Environmental Health Perspectives
Vol. 36, pp. 135-154, 1980

Report on Health and Environmental Effects of Increased Coal Utilization*

by The Committee on Health and Environmental Effects of Increased Coal Utilization†

The National Energy Plan announced by President Carter on April 29, 1977 proposed a significant increase in the utilization of the vast domestic deposits of coal to replace the dwindling supplies of oil and natural gas, and increasingly expensive oil from foreign sources, to meet national energy needs. At the same time, in recognition of possible adverse health and ecological consequences of increased coal production and use, the President announced that a special committee would be formed to study this aspect of the National Energy Plan.

The Committee held a series of public meetings during November and December 1977 to review a number of special papers on particular problems associated with increased coal utilization. These papers, which were prepared by scientists of the US Environmental Protection Agency; the Department of Energy; the HEW National Institute for Occupational Safety and Health, and the National Institute of Environmental Health Sciences; New York University; and Vanderbilt University; provided essential background information for the deliberations of the Committee and were published in EHP Vol. 33, pp. 127–314, 1979. One paper by A. P. Altschuler et al. is published in this volume of EHP.

The Committee's basic finding was that it is safe to proceed with plans to increase the utilization of coal if the following environmental and safety policies are adhered to:

- **Compliance with Federal and State air, water, and solid waste regulations**
- **Universal adoption and successful operation of best available control technology on new facilities**
- **Compliance with reclamation standards**
- **Compliance with mine health and safety standards**
- **Judicious siting of coal-fired facilities**

The Committee concluded that, even with the best mitigation policies, there will be some adverse health and environmental effects from the dramatic increase in coal use. However, these will not impact all regions and individuals uniformly. The Committee identified six major areas of uncertainty and concern requiring further investigation if the nation is to minimize undesirable consequences of increased coal utilization now, and in the future. Two critical health issues of concern are air pollution health effects and coal mine worker health and safety. Two critical environmental issues are global effects of carbon dioxide in the atmosphere and acid fallout. Two additional important issues of concern are trace elements in the environment and reclamation of arid land.

Finally, because of the inadequate data and methodology used in the study of these matters, the Committee strongly recommended the establishment of an improved national environmental data collection, modeling and monitoring system.

† Committee members: David P. Rall (Chairman), National Institute of Environmental Health Sciences, Research Triangle Park, N.C.; Stanley Auerbach, Oak Ridge National Laboratory, Oak Ridge, Tenn.; Sheldon Friedlander, California Institute of Technology, Pasadena, Calif.; Marcus Key, School of Public Health, University of Texas, Health Science Center at Houston, Tex.; Norton Nelson, Institute of Environmental Medicine New York University Medical Center, New York, N.Y.; Monroe Newman, Pennsylvania State University, State College, Pa.; Gordon Orians, Institute for Environmental Studies, University of Washington, Seattle, Wash.; Donald L. Rasmussen, Appalachian Pulmonary Laboratory, Inc., Beckley, W. Va.; Adel F. Sarofim, Massachusetts Institute of Technology, Boston, Mass.; Carl Shy, Institute for Environmental Studies, University of North Carolina, Chapel Hill, N.C.

* This report, and the accompanying paper by Altshuller et al., are part of the series of papers previously published in Environ. Health Perspect. 33: 127 ff. (1979)

Introduction

Coal is harder to handle and is dirtier in combustion than either oil or natural gas. Yet, because coal is the most abundant domestic fossil fuel, economics, national security and common sense provide parallel and strong incentives to use more coal. By careful control of all aspects of the mining, transport and use of coal, these adverse effects can be reduced, but not eliminated, and they form part of the social costs of coal utilization. Some of the potentially serious health and environmental effects of increased coal utilization are as follows.

• Underground mining of coal is associated with a high rate of worker accidents and chronic debilitating lung disease, particularly coal worker's pneumoconiosis (black lung).

• Surface mining causes disruption of natural landscapes and aquifers, and drainage from mine tailings and abandoned mines may impact natural waters and their inhabitants.

• Coal combustion releases carbon dioxide to the atmosphere and at elevated levels this could cause climate modifications with potential for serious social disruption.

• Coal contains sulfur, nitrogen and trace elements; during combustion sulfur dioxide, oxides of nitrogen, trace elements and particulate matter are released in stack gases and become airborne. These pollutants are irritants of the respiratory system. Both sulfur dioxide and nitrogen dioxide can react in the atmosphere to become even more toxic. Exposure to elevated levels of these pollutants can increase the number and severity of attacks in persons with existing bronchial disorders, and can contribute to chronic respiratory diseases.

These airborne pollutants contribute to the formation of acid rain, which is already decreasing fish populations and may damage crops and reduce agricultural and forest productivity.

• Even very low levels of air pollution can have visibility effects, and many individuals are vehemently opposed to degradation of esthetic values, particularly in the less developed areas in the West.

• Unburned residues, i.e., coal ash, sludge from desulfurization systems, or particles trapped by other control systems, contain trace elements such as heavy metals and radionuclides. These solid wastes are retained in land disposal systems. If toxic trace elements leach into drinking water supplies or soils, they can become incorporated into living organisms, and, perhaps, concentrated in food chains, potentially causing a series of chronic toxic effects on human and other organisms.

Although much is known about the relationship between coal and its health and environmental effects, important uncertainties remain. The primary objective of the Committee was to address these uncertainties and to determine whether the coal utilization goals of the National Energy Plan (NEP) are compatible with health and environmental goals established by the Congress.

Findings

The National Energy Plan (NEP) proposed a significant increase in the use of coal, our most abundant fossil fuel, to reduce U.S. reliance on foreign oil. Total U.S. coal consumption in 1976 was 665 million tons. Under NEP, coal consumption would reach 1265 million tons by 1985; even without the plan, coal consumption is expected to increase to 1066 million tons by 1985—according to a "business-as-usual" (BAU) energy scenario (see Table 1). In view of the potential for adverse effects, the Administration indicated its support

Table 1. Coal Consumption forecasts.[a]

	Coal consumption, millions of tons					
	Utility	Industrial	Metallurgical	Export	Other	Totals
1976 Base Case	444	65	85	65	6	665
1985 Estimates						
BAU	763	101	105	90	7	1066
NEP	779	278	105	90	13	1265
House/Senate Conference	779	198	105	90	13	1185
National Coal Association	820-850	130-160	80-110	80-110	7	1117-1237
American Gas Association	680-705	170-375[b]		No est.	No est.	850-1080

[a] BAU and NEP case are from official DOE estimates; House/Senate Conference case is an informal guesstimate by DOE staff (December 1977); NCA case is most current staff estimate supplied to the Committee; AGA case is based on very restrictive interpretations of Clean Air Act Amendments (P.L. 95-95).

[b] Combines Industrial and Metallurgical consumption.

for strong environmental and safety policies concerning ambient air quality standards, continuous emission control technology, non-degradation, reclamation, and coal mine health and safety to mitigate adverse effects associated with this increase in coal production and utilization.

Even with the best mitigation policies, there will be some adverse health and environmental effects from the dramatic increase in coal use, which will not affect all regions and individuals uniformly. Singly and collectively, these effects should not be of sufficient mignitude by 1985 to require modification of the NEP if the following policies are adhered to rigorously: compliance with Federal and State air, water and solid waste regulations; universal adoption and successful operation of best available control technology on new facilities; compliance with reclamation standards; compliance with mine health and safety standards; judicious siting of coal-fired facilities.

Given the inherent uncertainties in environmental forecasting, it is very difficult to discern significant differences in environmental or public health effects between BAU and NEP coal consumption levels. The minimization of adverse health or environmental effects from the 1985 coal production and use levels in either the NEP or BAU scenarios requires that the following be recognized.

First, while increased health and environmental problems resulting from either the BAU or NEP probably will be modest and localized, this conclusion is sensitive to all of the five policies listed above. Industry, government, and the public need to realize that a part of the price tag on NEP, or any other plan resulting in increased burning of coal, is the cost of a pollution control program administered to achieve congressionally mandated environmental goals.

Second, most of the incremental consumption of coal under NEP would be by nonutility industries. Unlike large power plants, most of these smaller facilities are likely to be located near high density population areas, and emissions from these smaller industrial plants are more difficult to control. DoE and EPA should pay attention to the siting and control of these sources.

In addition, there are a number of uncertainties that impair the confidence with which we assess potential adverse health and environmental effects. The Committee identified six issues which urgently need resolution if we are to minimize undesirable consequences of increased coal utilization now, and in the future.

Air Pollution Health Effects. Current standards may not provide adequate health protection from all coal combustion products. The evidence that some acidic particles have greater impact on public health than other particles increases our need to resolve the critical problems related to the transport, transformation and health effects of the gas-aerosol complex.

Coal Mine Worker Health and Safety. Strict enforcement of the Federal Coal Mine Safety and Health Act of 1977 should further reduce the risk to workers in the coal industry. Even with strict enforcement, in order to be certain that present standards provide adequate protection, effective health monitoring and assessment will be necessary. Continued improvement in miner's safety will require increased education, especially for new miners. New developments, such as use of diesel-powered underground equipment, require further study of potential deleterious health effects.

Global Effects of Carbon Dioxide in the Atmosphere. Combustion of fossil fuels, and especially coal, is increasing global atmospheric CO_2. This could induce climatic changes with potential for generating global sociopolitical disruption after 2025. It is urgent that we continue a strong research program to provide a sound basis for action no later than 1985. Because this problem is global in character, the U.S. should initiate a continuing international dialogue immediately.

Acid Fallout. Emission of SO_2, particularly from coal, and NO_x from all fossil fuel combustion have increased the acidity of precipitation in northeastern U.S. This has decreased fish populations in many lakes, and may already be reducing forest and agricultural productivity. Since both BAU and NEP are projected to increase emissions of SO_2 and NO_x, a major study is needed to verify causal relationships and project future effects.

Trace Elements. Increased use of coal results in wastes that contain trace elements, many of which are toxic. These elements can leach and migrate into water or enter food chains in quantities which could impact public health and environmental quality. More data are needed to assess the extent to which these elements enter into the biosphere.

Reclamation of Arid Lands. Enforcement of the Surface Control and Reclamation Act of 1977 will mitigate many adverse environmental effects of surface mining. However, it is not certain that some arid areas can be restored, even following full compliance. Prudence dictates that surface mining be deferred in these arid areas when information about their reclaimability is incomplete.

An important element of the Committee's review involved environmental forecasting, a task which should be done systematically on a recurring basis. However, the Committee members unanimously expressed reservations about the tools available for effective forecasting. Data on future coal consumption, on emission inventories, and on current and future ambient air quality are often incomplete, discontinuous, conflicting, or unavailable for specific pollutants and for specific locations. Methods for converting emissions into concentrations of substances in air and water (modeling) are controversial and sensitive to their initial assumptions. Monitoring systems, which could generate data and verify modeling forecasts, are inadequate as to number, location, uniformity and reliability. Often, these systems measure the wrong pollutants at the wrong time. Current public and private expenditures for air pollution control alone are estimated to exceed $13 billion per year. The new requirements for BACT and for nondegradation will add to these already substantial sums.

Committee Recommendation

An improved data collection, modeling, and monitoring program appears to be a very cost-effective Federal investment. Such a program, with input on health and environmental effects, would result in more precise answers and yield better public policy decisions. The Committee is convinced that an improved national monitoring system is a prerequisite for making good public policy choices, reducing levels of controversy and providing a basis for a cost-effective evaluation of the standards enforced.

The Committee has traced known or anticipated health and environmental effects of increased coal utilization through the entire coal fuel cycle (see Fig. 1), from mining to the effluents of combustion and their disposition, and the disposition of the spent mine itself. We have dealt with conventional coal combustion and looked at the effects anticipated through 1985. We have, however, considered certain important longer term problems. Separate studies are underway on other important issues, such as water availability, coal transportation and socioeconomic impacts of energy development. The eleven papers prepared by authors from EPA, DOE, NIOSH, NIEHS, and several universities provide additional background information and are in a separate appendix which is available upon request. Brief issue summaries of each of these papers prepared by the Committee are included as a part of this report. The most critical problems are summarized below in five major categories: hazards of mining coal; problems of disposition of mined land; combustion effluents and their disposal; human health effects of effluents; and environmental effects of effluents.

Hazards of Mining Coal

Underground mining is associated with chronic disabling lung diseases, particularly coal worker's pneumoconiosis (black lung). The incidence and severity of these diseases are related to the concentration of coal dust. Recent legislation, in 1969 and 1977, properly enforced, has and will significantly reduce this hazard. Until more experience is gained with workers exposed to the new lower dust levels, the extent of the reduction in disease will not be known. More comprehensive surveillance techniques using indices of lung function must be developed, and studies must continue to monitor the effectiveness of these new standards in protecting human health. Underground coal mining accidents continue to be a serious problem. Control technology and worker training (particularly of new workers) must be empha-

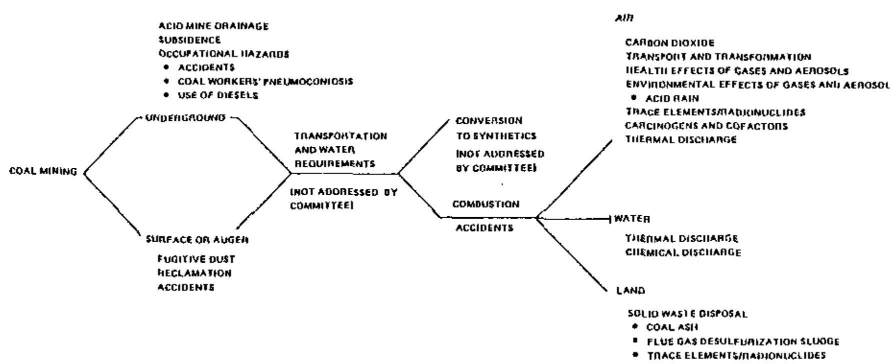

FIGURE 1. The coal-fuel cycle.

sized to minimize these problems. The introduction of underground diesel engines is claimed to increase worker productivity, but may create new health problems. Research must proceed to identify the extent of any problems associated with diesel exhaust. Surface or strip mining is less hazardous for miners—the primary problem being accidents. Training, particularly of new workers, in safety procedures is important.

Problems of Disposition of Mined Land

Coal mining, whether underground, surface, or augur, has the potential to disrupt natural terrestrial systems both during and after mining operations. Problems, arising from abandoned mines, are primarily environmental. Both surface and underground mines often are a source of acid and drains into surrounding watersheds. Technology is inadequate to control this problem, and we can look forward to increased acid loadings, particularly from underground mines, as their useful life is exhausted. Subsidence of the ground above mines can be avoided by leaving larger amounts of coal underground. However, coordinated planning of surface and subsurface activities is probably the most efficient control mechanism. Siting of mines and controlling industrial and residential growth above mines will mitigate the effects of future subsidence.

The recently passed Surface Control and Reclamation Act of 1977 requires that surface mined areas be restored. The requirements and costs of restoration will preclude mining at some locations, particularly on steep slopes where erosion problems would be severe. However, reclamation of most surface mines is feasible and relatively inexpensive in those areas with reasonable annual rain fall. Problems are more acute in particularly arid regions, and we do not yet know whether arid region rangeland can be restored. Consequently, surface mining should be avoided in areas with limited rainfall until we have better empirical evidence of reclamation feasibility.

Combustion Effluents and Their Disposition

The effluents of coal combustion appear to pose the most significant problems, both with respect to human health and to the environment. Combustion of all fossil fuels produces emissions of carbon dioxide (CO_2). However, for identical energy outputs, coal generates 1.8 times as much CO_2 as does natural gas and 1.2 as much as fuel oil. Very large increases in atmospheric concentrations of CO_2 could produce significant climatic changes primarily through the "greenhouse" effect. The CO_2 increase resulting from the NEP coal scenario by 1985 is of minor consequence, but may pose serious future problems. Furthermore, if the rate of fossil fuel, and of coal in particular, consumption were to continue increasing, both in the U.S. and elsewhere, then the amounts of CO_2 could have severe impacts by the year 2025. By 1985, the nation must have better information concerning future rates of fossil fuel use, the rates and movement of CO_2 from all man-made sources to their ultimate sinks or reservoirs, the factors which drive global climate, and the impact of climatic changes on agricultural and other socio-biological systems. Certain projections indicate that after 1985 the relative contribution of U.S. CO_2 production will be proportionally lower on a global scale. Thus international cooperation is vital to resolving this potential problem.

The other major effluents of coal combustion are SO_2, formed by the oxidation of sulfur in the coal; NO_x, formed by the oxidation of both the nitrogen in the air; and particles which are the result of unburned materials, as well as the resolidification of materials volatilized during burning. Some trace elements, such as mercury, may be volatilized and discharged as gaseous effluents; others remain as particles.

Flue gas desulfurization (FGD) and particulate control equipment attempt to capture certain toxic gaseous elements, particularly sulfur, and particles, before their dissemination into the atmosphere and deposition locally or regionally. The BACT policy requires installation of continuous FGD systems on all coal-fired plants above 25 MW in an effort to reduce SO_2 emissions below current requirements for new sources. The resulting retained solid wastes can then be disposed of in a more controlled and less hazardous manner than nationwide atmospheric dispersal.

Gaseous effluents, SO_2 and NO_x and particles can interact chemically in the atmosphere to yield new chemicals that are more toxic. SO_2 is converted to the more acidic, more toxic sulfate ion; NO_x to nitrate ion. This can occur up to hundreds of miles away from the coal burning plant. Particles, ultraviolet light from the sun, humidity and natural or man-made hydrocarbons can influence the nature and speed of these reactions. Sulfate ions, and possibly nitrate ions, play major roles in the lung irritation that results in those pulmonary diseases associated with or aggravated by air pollution, e.g., acute and chronic respiratory disease including asthma. In addition, these pollutants may, in association with polycyclic organic material (POM), such as benzo(a)pyrene, contribute to lung cancer.

Sulfate and nitrate ions are the predominant cause of the acid fallout that has lowered the pH (increased the acidity) of lakes and soils, and lowered productivity in many areas impacted by emissions from fossil fired plants.

Benzo(a)pyrene and similar POM can be produced by coal burning. In the past, often as a result of incomplete combustion, these carcinogenic agents were an important effluent, particularly of coal burned in home furnaces or other small boilers. Modern coal burning utility plants are highly efficient and little POM is discharged. Smaller industrial plants may, however, be less efficient and the emissions of POM may increase. Unlike large central station power plants, most smaller coal-fired industrial facilities would be located in or near high density population areas. These facilities would have lower stacks than utilities and there would be many separate point sources to maintain, monitor and evaluate. The percentage of emission reductions required by small scale facilities has often been less than for large facilities. There are reasons to believe that these smaller facilities are less likely to attain consistently emissions reduction goals. It is crucial that both DOE and EPA proceed cautiously with the industrial coal use program.

There is inadequate understanding of the atmospheric chemistry that explains how acid sulfates and nitrates are formed, which are the most toxic sulfates and nitrates, and the extent to which photochemical oxidants—a major cause of eye and lung irritation, as well as damage to vegetation, from air pollution—may be formed in the plumes of coal-fired plants. Further, meteorological models that can trace toxic effluents as they are moved by air currents across regions or the entire country, or which can predict what happens when effluents are concentrated in local areas as a result of air stagnation, are inadequate.

Therefore, it is impossible to predict with comfortable precision ambient air levels of toxic compounds even when the locations of the sources and the quantities of emissions are known. This has introduced an unsatisfactory degree of uncertainty to all such estimations.

The solid waste effluents consist of coal ash collected by various control techniques and sludge from flue gas desulfurization. Although large quantities of these effluents will be produced, they should not pose major disposal problems solely because of their volume, if proper planning has occurred. Toxic and potentially toxic trace elements, many of which had previously been widely dispersed and sealed in underground coal deposits far removed from contact with the biosphere are concentrated in these effluents.

Sulfur and its by-products—as a solid waste—are not particularly toxic. Certain other elements, including heavy metals, radioactive thorium, and uranium in coal ash and sludge, can, however, cause deleterious human health and environmental effects. Preliminary evidence indicates that radioactive material in coal is primarily trapped in solid wastes. However, further study is needed to determine the quantities of radioactivity emitted to the atmosphere as a result of coal combustion. Problems could arise if trace elements leach from disposal sites and contaminate water supplies and aquatic and terrestrial organisms. Generally, disposal sites are designed to prevent such leaching. There is, however, little experience with disposal on such a large scale, and little evidence to indicate the leaching and migration rates of toxic trace elements.

Finally, the cooling systems of coal-fired plants can discharge large quantities of hot water. This thermal pollution can pose local problems, but it does not appear to be important on a regional or national scale.

Human Health Effects of Effluents

The Committee provisionally accepts the current EPA standards for the so-called criteria pollutants, with the full understanding that information and insights developed in the future may engender changes in these standards. TSP and SO_2 have been, and are today, used as one index of the severity of air pollution from stationary sources. No separate standards exist for the fine respirable portion of TSP or for sulfates originating from SO_2. Yet, it is widely accepted that TSP and SO_2, are much less toxic than sulfates that are formed as these pollutants mix in the atmosphere. Even less is known about NO_x and nitrates.

The primary health problems of these air pollutants relate to the lung. It is not anticipated that air pollutants will increase to levels that will cause the striking increase in acute mortality, seen in Donora in 1948 or London in 1952; rather, we can anticipate an increase in the number of asthma attacks in susceptible individuals and increased incidence or exacerbation of acute and chronic respiratory disorders.

The Annual Environmental Analysis Report of DOE projected very small differences between BAU and NEP by 1985 for total national emissions of TSP, SO_2 and NO_x. For the year 2000, total emissions for all pollutants would be lower using the NEP rather than the BAU scenario. However, SO_2 and NO_x emission levels, according to either the NEP or BAU scenarios, would exceed 1975 emission in 1985 and in 2000 (Table 2).

These are, however, national averages and we must look to local or regional areas to estimate with greater confidence human health effects. For example, in Federal Region VI, the Southwest, significant increases in SO_2 emissions would result as coal replaces natural gas and fuel oil used by utilities and industry. In Federal Region V, the Midwest, SO_2 emissions would remain almost constant at today's high levels.

Many areas now enjoy very good quality air, with respect to the criteria air pollutants. NEP (or BAU) induced deterioration in air quality, even if it does not exceed current standards, may affect susceptible individuals, such as the elderly and those with existing pulmonary diseases, under these circumstances. In other areas with poorer quality air, where pollutant levels already are at or near standards, increased use of coal may have to be constrained. Forecasts received by the Committee indicated that many adverse health effects could be avoided by careful siting of new coal-fired facilities. However, if the standards are significantly violated, there inevitably will be deleterious public health impacts. The Committee is also concerned about those other pollutants, not covered by EPA criteria standards, such as sulfates, POM, etc., for which emission forecasts are not available. We need more information.

These considerations emphasize the need for strict compliance with Federal and State anti-pollution regulations, adoption and successful operation of BACT and judicious siting of coal-fired facilities. While there has been great progress since passage of the Clean Air Act of 1970, the number of areas remaining in violation is disappointingly large. As more coal is used, especially as a substitute for cleaner natural gas, extensive use of BACT becomes more critical. As an example, BACT will require flue gas desulfurization systems on all coal-fired power plants. These systems are designed to remove 90% of the sulfur 90% of the time, resulting in 81% average removal of all sulfur. If either removal efficiency or reliability should drop to 50%, then only 45% of the sulfur would be captured. The key point is that environmental protection requires successful operation and maintenance of controls once they are installed. Every single failure of pollution control equipment, or failure to follow control procedures, would produce an increment of pollution and the cumulative effect could pose severe risks.

Table 2. National annual pollution projections.[a]

	Emissions, millions of tons				
	1975 (base case)	1985		2000	
		BAU	NEP	BAU	NEP
TSP	15.5	9.4	9.5	14.0	12.5
SO_2	26.4	28.9	28.5	33.7	29.3
NO_x	17.4	22.1	21.8	29.1	28.0

[a] From Annual Environmental Analysis Report, DOE, June 1977.

A second health issue concerns evidence that air pollution has in the past been implicated as the cause of an increased incidence of lung cancer in polluted urban areas, although clearly cigarette smoke is the predominant cause. Since the concentrations of benzo(a)pyrene and other POM in urban air have been decreasing significantly, and there will only be small increases in other pollutants, NEP should not exacerbate this problem. Monitoring for POM, particularly around smaller, less efficient industrial plants, is important.

A third health problem may develop if toxic trace elements, including radioactive compounds, leach from the disposal sites of coal ash and flue gas desulfurization sludge. Because of the lack of experience and uncertainties involved, it is difficult to estimate the extent of leaching and the associated risks. If this ultimately does become a problem, it will develop slowly. Careful monitoring of aquatic systems and vegetation near such sites will allow for the early detection of the problem in time to develop and institute measures to prevent leaching and the development of serious contamination.

Environmental Effects of Effluents

Concentrations of sulfur oxides sufficient to cause extensive damage to plants are likely to occur only in the immediate vicinity of coal-fired facilities. The generation of increased acid fallout will probably be the most serious environmental effect of an increase in the use of coal. Even at current levels the pH of precipitation has been lowered over large areas of North America and this area is steadily expanding. Though these adverse effects will be less if the best available control technology is employed, increases in SO_2 and NO_x will occur under both BAU and NEP scenarios. If so, agricultural and forest production may decrease in large regions of the country and fish populations will disappear or be seriously reduced in certain lakes. The total energy losses to society cannot as yet be estimated accurately, but they may be large enough to significantly reduce the net energetic gain from coal burning. Damage to materials and losses of visibility due to increased coal consumption should impose further economic and esthetic costs in direct proportion to the increment in emissions. Visibility loss occurs at relatively low pollution levels and will be particularly troublesome in the West.

Committee Procedure

The NEP recognized that some uncertainty will continue over the health and environmental impacts of increased coal utilization. This Committee was appointed to address these uncertainties, and report its findings to the President before the end of 1977. The Committee was not requested to and did not contrast coal with nuclear, solar, or any other energy system, and we make no recommendations relating to preferences for any system. The National Academy of Sciences, through its Committee on Nuclear and Alternative Energy Systems, has underway a study which will address comparative fuel technologies. Because of time constraints and because other studies are already underway, several areas of possible investigation were eliminated. Transportation impacts associated with coal are being studied by the Department of Transportation. Water availability for energy development is being assessed by the Department of Interior. A task-force chaired by OMB is considering the socio-economic impacts of increased coal development. An interagency committee is reviewing the health and environmental effects of advanced technologies for conversion of coal to synthetic liquid or gaseous fuels.

In view of the limited time available, the Committee focussed attention on impacts in the 1985 time frame, yet whever practical, looked beyond to the year 2000. The Committee has made some recommendations concerning environmental research, but time limitations have precluded any review of existing programs. The Administration should immediately initiate such a review.

The full Committee met for seven working days in November and December. All meetings were announced in the Federal Register and were open to the public. Observers from DOE, EPA, NIOSH, OMB, and CEQ attended every session. The Committee commissioned preparation of eleven papers on the following subjects:

- Carbon dioxide effects of increased coal utilization
- Transport and transformation of gases and aerosols
- Health impacts of gases and aerosols
- Environmental effects of gases and aerosols
- Trace elements and radionuclides
- Occupational hazards of increased coal utilization
- Carcinogens and cofactors
- Acid mine drainage and subsidence
- Reclamation
- Solid wastes from coal combustion
- Thermal consequences of increased coal utilization

The Committee held a two-day public hearing (November 21 and 22, 1977) during which the authors summarized their papers, and the public and Committee members discussed both the subject papers and other issues related to the production and use of coal. The public was invited to present their views directly to the Committee on any relevant matter, either orally and/or in written form. In addition, the Committee invited knowledgeable individuals from the government and the private sector to meet and discuss emission data, pollution control technology, health damage functional relationships and additional complexities not covered in the papers.

Individual committee members were assigned lead responsibility for each of eleven subject areas covered by the assigned papers. Each member prepared an issue synopsis based on the assigned paper, and led the full committee in a discussion of the subject. These issue summaries are attached to this report. In evaluating and comparing discrete issues, the committee assessed the relative severity of the hazard, i.e., the potential adverse health or environmental effect; the probability of its occurrence; the degree of certainty we currently have regarding that probability; the time frame in which the hazard was expected to occur; and the spatial impact of the hazard (i.e., whether the effects were local, regional, national or global in scope). Our ability to mitigate the hazard or its relative irreversibility was also taken into consideration. In addition, the committee reviewed other documents available (*1–9*) which dealt with the problem.

Recommendations

The recommendations of the committee are summarized below.

1. Establish an improved national environmental data collection and monitoring system.

2. Require rigorous adherence to the following policies: strict compliance with Federal and State air, water and solid waste regulation; universal

adoption and successful operation of best available control technology; compliance with reclamation standards; compliance with mine health and safety standards; judicious siting of coal-fired facilities.

3. Expand research programs necessary to resolve uncertainties regarding the transport, transformation and health effects of the gas-aerosol complex (fine particles, sulfates, nitrates and organics).

4. Develop a health monitoring and assessment program to evaluate effectiveness of underground coal mining standards.

5. Monitor training and safety programs for new coal workers.

6. Support a continuing comprehensive research program on atmospheric effects of CO_2.

7. Initiate an international forum for addressing global CO_2 problems on a continuous basis.

8. Initiate a major study to verify causal relationships between SO_2/NO_x emissions, acid fallout, and decreased biomass productivity.

9. Establish a system to assess the extent and rate with which toxic trace elements migrate from waste depositories into the biosphere.

10. Conduct small-scale demonstrations to determine the feasibility of reclamation of arid areas.

Summary of Issues

The CO_2 Problem

The concentration of atmospheric CO_2 has been reported to have steadily increased from about 295 ppm by volume in 1860 (prior to the industrial era) to the current value of 331 ppm. It is projected that the concentration of CO_2 in the atmosphere could reach two or three times its present value within the next 100 years. Estimates of the anticipated effects of this increase range from possibly acceptable to catastrophic. Of primary concern is the warming ("greenhouse") effect which could be produced near the ground. Man-produced particulates in the atmosphere are not likely to have as great an effect on climate as the increased CO_2 and could result in either warming or cooling. The energy panel of the November 1976 meeting on "Living with Climatic Change" (MITRE Corporation, 1977) reached a consensus that particulates as well as waste heat probably constitute a risk of a lower order of magnitude than the risks related directly or indirectly to CO_2. Although the exact amount of warming produced by a given CO_2 concentration increase is still uncertain, it is the change in the global circulation pattern associated with the warming which is of greatest concern. The regular pattern of seasonal rainfall, as well as the earth's reflective power, can be altered substantially and affect a wide variety of biological and social activities.

The emission of CO_2 by the United States, and by the rest of the world, is strongly related to energy consumption for industrial, domestic, and transportation uses, and has been increasing rapidly. Moreover, there is strong evidence that the fossil carbon flux (from combustion of fossil fuels) is primarily responsible for the observed secular increase in atmospheric CO_2. This evidence is not contradicted by the growing recognition that nonfossil fires (wood fuels, forest burning) and shifts in biological oxidation have a share in the man-made inputs of CO_2 to the atmosphere. Furthermore, as more coal replaces natural gas and oil as fuel, more CO_2 will be produced and emitted to the atmosphere. For a given energy output (not taking into consideration end-use efficiency), about 1.8 times as much CO_2 is generated by the combustion of coal than by the combustion of natural gas, and about 1.2 times as much as when fuel oil is burned.

Increases in the atmospheric concentrations of CO_2 cause concern mainly because the commitment to much higher releases will be difficult or impossible to reverse, if recognition of the need for doing this is postponed until the observed atmospheric excess quantities become large: i.e., several hundred billion tons of additional carbon. The direct contribution from the U.S. based on additional coal use under NEP through 1985 is of minor consequence, but the global implications of such a policy can be profound. If such a policy continues into the next century, or if it serves as a model for the rest of the world, then the quantity of CO_2 could have serious consequences early in the next century. The following issues and uncertainties need to be resolved between now and 1985.

Rates of fuel are critical; a better understanding of the future energy requirements are both essential in determining and possibly controlling rates of fossil fuel use. Potential and actual use of wood burning (and other kinds of fires occurring in different ecosystems) need to be considered also.

The redistribution of CO_2 produced from fossil fuel combustion and from other anthropogenic sources among the several reservoirs in the carbon cycle must be known. We must better understand the roles of both the biosphere and the oceans in the carbon cycle.

Given the ability to predict the levels of CO_2 in the atmosphere at some future time, there is considerable uncertainty as to the effects on climate. We must develop a better understanding of the factors which drive global climate in general, and develop refined and reliable climate models sensitive to CO_2 variations, in particular.

There is little conception of how the world might manage a substantial climate change without drastic social dislocation. There is need to initiate studies of the ecological zones which might respond quite differently to given climatic shifts from the present pattern and to conduct analyses of possible global responses in the social-political and economical areas to such an eventuality.

To develop answers or plan definitive policies necessary for decisions before the turn of the century will require an international commitment of considerable scale. Only with a major aggressive effort will results be forthcoming sufficiently credible to induce what changes might be required in our global use of fossil energy.

Transport and Transformation of Gases and Aerosols

Nature of the Problem. Increased use of coal can have effects on the local scale because of the fallout of aerosol particles or because of meteorological conditions causing plumes carrying the pollutants to reach ground near the source. Other meteorological conditions may result in the movement of the plumes aloft over longer distances. Depending on the time interval and atmospheric conditions, the pollutants originally emitted may be converted to other gases or aerosols with increased potential for adverse effects. Examples are the conversion of sulfur dioxide to sulfuric acid and other sulfates or the conversion of nitric oxide to nitrogen dioxide and to nitrates. The use of tall stacks should reduce local effects, but will contribute to effects on a regional scale because of long range transport and transformation of pollutants.

Finely divided sulfates are formed during combustion of sulfur-containing fuels. Atmospheric chemical reactions are even more important sources of finely divided sulfates. The finely divided sulfates can be transported for long distances because these particles are much less readily removed from the atmosphere than sulfur dioxide or nitrogen dioxide. Similar considerations probably apply also to nitrates. Sulfates and nitrates are of particular concern in health effects, acid precipitation and corrosion effects when present as acid sulfates and nitric acid. Finely divided sulfates in all chemical forms can contribute significantly to visibility degradation and turbidity. This latter effect is of particular concern in the western U.S. where large coal-fired sources can cause visibility to be reduced substantially. These effects are well established; some are important on the short (daily) and others on the long (over years) time scales.

Emissions. Estimates have been made of the effect of the NEP on the magnitude and locations of emissions from steam electric and industrial plants in the eastern U.S. The estimates are based on assumptions concerning the efficiency of the best available control technology (BACT). If BACT is implemented, total emissions of particulate matter in 1985 will be reduced to about 60% of the 1975 value; emissions of sulfur oxides in 1985 will be about 10% greater than the 1975 value and emissions of nitrogen oxides about 25% greater than 1975. This represents an improvement over several realistic plans alternative to NEP. If BACT is not successfully implemented—and this is a real possibility—significantly greater emission levels may result than projected depending on the level of nonattainment. Thus a strong program of research and development in the control technology field and careful monitoring of the performance of newly installed devices are necessary to the successful implementation of NEP. In the control of particulate matter, there is a danger that emission standards can be met by controlling coarse particulates at the expense of the fine particulate component which contains many chemical species of public health concern. This problem requires further examination.

Effects on Environmental Quality. If NEP control technology estimates are accepted, source controls will keep the short-range impacts of gaseous and aerosol pollution below the levels of ambient air quality standards. Likewise, sulfate emissions from individual sources will not by themselves create an air quality problem. Problems of short range impacts can be avoided by judicious local controls that can be justified on the basis of ambient air quality standards.

Sulfates formed in the emissions from sources can be transported hundreds of kilometers. Sulfates originating from diverse sources as a result of long-range transport and transformation can be superimposed on each other to create episodes of air pollution far from the sources. However, existing monitoring data are inadequate to provide a baseline from which future changes in regional air quality resulting from long range transport and transformation can be evaluated.

Emissions from large coal-fired facilities present the risk of degrading visibility particularly in relatively clean areas in the west. However, the effects of the NEP on the western U.S. have not been analyzed.

Increased emissions of sulfates and nitrates could, depending upon as yet undetermined chemistry and meteorology of the atmosphere, increase the problem of acidity in rainfall in selected areas of the country.

The large increases in nitrogen oxide emissions projected under the energy development plans, including NEP, cause concern for further increases in ozone levels as a result of chemical reactions in rural areas. This problem requires further examination. Along with sulfate and nitrate formation, it calls for careful monitoring of air quality throughout affected areas.

Health Impact of Gases and Aerosols

The committee, in its evaluation of the possible health impact of gases and aerosols relating to increased coal utilization starts with several considerations. These are: (a) the gas/aerosol complex arising from the combustion of fossil fuels is clearly associated with acute and chronic respiratory disease and less clearly associated with lung cancer; (b) there is evidence that some of these effects may be occurring at or around current ambient levels; (c) there is no firm evidence of a threshold for effects. Accordingly, prudence requires the presumption that increase in air pollution toward or above current ambient levels will be associated with health costs. It is, however, not possible to be firmly quantitative as to these costs. These considerations are discussed below in somewhat more detail.

It is imperative that the extent to which increased coal use will alter current ambient pollution levels be reliably predicted and carefully monitored. The information should be based on a realistic assumption of the implementation of control technology. These projections should consider industrial use of coal (including low stacks) and should consider the impact in different areas, particularly those with currently relatively high pollution levels.

At this time, levels of criteria pollutants (SO_2, TSP, NO_2) are at or somewhat below air quality standards in various areas of the country. Increases in pollutant levels to the air quality standard in areas which presently have somewhat cleaner air would risk health impairments to more sensitive members of those populations. Any increase in pollutant levels above the standard are likely to cause adverse health effects to a larger population and should be viewed with grave concern.

Long-term exposure to coal combustion products associated with SO_2 and TSP concentrations approaching the present standards is a causal factor in chronic respiratory diseases. Cigarette smoking, an overwhelming cause of these disorders, appears to exacerbate these effects. Short-term peaking of pollutants may pose greater health problems than uniform concentrations.

A major impact of coal combustion products is on the local area surrounding the local point sources. Long-range atmospheric processes are important on a regional basis and have health significance. The siting of coal use is a major factor in the extent to which coal combustion products will produce adverse health effects. Two major considerations are the number of individuals at risk and the baseline levels of pollution.

The measurements of both SO_2 and TSP are indirect means of representing the total effects of the gas/aerosol complex. NO_2 may also be an indirect measure of health effect. Sulfur dioxide is clearly a precursor of toxic compounds, but also acts in conjunction with other agents (e.g., respirable particulates, ozone) to produce effects. The process by which sulfur dioxide is converted to other toxic compounds (e.g., sulfates) are complex and varied. It is unlikely that control of the atmospheric oxidation process is feasible. Rather, prevention of toxicity due to sulfur oxides should be based on control of sulfur emissions. The toxicity of TSP is essentially due to the respirable fraction. One implication is that control measures which remove only the larger nonrespirable particulates may cosmetically lower the level of TSP without having any impact on health effects. In fact, it is conceivable that reliance on such control measures (e.g., electrostatic precipitation) could lead to an unrecognized increase in respirable particulates and hence more of an adverse effect. Respirable particulates (e.g. sulfates, nitrates) are also formed from gases in the atmosphere after leaving the stack and are not directly controlled by particulate emission technology. Relatively less is known about the conversion of NO_2 to atmospheric products (e.g., nitrates) and the potential toxicity of these derivatives.

In summary, it is the conclusion of the committee that elevation of gases and aerosols near or above current ambient levels may be associated with increased respiratory disease, acute and chronic, including lung cancer.

Thus, on these assumptions, the relative impact of increased utilization of coal should be regarded as proportional to the extent of any changes in the pollution levels and the population base exposed. Estimates of change in exposure levels and in the population at risk should be approximately derivable from realistic projections of emission levels.

Finally, it will be extremely important in connection with this major national effort to address two urgent problems: identification of the chemical species in the acid particulate complex chiefly responsible for the health effects, and quantification of the actual health impacts of defined ambient levels of air pollution.

Ecological Effects of Gaseous Emissions from Coal Combustion

Though sulfur oxides are toxic to animals, effects have not been produced experimentally at concentrations other than those occurring very close to coal-fired facilities. Direct foliar injury to plants, however, occurs at much lower concentrations and significant reductions in rate of photosynthesis by crops and forest plants may accompany increased emissions. But the dosage of relations of these effects are as yet very poorly known. Annual plants are, of course, affected only by emissions during the year of their growth, but recovery even of long-lived perennials is likely to take place within a few years if the insult is terminated. Microorganisms may be very susceptible to sulfur oxides, but we are largely ignorant of these relationships.

Nitrogen oxides are not known to be directly toxic to animals at concentrations likely to occur even close to coal burning facilities and vegetation is less susceptible to nitrogen oxides than to sulfur oxides. The major effects of nitrogen oxides are indirect ones resulting from the production of atmosphere oxidants and acid precipitation. Their effects on microorganisms are unknown.

The fine particles emitted by coal-fired power plants can remain airborne for long periods and the vast majority are not deposited within 20 km of the plants. Particles containing heavy metals and polycyclic organic compounds have adverse effects on terrestrial and aquatic organisms, but the magnitude of these effects cannot be estimated accurately because of a very inadequate data base.

Photochemical oxidants, particularly ozone and peroxyacyl nitrates (PANs) are the most damaging air pollutants affecting agriculture and forestry. Already they are causing millions of dollars of damage to crops and forests in the United States. Most of current damage is due to mobile sources, but increases in gaseous emissions from coal-fired facilities are likely to add to this effect. Photochemical oxidants are not known to affect animals directly, but they do predispose plants to attacks by herbivores whose outbreaks may kill plants over wide areas.

As a result of increased concentrations of sulfur and nitrogen containing compounds, most of which derives from combustion of fossil fuels, the pH of rain and snow falling on much of the eastern U.S. has been lowered to between 3 and 5 and the area affected is steadily expanding. The resultant acidification of lakes, particularly those occuring in areas of carbonate-poor granitic rocks is having major detrimental effects on the fauna of those lakes. Results have been most striking in Scandinavia, where thousands of lakes have lost their fish populations, but similar effects are now occuring in eastern Canada and northeastern United States. In addition, algal communities of acidified lakes contain fewer species, the growth of rooted plants is reduced, fewer invertebrates are present in the water column and in sediments, and the rate of decomposition of organic matter is reduced. Fungi become more important relative to bacteria and the development of submerged mats of fungi and mosses reduce nutrient cycling from the sediments and, as a consequence, also reduce overall productivity.

Rates of forest growth have also declined in southern Scandinavia and northeastern United States, but this cannot as yet be unequivocally related to acid precipitation. However, it is known that acid precipitation does damage foliage, affects germination of conifer seeds and establishment of seedlings, reduces availability of soil nitrogen, decreases soil respiration and increases leaching of nutrient ions. These effects are likely to increase in importance and may cause changes in ecosystems from which they will recover only slowly, if at all.

Living organisms do not encounter pollutants singly, but rather in complex mixtures. Unfortunately, because most laboratory studies are focused on the effects of single pollutants, existing knowledge of the effects of complex emissions is very scant. However, there is evidence that pollutants released by coal burning make plants more susceptible to insect attacks, perhaps by changing their defensive chemistry. Evidence suggests that herbaceous vegetation is more vulnerable than woody vegetation and that reproductively active plants are more susceptible than non-reproductive ones.

Reliable estimates of the incremental economic impacts on materials resulting from increased emissions of gaseous pollutants are not yet possible, but a 10% overall increase in levels of urban air pollution would probably increase economic material loss by 20-30%, and a 25% increase would probably more than double these losses.

Emissions from coal burning plants affect visibility at concentrations lower than those required to cause direct and indirect toxic effects on living organisms. In many parts of the West where scenery is especially beautiful and highly valued, reduced visibility is likely to be a serious consequence of increased burning of coal.

Concentrations of sulfur oxides sufficient to cause extensive direct foliar damage to plants are likely to occur in the immediate vicinity of coal-fired facilities, but indirect effects of emissions from these facilities, through their influence on generation of acid precipitation, are likely to be the most serious ecological effects of an increase in the use of coal. Even at current levels of emissions the pH of precipitation has been lowered over large areas of North America and the area affected is steadily expanding. Though these adverse effects will be less if the best available control technology is employed, increases in SO_x and NO_x will occur under both BAU and NEP scenarios. If so, agricultural and forest production will decrease in large regions of the country and fish populations will disappear or be seriously reduced in lakes in regions with granitic rocks. The total energy losses to society cannot as yet be estimated accurately, but they may be large enough to significantly reduce the net energetic gain from coal burning. Significantly, these losses occur in the most important renewable energy supply we have, the capture of solar energy through photosynthesis.

Damage to materials and losses of visibility due to increased coal consumption will impose further economic and esthetic costs in direct proportion to the increment in emissions. In addition, there may be important non-linear effects on ecosystems processes involving especially microorganisms and synergistic interactions, the paucity of knowledge prevents even crude estimates of their probable nature and magnitude. There is reason, however, for caution because what we don't know may well hurt us.

Trace Elements and Radionuclides

Major Areas of Consensus. Trace elements and radionuclides potentially hazardous to human health and ecosystems are present in coal. The trace elements of concern are, among others, arsenic, cadmium, mercury, lead, fluorine, beryllium. Concentrations of these elements vary considerably among different coal types. Radionuclides in coal include uranium-235 and -238, thorium-232, and associated decay products; concentrations of radionuclides in coal are generally less variable, with values of 1 ppm for uranium and 2 ppm for thorium being reasonable national averages. Extraction and combustion of coal effectively introduces these toxic, or potentially toxic, elements into the biosphere in a more concentrated form than they would appear as a result of natural weathering. Trace contaminants can enter the environment prior to coal combustion by runoff from coal mines and coal storage piles; during combustion, in atmospheric emissions of particles and volatile elements; and after combustion by runoff from slag, bottom ash, fly ash and scrubber sludge deposited in settling ponds and landfills.

At nearly every point along physical transport pathways in aquatic and terrestrial environments, opportunities exist for interactions of trace elements with life forms. Organisms, especially microorganisms in aquatic environments can absorb, concentrate and transform trace elements into more concentrated forms or into more toxic compounds. Biotransformation of trace elements is particularly important in determining effects on man and other organisms because the molecular form of these contaminants often determines their persistence, bioaccumulation and toxicity. Trace elements may enter food chains and undergo bioaccumulation in passage through higher forms of life. Of particular concern in this regard are concentrations of mercury, cadmium and lead because current intake levels for these substances are near tolerable human health limits.

The acidic nature of mine drainage from eastern coal fields tends to hold metal ions in solution and promotes transport to surface and ground waters. Acid mine drainage from inactive mines in the eastern U.S. is the greatest single source of drainage and transport to aquatic environments, and is very difficult to control. Western coal generally lacks acid-forming substances, although increased salinity of surface and ground waters in western coal regions could become a problem due to soluble salts in mine spoils. During overburden removal for strip mining, ground water aquifers are commonly intercepted; hazardous elements may enter these disturbed aquifers.

Concentrations of trace contaminants in atmospheric emissions from coal-fired power plants do not appear to be a significant ecological hazard. Trace element concentrations in soils fall rapidly with distance from power plants and tend to be at average levels at distances of 3 km from the plant. With installation of efficient precipitators, atmospheric emissions of trace elements should not be acutely harmful to vegetation and other biota, especially beyond a 3 km radius. Likewise, the potential for chronic toxicity to ecosystems is relatively low, except in local areas already enriched with a particular element. However, sublethal, chronic, or synergistic effects of trace elements on ecosystems have received little attention.

About 92% of particulate materials produced in utility boilers is removed by electrostatic precipitators. Fly ash, bottom ash and scrubber sludge all contain trace elements. These are generally released to ground water at low concentrations, with attenuation occurring very close to the disposal site. Very little information is available on the chemical form, bioavailability and toxicity of these contaminants. By 1985, 60 million tons of fly ash with elevated levels of trace elements will be annually discharged into settling basins situated in close proximity to coal-fired power plants. Elements such as arsenic, cadmium, cobalt, nickel, lead, selenium, uranium and zinc all exhibit potential mobilization rates from these deposits that are larger than 10% of the natural weathering rates. These elements have a definite potential for runoff to surface waters and leachate intrusion into ground water.

There is reasonable concurrence that some trace contaminants in coal may constitute health problems from either direct toxicity or risk of cancer. Among those most toxic to man are mercury, cadmium and lead; intake levels of these substances are already near tolerable health limits. Concentrations of trace contaminants in atmospheric emissions from coal-fired power plants do not add significantly to the total body stores of these substances, since their intake through food and water is large relative to inhalation. However, some atmospheric trace elements are active in the catalysis of sulfur dioxide to acid sulfates and, in this way, may contribute to the respiratory irritant effects of these other coal combustion products. Other trace elements in coal can combine with sulfate ions to form biologically reactive and harmful compounds in the atmosphere. Three elements—arsenic (III), chronium (VI), and nickel—are accepted as having high carcinogenic importance to man. All three of these elements can appear in fly ash leachate, but their magnitude is unknown. There is little or no teratogenic potential from cadmium, selenium or mercury compounds at concentrations in coal emissions of fly ash leachate. The potential for contamination of drinking water supplies by leachates from settling ponds and disposal sites is very real and needs to be evaluated. As previously noted, a large number of these disposal sites will be created, amounting to 60 million tons of wastes annually by 1985.

Estimated annual release rates for radionuclides from a 1000 MWe coal-fired power plant amount to 0.04 to 0.35 mrem/yr whole body dose, as a maximal annual dose commitment to the most exposed individuals. To compare the magnitude of radiation from coal combustion emissions, it is useful to use average dose equivalent rates for natural background and coal emissions. The average coal combustion radiation rate is different under the NEP or BAU scenarios. On this basis, radiation from increased coal combustion does not represent a significant public health problem.

Major Areas of Uncertainty. The chemical form of trace elements is very important as a determinant of transport through the environment and of toxic effects on health and ecosystems. Most studies of coal emissions and leachates focus on simple elemental analysis. Lack of knowledge of chemical species of trace elements precludes making a confident and adequate assessment of the potential health and ecological effects of trace elements from coal utilization.

Potential contamination of drinking water supplies by several toxic elements in leachates from waste disposal presents a real public health problem. The chemical form of each element may be significantly altered by microorganisms in the physical transport process, and these chemical forms will determine the rate of environmental transport, the bioaccumulation and toxicity of these elements. Too little is known about these processes.

Given that several trace elements in leachate could potentially be mobilized at rates that are larger than 10% of natural weathering rates, do these elements effectively remain in settling basins or are they injected into waterways and into food chains? Unquestionably, the movement of trace elements from coal combustion disposal sites should be regarded as a potentially significant health problem and bears intensive monitoring in some sites.

While the ambient atmospheric loading of trace elements does not appear to be as great a potential problem as intrusion into waterways from leachates, they do constitute a health hazard insofar as they catalyze the atmospheric formation of sulfates and react with sulfates to form a pulmonary irritant. There is a need, therefore, to monitor atmospheric concentrations of trace elements at selected sites. Few data exist on trace element ambient concentrations, fallout, and reentrainment from disposal sites. Atmospheric and environmental levels of cadmium, mercury, lead, arsenic (III), chromium (VI), and nickel should be particularly monitored at these selected sites.

Occupational Health and Safety Impact

Greatly increased production of coal in the United States will expose larger numbers of workers to the safety and health hazards of coal mining and processing. Such hazards have been very great in this country with many mine related accidental deaths and disabling injuries. Disability and death from chronic lung disease have also been excessive and recent evidence suggests other possible occupationally related diseases.

Legislation, enacted in 1969, aimed at reducing the dangers from accidents, and for the first time in this country, mandated environmental controls in the work place to reduce the risks of chronic lung disease. Although conditions in the mining industry have improved as a result of the implementation of these reforms, considerable doubt exists about the achievement of maximum compliance. Efforts to characterize the nature of coal miners' lung diseases have been incomplete and to date no adequate health monitoring program has been implemented.

Estimates of the potential health effects among an augmented mining work force are predicated not only on the above uncertainties, but also on the question of the surface/underground ratios and the potential impact of an anticipated expansion of long-wall mining methods and the use of Diesel powered underground mining equipment. Long-wall mining may subject miners to excessive dust levels and diesel exhausts may present additional, as yet, incompletely understood hazards.

It is essential, even with no increase in the mining work force, to fully implement the provisions of the Coal Mine Health and Safety Act, including achievement of total compliance with dust and safety standards. The nature of lung disorders of coal miners must be more carefully defined. Tests to detect early impairment in respiratory function must be developed and pre-employment and meaningful periodic health examinations must be instituted. Investigations into potential future hazards must be continued or increased.

The risks to safety and health of workers in the coal mining industry must not be underestimated. The nation's requirements for increased coal production must not be allowed to induce a relaxation of established health and safety standards for coal mining. Expanding the work force in the mining and processing of coal will require an increased effort to provide a safe and healthy work place for these vital workers.

Carcinogens and Cofactors

Assuming that best available control technology will be applied to the incremental use of coal in combustion processes, it is unlikely that there will be an increase in the present problem of environmental cancer. It is generally recognized that there is an air pollution factor resulting from fossil fuel combustion which, when added to cigarette smoking, explains the differential rates of lung cancer between urban and rural environments. However, the carcinogenic risk implied by these combustion products is relatively minor when compared to cigarette smoking.

There are a number of uncertainties regarding: the development of cancer including the interrelationships of polynuclear aromatics, cocarcinogens, promoters, and fine particulates; adequacy of standards for surrogate contaminants; and environmental indicators of carcinogenicity. Filling some of these gaps in our knowledge is obviously important to an environmental monitoring and control program. The following data gaps are of considerable significance in this regard: investigation of suspected roles of sulfur dioxide as a cocarcinogen and of fine particulates as vehicles for carrying carcinogens to target lung tissues; identification and measurement of the various carcinogens produced by coal combustion as well as characterization of operating processes and conditions producing them; development of other indicators of carcinogenicity besides BaP occurring in the emissions.

Although small amounts of radioactive substances are released by the combustion of fossil fuels, the dose received by the population from this source is so small in comparison with that received from natural background sources that the potential number of cases of lung cancer produced by it is negligible. However, western coal (especially low grade bituminous and lignite) contains 10 to 100 times more radionuclides than eastern coal and this potential problem will have to be closely monitored.

Three trace element contaminants occurring in emissions from coal combustion are of special concern in carcinogenesis. Arsenic (III) is volatized on combustion and condenses or absorbs on the fly ash on cooling. Chronium (VI) and nickel may be volatized and condensed or may form a melt that becomes both fly ash and slag. These three are generally accepted as having high carcinogenic importance to man. As with radionuclides this may not be a problem, but the movement and buildup of these elements certainly should be monitored.

Occupational cancer is not generally regarded as a problem in coal mining, although an excess of stomach cancer has been reported in some groups of coal miners. However, environmental and ethnic factors may also be operative especially when the wives of miners develop the same cancer. Increased lung cancer associated with underground coal mining is not believed to be a problem with current coal mining methods. The influence of diesel exhaust in regard to lung cancer is difficult to evaluate with present data. Diesel engine exhaust products contain chemicals which are known to be mutagenic and carcinogenic in some test systems. There is one U.S. mortality study of underground diesel workers who have been employed for periods of time approaching the latency period for carcinogenicity and these are essentially negative. Should a lung cancer factor (from diesel exhaust) be demonstrated it will probably play a minor role as compared to the influence of cigarette smoking.

Coking, coal gasification and coal liquifaction are acknowledged to be associated with significant occupational cancer problems and will require close attention, especially in the development of coal conversion processes. However, these problems are not considered to be within the purview of this Committee.

Acid Mine Drainage and Subsidence

Acid Mine Drainage. Acid mine drainage discharges occur from surface mines, mine waste, and underground mines. During active mining, the control of point discharges afforded under PL 92-500 and surface mines and mine waste under PL 95-87 should result in essentially no further discharges of acid to streams. In fact, as the enforcement of these acts becomes better, acid discharges from current discharges should be eliminated. In addition, nonpoint source acid discharges from surface mines and mine waste should be controlled under the regulations provided under PL 95-87. Thus, only underground mine acid discharges that occur after the mine is closed will increase between 1977 and 1985 and beyond, because technology to control this problem is not available. By 1985, the level of acid discharges will be a result of the closing of mines currently active, and not new mines, since the lag time to open an underground mine and the mine life will place its closure after 1985. The full impact of the new mines will not be felt until their closure.

Subsidence. Health and environmental impacts from unforeseen subsidence into underground mines stem largely from the disruption of man-made structures and the effects on surface and subsurface waters from alteration of flow and increase in sediment and silt and possibilities of increased slides and erosion. The magnitudes of these effects at present and the changes likely to occur with NEP are not known.

Three basic approaches to controlling these effects exist: (1) control mining practices, which requires that a considerable (roughly 50%) of the coal be left in place to support the surface; (2) hasten subsidence after mining so that surface effects are known before surface development occurs; (3) plan and coordinate surface use with a knowledge of past, present and potential mining and the related probable surface effects.

Neither the Federal law nor state laws are presently designed to require or encourage the selection of any of these three options as a given situation requires. Estimates are that as a result, the incidence of health and environmental effects will grow, particularly as the nation attempts to utilize the preponderance of reserves that are suited only to deep mining, given present technologies.

Reclamation

The problems centering about the extent of environmental disturbance due to coal mining both pre-NEP and NEP and consequently the extent of reclamation required will depend considerably upon recent legislation. These include the Clean Air Amendments of 1977, the Surface Mining Control and Reclamation Act of 1977 (PL 95-87) and NEP. The former and NEP (if enacted) are aimed at promoting underground mining, especially in the Eastern United States. PL 95-87 has resulted in the establishment of a new Office of Surface Mining in the Department of Interior. This office is responsible for establishing environmental performance standards and a federal regulatory program for controlling the surface effects of coal mining operations.

Due to the recent enactment of PL 95-87 it is difficult to perceive the extent of its effectiveness and its impact on future coal production. Currently it is alleged by small eastern mine operators that the costs of reclamation as required under federal control will result in the closing of many small surface mines, especially in the Appalachian region. Other constraints may become operative in the West and in the agricultural/coal lands of the Midwest. However, the additional cost of reclamation per ton of coal capable of being mined from these areas is sufficiently low so as to pose no economic hindrance. Nevertheless, there may be an adverse effect on short-term production goals. At least four problem areas related to the adequacy of coal mine reclamation could arise as a result of the new federal programs under PL 95-87. These are: improper permitting and site inspections because of poorly trained personnel; the emergence of new reclamation problems because of the promotion of underground and eastern versus western extraction; the occurrence of local post-mining land-use conflicts. The new programs should strive for coordination of reclamation with local development objectives; issuance of weakened reclamation standards under pressures for higher coal production—particularly in situations where information is insufficient to understand the consequences of mining reclamation operations.

Increased coal production under NEP will create additional impacts on water resources in the East and Midwest. Research is needed to evaluate the effectiveness of various mining and reclamation techniques to minimize water resource problems in mined areas during and after reclamation. Runoff rates and erosion on reclaimed mine areas have not been well documented. The ability of different reclamation techniques to minimize long-term erosion and sediment transport to streams has not been specifically investigated. The extent and magnitude of future problems will be determined primarily by the effectiveness of new legislation.

Reclamation-water resource problems in the West are those associated with erosion and increased sediment loading in streams. Site-specific impacts on local groundwater tables, especially in alluvial valleys, are another important problem. Alluvial valley floors are important for agricultural purposes and research is needed on reclamation of these valley floors and adjacent uplands before long-term impacts on agricultural and groundwater hydrology and water quality can be evaluated.

The approximate contour regulation of the new Federal Surface Mining Act presents a problem for restoration of both surface mining and the surface effects of underground mining in Appalachia. Returning a surface mine to original contour creates long uninterrupted slopes which promotes erosion and slope instability.

Surface mining for coal in the Midwest has encroached on valuable prime agricultural lands. Projected estimates for the Midwest indicate that land disturbance by surface mining will possibly double to meet the NEP 1985 goals. The major concern of mining prime agricultural lands is whether the technology or knowledge exists which will allow for the successful reestablishment of those soil factors conducive to successful crop production.

Increased Generation of Coal Ash and FGD Sludges

Implementation of the NEP will result in an increase in coal ash production in proportion to the increase in coal utilization and the amount of flue-gas desulfurization (FGD) sludges in proportion to the incremental amount of SO_2 removed from stack gases. It is estimated that by 1985 coal ash production will increase by 9% over pre-NEP projections and that the corresponding increase in FGD sludge production will be 26%. Local regions, particularly those in which little coal has been used traditionally, are expected to experience larger percentage increases. The largest impact, however, will be in areas of light population density and high coal usage which are expected to experience difficulty in siting disposal areas for the wastes generated by new coal-burning industrial boilers, and by existing utility boilers shifting to coal from other fuels.

The composition of the wastes generated will be dependent upon coal source, boiler design and operating conditions, and the system selected for FGD. Although regenerable FGD systems are under development, it is expected that for the period through 1985 FGD processes will be predominantly of a throw away design generating a mixture of calcium sulfite and sulfate, the exact composition of which will be determined by the particular coal type and FGD process in question.

Regardless of the NEP initiatives, the generation of solid wastes will increase rapidly and it is estimated that by 1985 coal ash will be generated at a rate of 92×10^6 tons/year and FGD sludges at a rate of 33×10^6 tons/year, on a dry basis. The most common disposal methods for both ash and FGD sludges are by settling in ponds and landfill; limited amounts of ash, currently about 15 percent, are used for the production of cement, as a filler, and other industrial applications. Ocean and mine disposal under carefully controlled conditions offer potential future alternative disposal options. Selection of the method of disposal depends upon the availability of suitable sites and on the ability to satisfy Federal and local regulations. It is estimated that under the NEP the solid waste to be disposed of in the decade up to 1985 will be 350,000 acre-ft. The land committed to disposal sites will be large, ranging from 0.4 to 0.7 acres per MW of installed boiler capacity.

Potential adverse consequences of disposal are the diversion of land from other uses, the contamination of ground and surface waters, and fugitive dust emissions from landfill sites. Additional problems are provided by the difficulty of dewatering sulfite-rich FGD sludges and the poor compaction characteristics of untreated sludges. These problems have been identified and technical solutions are either available or are under development.

In view of the limited experience with the disposal of sludges, and the long lag between the times of disposal and the observation of potential adverse effects, it is imperative that disposal sites be carefully evaluated prior to approval and that legislation expected to restrict contamination from disposal sites be rigorously enforced. Continued priority should be given to the reduction of wastes by the development of processes for the utilization of solid wastes and by the development of regenerable FGD systems. The impact on the terrestrial environment should be minimized by the ensurance that the sludges disposed are stabilized in order to permit reclamation of landfill sites. Discharges from ponds, where contaminated, should be either treated or recycled to the power plant for reuse. Uncertainty exists on the potential for leaching of trace metals, radionuclides and other contaminants from ash and sludge, as a consequence of which the movement of leachate at disposal sites should be closely monitored. The above potential problems have been stressed because the degree to which existing legislation will be implemented and enforced at the state level is presently unknown.

Thermal Consequences

The thermal consequences of coal utilization are most meaningfully assessed in comparison with the form of power generation replaced by coal. If coal replaces oil or gas, there are no significant thermal differences. However, light water nuclear power plants discharge approximately 50% more waste heat to the atmosphere through cooling towers or to a water body than coal-fired plants. Coal-fired plants require about ⅔ as much water as nuclear power plants. Therefore, for comparable siting, the effects, if linear, are only ⅔ those of nuclear plants. The different effects are influenced by siting decisions and the intrinsic thermal efficiencies of the two fuel systems.

Nearly every property of water is affected nonlinearly by temperature, and biological effects may amplify these changes because protein denaturation takes place more rapidly above 30°C and these high temperatures affect bactericidal and virucidal activity of chlorine compounds. Usually algal populations change from a dominance of diatoms and green algae to dominance by blue-green algae. All organisms experience elevated metabolic rates at higher temperatures which may affect total energy needs, foraging ability, reproduction, migration and susceptibility to disease.

Intake structures inevitably draw many organisms into the cooling system of a power plant, but the number and kind are influenced by its location, configuration, and mode of operation. Use of water recirculation systems reduces water use and with it, the number of organisms entrained. Damage in the cooling system to very small organisms may be small, but fish and their larvae and eggs may be seriously damaged. The effects will determined by rate of reproduction, percent of flow withdrawn, mortality rate, and the life span of the organisms.

Discharge effects in water may also be severe but are generally local. The near field, where there are strong shear velocities and rapid temperature changes are particularly stressful to fish, and stringent limitations on the timing and strength of discharges may be required to reduce these stresses to nondamaging levels.

Off-stream cooling systems may transfer the harmful effect to the atmosphere and increase cloudiness, ground fog, precipitation, temperature, and local winds, but these effects generally extend no further than 1000 m, even in winter.

There is considerable potential for using condenser cooling water for agricultural and aquacultural purposes, such as irrigation, frost protection, undersoil heating, greenhouse heating and climate control. However, over the next few decades little of this waste heat is likely to be used creatively.

In summary, the thermal consequences of implementing NEP are locally serious but do not pose regional problems. Creative use of the waste heat for aquaculture, agriculture, cogeneration, and power for energy intensive industries can be a powerful means of mitigating undesirable effects.

REFERENCES

1. Air Pollution and Cancer: Risk Assessement Methodology and Epidemiological Evidence. Report from an International Symposium at the Karolinska Institute, Stockholm, March 8-11, 1977
2. An Analysis of the Constraints on Converting Large Industrial and Utility Boilers from Natural Gas to Coal, American Gas Association, November 23, 1977
3. Annual Environmental Analysis Report, DOE (ERDA), September 1977.
4. Environmental Control Aspects of Increased Coal Utilization, DOE, November 1977.
5. Hamilton, L. D. U.S. Electricity Through The Year 2000: Coal or Nuclear? Alternative Sources and Health. Brookhaven National Laboratory, March 1977.
6. Jones, K. E. Urban Air Quality Impacts of the National Energy Plan; An Assessment of Six Cities. CEQ, December 1977.
7. Pechan, E. H. Regional Air Emission Analysis of Alternative Energy Policies in 1985. DOE, October 1977.
8. Potential Siting Problems for Increased Coal Use—A County-by-County Analysis of the Administration's Coal Substitution Program Considering Projected Air Quality for the Year 1985. EPA, September 30, 1977
9. Steam Electric Plant Factors. National Coal Association, 1977.