-rate of air pollution related problems. Those adversely effected areas receiving high concentration of pollutants from coal powered plants are in northeastern regions of the United States and southeastern regions of Canada.

A shocking statistic is that the United States has 6% of the world’s population and consumes 1/3 of the world’s energy. [4] The problem of increased consumption mandates recognition of the problem in the United States and recognition that Americans lead the world in energy consumption per capita. [5] Further, the statistics relating energy consumption, population growth and production growth show that the disproportionate rate of production and energy consumption per capita has caused hazardous levels of air pollution. The pollution increase is not due to the growth of the population alone. Air pollution increases *a* t a rate of 4.4% on a mass basis and 4.9% on air quality basis annually. [6] (Appendix 4).

Here, these statistics remind us that the U.S. has an inordinantly high per capita consumption of energy compared to all other nations. The questions that should be considered are: Whether this consumption can and should be moderated? Whether the national controls can be applied without impinging on individual rights? Whether other nations should have the opportunity to share in the large energy consumption?

Sharing the world’s energy supply poses questions far more complicated than sharing in the assessment of air pollution and extracting fair compensation for damages. What also should be considered when balancing the world energy supply and demand that the U.S. per capita consumption increase has risen with the production of industry (which requires the energy) so to redistribute energy would mean redistribution of industrialization. Interestingly, Japan’s energy consumption has far exceeded that of the U.S., United Kingdom and the USSR from 1960. This increase is a direct indicator of Japan’s economic and industrialization growth for that same time period. Emphasis of the industrialized energy usage is made from the energy supply and demand scenario. (Table 2 in appendix 4). Of the 150 quads of energy supplied in 1977, over 1/3 or 56.4 was used industrially, 54.2 for residential/commercial use and the remaining went into other usage dominated by 31.5 to transportation. Coal contributed 41.3 quads to the 150 total and 28.9 of the 41.3 were used for energy production. Of the 48.4 quads for oil as a fuel only 3.0 were used for electrical power. So coal is the major fuel used to provide electrical energy therefore the study of the pollutants from the coal production is significant.

Air pollutants are quantifiably measured from air samples and from acidity concentrations in all forms of precipitation.

Particularly effected areas in the northeast include two hundred and twelve (212) lakes in the Adirondak mountains of New York state. These lakes have been rendered unfit for fishlife. Other northeastern states particularly hardhit by acid rain are Massachusetts, Rhode Island, Vermont, New Hampshire, Maine, New Jersey, Pennsylvania and Maryland. [7]

The midwestern states of Ohio, Illinois, and Indiana are responsible for one-fourth of the total sulfur dioxide pollution in the U.S. Studies reveal that 23.4 million tons of S02 were released in 1974 and 20% more in 1985. Two-thirds of that, almost 20 million tons, came from coal and oil-fired power plants. The other third of the S02 pollution was contributed as follows: 26% from industrial boilers, 5% from commercial and residential buildings and 3% from transportation. Ohio, Illinois and Indiana produced nitrogen oxide emissions accounting for 22.2 million tons in 1974 growing 40% in the 1975-85 period. The emissions of N02 are growing twice as rapidly as S02. Forty per cent of the N02 comes from transportation and 30% from power plants. [8]

Lesson 2

Calculating the effect of pollutants "loaded" into the atmosphere

Computing the total mass of pollutants 'loaded' into the atmosphere requires calculating the percentage by volume of specific substances. The mass volume of the atmosphere without additional pollutants is computed from the atmospheric pressure, the earth's mean radius and gravitational acceleration. This formula is $4 * ( ) * 1.013 * 10^{5}$ N/m ^{2} /g and g equals 9.8 m/s ^{2} . The total mass of the atmosphere is $5.1 * 10^{18}$ kg after the total mass of mountains has been deducted from the above formula which does not allow for irregularities of the earth's surface. Testing for pollutants in a specific volume of atmosphere requires finding a per cent by volume of the pollutants. This is expressed in parts per million (ppm). That is x number of pollutants per million of atmospheric air. To find the number of molecules of a substance the total weight is divided by the molecular weight. For instance, the normal unpolluted dry air has a total mass of nitrogen or 3,850,000,000 metric tons (78.09%) and 1,180,000,000 metric tons of oxygen (21%). [9] (Appendix 6).

Similarly, the pound-moles of input and output products in coal combustion can be calculated. In the coal-fired furnace where 2000 pounds of coal is burned, the percentage of carbon is converted to pounds and then to pound moles. The weight of gaseous emissions in flue gas can also be computed. Carbon is released in combinant form with oxygen as carbon monoxide or carbon dioxide. Sulfur and nitrogen are released in oxide forms. Or, minute particles called particulates enter the atmosphere in the form of ash.

Particulates are graded according to size, and the size is an indicator of the settling speed with which the matter is removed by gravitational pull. Particles are Aitken, large or giant according to increased size; and, the settling speed is determined by density. Smoke is a term used to describe a mixture of particulate material gases and mists. Dust refers to solid dispersion aerosols and mist to liquid aerosols. [10]

Even though the mass volume of pollutants can be determined by using the formulae below, it is not always easy to document the strength of pollutants or the exact location of particular emissions. An accumulation of materials over a long period of low concentration depositions called 'loading' results in the long-range transportation and long-term accumulations. Pollution often extends over several states. The environmental impact in any one specific region is assessed according to the variable factors specific to that region. Areas of great humidity, temperature inversion zones and frequent precipitations are more susceptible to smog and acid rain damage than arid areas. Further geological formations and soil composition can enhance an areas vulnerability to acid rain damage through changes to soil chemistry. [11] (Appendix 7).

The calculations below are completed to show the pound-moles of flue gas emissions released by a single coal-fired furnace.

MATERIAL 7 ENERGY BALANCE ON A COAL-FIRED FURNACE

(figure available in print form)

MATERIAL BALANCE BASIS: 2000 LB. COAL

WEIGHT OF ASH PRODUCED = (2000)(0.1671) 334.2

CARBON BALANCE Lb.moles carbon in coal = lb.moles carbon in flue gas

(2000)(0.6593) = 109.88

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OTHER COMPONENTS OF FLUE GAS (DRY BASIS) Lb.moles 02

(figure available in print form)

Lb.moles N2

(figure available in print form)

Lb.moles SO2

(figure available in print form)

TOTAL MOLES DRY FLUE GAS

C0	109.88
02	29.91
N2	598.79
SO2	1.85
	740.43

NITROGEN BALANCE Lb.moles N2 in flue gas = lb.moles N2 in coal + lb.moles N2 in air

(figure available in print form)

Lb.moles N2 in air = 597.86

(figure available in print form)

HYDROGEN BALANCE Lb.moles net hydrogen in coal + lb.moles water in coal

= lb.moles water in flue gas

(figure available in print form)

Lb.moles water in flue gas 46.88

SUMMARY OF MATERIAL BALANCE

INPUT	*LB.MOLES*	*MW*	*POUNDS*
COAL			2,000
N2 IN AIR	597.86	28	16,740
02 IN AIR	158.93	32	5,086
			23,826

OUTPUT

CO2	109.88	44	4.835
O2	29.91	32	957
N2	598.74	28	16,766
SO2	1.85	64	118
H20	46.88	18	844
ASH			334
			23,854

Lesson 3

Air Pollution Chemistry

Nitrogen—The atmospheric chemistry of nitrogen oxides is more complex than that of sulfur and because of the 40% increase in NOx emissions from Ohio, Illinois and Indiana, nitrogen compounds are of paramount concern. Nitrogen reactions include the following: (1) Nitrogen reacts with oxygen to form nitrogen oxide which rapidly oxidizes further to produce nitrogen dioxide: (2) Ozone is produced in the presence of nitrogen oxides when photochemical reactions and hydrocarbon reactions take place: (3) Nitrogen oxides react with H20 to form nitric acid, a great contributor to acid precipitation, and: (4) Nitrogen oxides result in the production of PAN (pereoxyacetyl nitrate) which has a deleterious effect in laboratory testing of vegetation. Both nitrogen oxide and nitrogen dioxide have a low ‘dry deposition’ velocity and stay airborne longer. They are less water soluble than sulfur oxides making cleansing by washout limited. Oxidation of NO2 to HNO3 involves the OH radical of atmospheric ozone. Nitric acid aerosols are removed from the atmosphere by dry deposition. [12]

(figure available in print form)

Sulfur, the greatest mass quantitatively of air pollutants is attributed to sulfur dioxide emissions and particulate matter. Both in dry deposition and when reacting with H20 to form dilute sulfuric acid, sulfur has taken its environmental toll.

(figure available in print form)

Concurrent with the above process of dry deposition, rainout, and washout, a continuous homogenous oxidation of sulfur dioxide occurs in the presence of ultraviolet energy. The oxidation rapidly increases in the presence of nitrogen oxide and olefinic hydrocarbons which act as catalysts. Particulate sulfates have a greater atmospheric lifetime than does sulfur dioxide and sulfuric acid aerosol can stay in the air for 2-4 days and travel 1000 plus km with an atmospheric speed of 20 km per hour. [13] The particulate matter both solid and liquid aerosols, arise in the atmosphere from condensation or dispersion and drop by gravitational settling. The particulate matter varies in size and is measured in the atmosphere in mG/m^3 (milligrams per cubic meter) because being non-gaseous it is not possible to measure it by volume. The particulate matter has an effect on the environment by scattering or absorbing sunlight. Cities effected receive 15-20% less or sometimes 1/3 reduced solar radiation. Particulates reduce visibility by attenuating air molecules therefore reducing contrasts. [14] (Appendix 7)

(figure available in print form)

Carbon dioxide, a byproduct of hydrocarbon consumption and specifically dense in areas of great coal combustion, enters the atmosphere in relatively large quantities. The ambient C02 pressure remains fairly constant however due to plant utilization in photosynthesis and therefore poses no great threat. With increased CO_2 atmospheric radiation balances are subject to change. Increased C02 which allows visible infrared (heat) rays to penetrate but prevents terrestrial radiation can cause the earth's surface temperature to rise. This is known as the 'greenhouse' effect. [15] Appendix 8. A past value of 290 ppm of C02 has now increased to 337 ppm or 15% more. The earth's surface temperature increases 1.9°C for every doubling in the ppm amount of atmospheric C02. When temperature inversions occur or there is movement of high pressure cold fronts, severe smog episodes result. These episodes pose extreme environmental problems and thousands of human fatalities. [16]

Lesson 4

The Anthropogenic Effects of Air Pollution Upon Soil, Terrestrial Vegetation and Materials and Building Facades

Adverse chemical impacting on soil and vegetation is due to dry deposition where the air is cleansed by direct absorption by plants and soil of air pollutants. Further cleansing is accomplished by washout and by rainout, the latter a cleansing of clouds and the former a removal of pollutants in the air beneath clouds by falling precipitation. Soil is a hetero—colloidal mix of organic and inorganic matter stratified into horizons. Horizon "A" near the surface is where the weathering of inorganic material occurs and where biological organic matter decomposes. Horizon "B" beneath "A" receives the dissolved matter and minerals which percolates through. Themetallic compositions remain in equilibrium in the pH of the soil. Acid rain alters the pH in "A" horizon and subsequently in horizon "B" as well. [17]

The equilibrium is maintained because under normal conditions weathering and gas extraction from the soil lead to the release of gases, whereas the litter (biotic decomposition) and atmospheric acid lead to acidification. Slow acidification called podsolization can be accelerated by leaching and increasing the rate of biotic matter decay. Interestingly, nutrient elements needed in the Soil are N, P, K, NA, Mg, S but soil contamination by toxic metals as a result of aerial deposition are Pb, Zn, Cu, Cd Ni and Hg. Atmospheric fluoride is phytotoxic at 25-50 ppm and aluminum is abundantly toxic in soils. [18]

Some elements essential for plant growth and also injurious to plants in certain forms and concentrations are nitrogen and sulfur. Both are necessary for plant protein synthesis but deleterious in dry deposition and acid rain form. Additionally, acid precipitation impacts directly on plant foliage and by contributing to impoverished soil conditions and by destroying beneficial microorganisms.

Experimentation has produced quantitative and qualitative parameters of tolerance of polluting chemicals upon plant life. It has been determined that pollutants can plasmolyze cells and thereby destroy plant chlorophyll which then reduces plant food production.

Ozone causes tobacco leaves to develop light-colored lesions and pinto beans to develop stippled pigmentation.

PAN injuries are similar to other pollutants manifested by silvering or glazing of the leaf surface and the plasmolization of the parenchyma cells. It is noted experimentally, that varying the conditions of light intensity, temperature, humidity and nutrition alter the “threshold” of injury in most vegetative forms. For example, nitrogen dioxide at 55 ppm and SO2 at 3 ppm for 8 hours is sufficient to overcome the “injury threshold”. [19]

The accumulative deleterious effect upon vegetation and other environmental problems depends on ‘local receptors’ for ethylene.

Lesson 4

Part 2

There are a number of examples where pollution clearly has damaged materials. Ambient sulfur products historically are responsible for corrosion of metals again dependent upon he level of oxidants, temperature and humidity. Greater water vapor pressure causes a faster rate of corrosion. It is believed by many that the bendability and pliability of metals may be adversely effected by sulfur. [20] Sulfur products also damage fabrics, in acid from S carbonates stone and erodes electrical equipment. Cotton material looses its breaking strength at the rate of .025% every 10 years for lmG/m^3 of S02 pollution.

Many of the titration experiments performed in the laboratory serve to demonstrate the accumulative effects of acid to change a basic solution. These activities are demonstrative of the slow and hardly determinative effects of small amounts of acid rain on water reservoirs. But if the acid rain continues as in titration experiments eventually the total acidity of a large body of water can be effected which will in turn effect the entire biotic community. Litmus paper demonstration from even dilute nitric and sulfuric acid will reaffirm the products as acid.

The use of acid in dilute form on limestone or other calcerous stone is a vivid example of the effects of acid on geological formations. Such natural dissolution of rock can effect the water reservoirs by changing the composition of aqueous solutions.

There is available information in all local communities on the cost of cleaning the facades of buildings which have been eroded by atmospheric elements.

The damages resulting from the pollution can be extremely depending upon the locale.

The Council on Environmental Quality has estimated the total air pollution costs in the United States at $16 billion annually, which corresponds to $80 for every man, woman, and child in the country. In 1970 the council estimated some particular annual costs as follows: $100 million for painting steel structures; $800 million for laundering and dyeing of soiled fabrics; $240 million for washing cars dirtied by air pollution; $500 million for damage to agricultural crops and livestock; $40 to $80 million for adverse effects on air travel, largely due to reduced visibility [22] Not included in these figures were costs of absenteeism from work due to illness, medical costs and the scraping and restoring of buildings. [23]

Lesson 5

Culpability and Liability, The Legan and Political Problems in Assigning Fault/Cost

Some of the material available relates the difficulty of assembling the complete and reliable chemical knowledge of soil deterioration and the long-range deleterious effect of air pollution upon health and aquatic systems and agriculture. For instance, the long-term cause/effect relationship between lake acidification (and subsequent fishkills) and pollution offenders has been difficult to establish. Another problem arises when assigning a cost/benefit ration. [24] Consumers argue that they are paying double when asked to pay abatement costs and to suffer the damage of air pollution without legal recourse for those damages through tort litigation. Justifiably the consumer does not want to be taxed with the financial burden that abatement methods require. Most feel that the cost of cleaning the air should be borne by those who are using the air for disposal. The counter argument that air pollution is a universal problem and therefore should be universal borne simply does not stand. Changes in international law covering injuries were made after long-range transportation of pollutants in Canada occurred. Jurisdiction is given over a non-resident defendant in Canadian courts and convention provides that tort action law of “delegable liability” applies. [25] The reasonable man standard applies as in all negligence cases. The “due diligence” standards also applies in the protection of water rights. Riparian rights refer to those rights to have a water supply free from pollutants and law protecting the riparian rights was adopted in the U.S. from English common law. Many courts have interpreted the protection of riparian rights very strictly saying that it is not enough that manufacturers use due diligence or precautions that a reasonable person would take to protect the water supply but, any harm at all to the water supply regardless of the reasonableness of the standards of precaution is the responsibility of the wrong-doer.

When the court has made a decision regarding the alleged damages caused by air pollution, the damages are then assessed to all the proven wrong-doers so that there is a shared or delegable liability which means that offenders are assessed damages according to their total contribution to the fault.

The human rights approach granting life, liberty and the pursuit of happiness as a constitutional right does not apply to cases of international offenses. Howegver, the concept is loosely conferred in transfrontier relations under the doctrine of the Universal Development of Human Rights. [26]

The legislature on the national scene has promoted the Environmental Protection Agency (EPA) which handled problems that involved oceanic oil spills, waste disposal plants and thermal and chemical pollution of rivers and underground water supplies. The EPA did not control air quality which was temporarily provided for in 1955 with a federal program for research and technical assistance to state and local governments. The program after being given extended authority in 1959 became a permanent authority, Clean Air Act in 1963. "Major provisions: (1) provided for federal grants to state and local air pollution control agencies to establish and improve their control programs; (2) provided for federal action to abate interstate air pollution through a system of hearings, conferences, and court actions; (3) provided for an expanded federal research and development program with particular emphasis on motor vehicle pollution and sulfur oxide emissions from coal and fuel oil combustion." [27] The act was amended in 1965 to provide for cooperation with Canada and Mexico to abate international air pollution. Throughout the rest of the 60's the act was amended to set standards and means of cooperation between state and local governments and to control fuel additives in motor vehicles. In 1970 the amendments "provided for the establishment of national ambient air quality standards and their achievement by July 1, 1975. [28]

The greatest critics of the Air Quality Act complain that the deadlines set in the act have not been observed or have been extended to prolong the "clean up". Other criticism is that control boards are not setting rigid enough standards. Karl Grossman is *Poison Conspiracy* states that those who are responsible for administering the Act are also those who have grivate interests that oftentimes conflict with the goals of the agency.. [29]

Some of the devices utilized by coal-powered plants that are now employed to reduce pollution to meet the ambient emissions set down in the act in 1963 are scrubbers, static screens and long stacks. The scrubbers and static screens actually remove the particulate matter from the flue gas. The smokestacks of greater height allow the pollutants to be carried higher into the atmosphere and away from the immediate area so that local residents do not feel the brunt of heat and gaseous pollutants. Critics comment that the longer stacks only facilitate long-range transport in the atmosphere so that pollutants are carried over greater regions.

Other verbal groups that have entered the air pollution arena of debate include The National Clean Air Coalition which is composed of the American Lung Association, League of Women VOters, Urban League, International Association of Machinists, United Steelworkers, Natural Resources Defense Council, Environmental Defense Fund, National Wildlife Federation, National Audubon Society, Friends of the Earth, Sierra Club, Isaac Walton League and National Parks and Conservation Association. [30]

On the local scene in the city of New Haven, a populous of 137,700, an estimated material and energy flow chart has been prepared. The chart reports the total in tons of fuels being consumed and the heating capacity in BTUs. The highest fuel sued is residual fuel oil (1280) producing 46,500 BTU of energy. On the opposite side the amount of sewage, solid waste and gaseous products from industry is computed as well as the shortwave and long-wave radiation. Water available for consumption is an important material and the rate of flow of rivers through the city reflect the energy potential available in the flow. (Appendix)

In concluding, the material and energy balance sheet helps to quantify energy waste and air pollution in mass amounts.

A DAY IN NEW HAVEN, CONNECTICUT

(figure available in print form)

Notes

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