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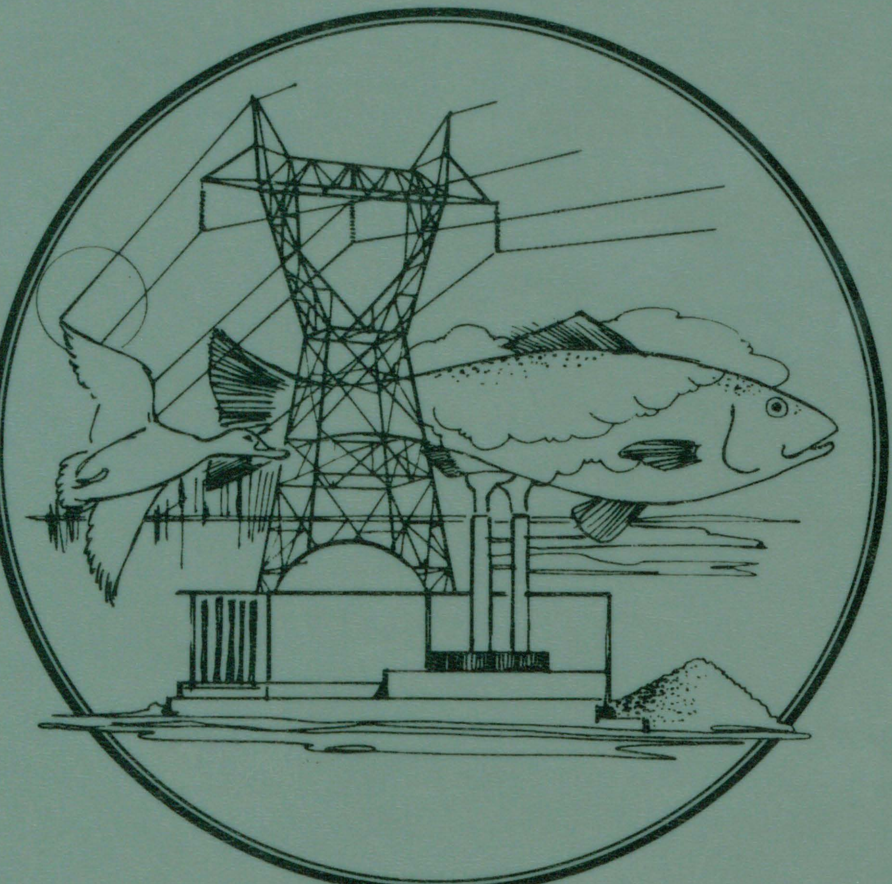
Biological Services Program

FWS/OBS-78/75
August 1978

A Biologist's Manual for the Evaluation of Impacts of Coal-Fired Power Plants on Fish, Wildlife, and their Habitats



Fish and Wildlife Service

U.S. Department of the Interior

The Biological Services Program was established within the U.S. Fish and Wildlife Service to supply scientific information and methodologies on key environmental issues which impact fish and wildlife resources and their supporting ecosystems. The mission of the Program is as follows:

1. To strengthen the Fish and Wildlife Service in its role as a primary source of information on national fish and wildlife resources, particularly in respect to environmental impact assessment.

2. To gather, analyze, and present information that will aid decision makers in the identification and resolution of problems associated with major land and water use changes.

3. To provide better ecological information and evaluation for Department of the Interior development programs, such as those relating to energy development.

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° Power plants

° Geothermal, mineral, and oil shale development

° Water resource analysis, including stream alterations and western water allocation

° Coastal ecosystems and Outer Continental Shelf development

° Systems and inventory, including National Wetlands Inventory, habitat classification and analysis, and information transfer

The Program consists of the Office of Biological Services in Washington, D.C., which is responsible for overall planning and management; National Teams which provide the Program's central scientific and technical expertise and who arrange for contracting Biological Services studies with States, universities, consulting firms, and others; Regional staff who provide a link to problems at the operating level; and staff at certain Fish and Wildlife Service research facilities who conduct inhouse research studies.

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A BIOLOGIST'S MANUAL FOR THE EVALUATION OF IMPACTS OF COAL-FIRED POWER PLANTS ON FISH, WILDLIFE, AND THEIR HABITATS

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EDITOR'S NOTE

The major data base for this Manual is the Report entitled "Impacts of Coal-Fired Power Plants on Fish, Wildlife, and Their Habitats" (FWS/OBS-78/29).

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PREFACE

Field biologists of the U.S. Fish and Wildlife Service often review environmental reports and impact statements relating to coal-fired power plants. Biologists may also be asked to provide input to the process of power plant site selection, and to make recommendations regarding mitigative measures for subsequent power plant construction and operation. This Manual provides initial guidance for these tasks, specifically as they relate to terrestrial and aquatic biota. The Manual includes, in highly abbreviated form, a generalized summary of the major impacts to biota that are unique to the operation of a coal-fired steam-electric power plant. The impacts were discussed in detail in the Report entitled "Impacts of Coal-Fired Power Plants on Fish, Wildlife, and Their Habitats" (FWS/OBS-78/29). The Manual is to be used in conjunction with the Report.

Features that are common to all steam-electric generating plants (e.g., water intakes, condenser cooling systems, power transmission facilities) are outside the scope of the Manual and are only briefly mentioned. These features have been discussed in detail elsewhere.

The Manual provides material that will aid in the review of environmental impact statements and environmental reports, and complements the FWS Steam Electric Power Plant Review Manual. It is a primer for biologists new to impact assessment work, who will benefit from initial guidance in formulating an evaluation. Several approaches to the assessment of impacts to biota from the operation of a coal-fired power plant are described, but the main approach taken throughout the Manual is a "best judgment" evaluation, made by a biologist familiar with the respective locality and region.

Impact assessment is a young, evolving area of human endeavor, with room for new approaches, and should not be confused with impact measurement. There are a number of scientific methods for measuring the extent of certain impacts, but such measurements presume a knowledge of pre-impact conditions, and also presume that the magnitude of the effect is large enough to be detected by the methodology. Impact assessment, on the other hand, is essentially predictive, and must often be accomplished in the absence of site-specific data, before a project is begun or put into operation. In cases where site-specific data are available or where biological effects can be monitored and measured, impact assessment must still rely on a "best judgment" approach toward predicting the long-term and secondary effects on the overall local, regional, national, and global ecosystems.

ORGANIZATION OF THE MANUAL

The Manual is a summary of the Report, "Impacts of Coal-Fired Power Plants on Fish, Wildlife, and Their Habitats," (FWS/OBS-78/29). The Report serves as the major data base for the Manual and includes literature citations for the information summarized in the Manual; for brevity, no literature is cited in the Manual.

The introductory section of the Manual includes a description of coal-fired power plants, with emphasis on components that are unique to such installations. Associated facilities such as condenser-cooling systems and power transmission systems, which are common to alternative methods of steam-electric power generation, are not described. Some environmental considerations involved in the siting and construction of power plants are briefly discussed. Although such considerations are not unique to coal-fired units, they warrant brief discussion to introduce the biologist to the complexities and potential impacts of siting and construction. References listed at the end of the introductory section provide additional information on power plant facilities, siting, construction, environmental measurement, and environmental impact assessment.

The remainder of the Manual is divided into topical sections corresponding to power plant features that have the potential for adverse effects on fish, wildlife, and their habitats. The page numbers of the Report (FWS/OBS-78/29) which correspond to particular topical sections in the Manual are listed, in brackets, to the right of the topical headings in the Manual. Each of the topical sections is divided into the following subsections:

- DESCRIPTION - A brief description of the particular feature is provided.

- SUMMARY OF IMPACTS - A summary is given of the major impacts on terrestrial and aquatic biota that were discussed in the main Report. The Report should be consulted for a detailed discussion of the impacts and for literature citations that provide supporting documentation.

- STANDARDS AND CRITERIA - Applicable standards, if any, or criteria that may be used to evaluate impacts in the absence of specific standards are listed.

- QUANTIFICATION - Tables, graphs, and/or calculations referred to in other portions of the sections are collected here.

- INFORMATION REQUIREMENTS AND SOURCES - Items of information needed and/or desirable for the evaluation of impacts are listed, together with the sources from which the information may be obtained. The lists are by no means inclusive, nor will all the items be relevant to all power plant sites. The lists can be used as guides for preparing fact sheets on a specific power plant and power plant site.

- IMPACT ANALYSIS - Approaches to impact evaluation and prediction are suggested, using data provided in the quantification subsection and other information. Examples are given where appropriate.

- MITIGATIVE MEASURES - A brief description is given of some measures that the biologist can recommend to prevent or alleviate adverse effects of specific actions.

- ADDITIONAL DATA SOURCES - A list is provided of some Federal, State, and other agencies that can assist the field biologist with information outside his/her expertise or information on specific aspects of the respective locality.

- REFERENCES - A number of documents are listed that provide the biologist with assessment information of a general nature. No literature is cited in the body of the Manual; the main Report should be consulted for such citations.

Following the series of topical sections are a number of Appendices that include information too lengthy for incorporation in the body of the Manual or that are of general applicability. Also included are a glossary and tables of metric/English and English/metric equivalents.

INTRODUCTION

A biologist's ability to prepare an adequate evaluation of power plant effects on biota is greatly enhanced by familiarity with the structure and function of various physical components of the power plant. It is also essential that the biologist be cognizant of impacts that are likely to occur from siting and construction of the power plant. These latter considerations are not unique to coal-fired steam electric power stations, and detailed discussion is outside the scope of this Manual; however, the biologist should be alerted to some of the environmental considerations of siting and construction, and a brief overview is therefore included. The references listed at the end of this introductory section should be consulted for more complete treatment of the topics discussed.

MAJOR PHYSICAL COMPONENTS OF A TYPICAL COAL-FIRED POWER PLANT

A coal-fired power plant transforms the chemical energy in coal into electrical energy by a sequence of three conversion processes. Physical components required for these processes include furnaces and boilers (where chemical energy is converted to heat energy and heat is transferred to water to make steam), turbines (where heat energy of the steam is converted to mechanical energy), and generators (where mechanical energy is converted to electrical energy). Ancillary equipment includes cooling systems (where low-temperature heat is rejected), coal storage and handling facilities, and, frequently, stack-gas cleaning equipment to remove particulates and noxious gases released during coal combustion. These basic components and processes are described below. A flow chart of the conversion process is shown in Figure 1.

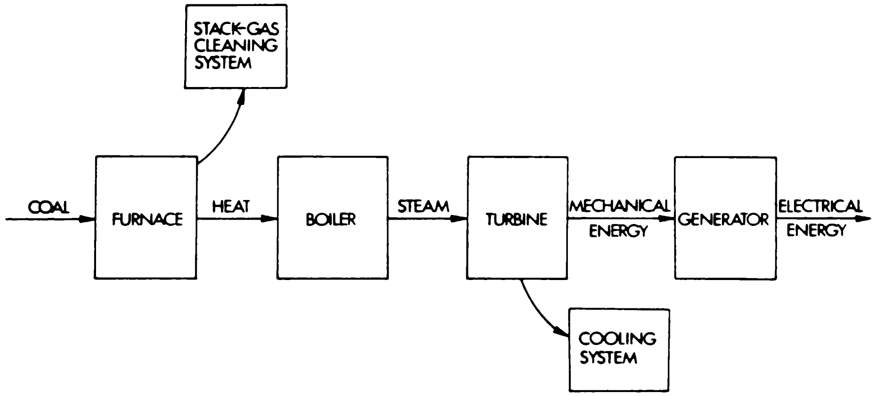

Fig. 1. Conversion of Coal into Electrical Energy in a Coal-Fired Power Plant.

Furnace

Furnaces in common use include: stoker-fired, cyclone-furnace-fired, and pulverized-coal-fired units. Stokers are mechanisms which feed fuel onto a grate within the furnace. Stoker-firing is only practical for atypically small (< 40 MWe) power plants. Cyclone furnaces burn crushed coal in a horizontal cylinder. A high velocity stream of air is injected into the cylinder and moves along the cylinder boundary to create a cyclonic flame pattern. Although they offer a number of significant advantages, cyclone furnaces produce relatively high concentrations of nitrogen oxides. For this reason, it is expected, and assumed within the remainder of this Manual, that new coal-fired plants will utilize pulverized-coal firing rather than cyclone-furnace firing.

With a pulverized-coal system, the coal is pulverized to a powder, mixed with air, and then blown into the furnace. Figure 2 shows air and flue gas circulation patterns for a somewhat simplified pulverized-coal boiler. A modern pulverized-coal-fired power plant will typically produce steam at 2400×10^4 Pa (3500 psi) superheated to 538°C (1000°F) with 538°C (1000°F) reheat.

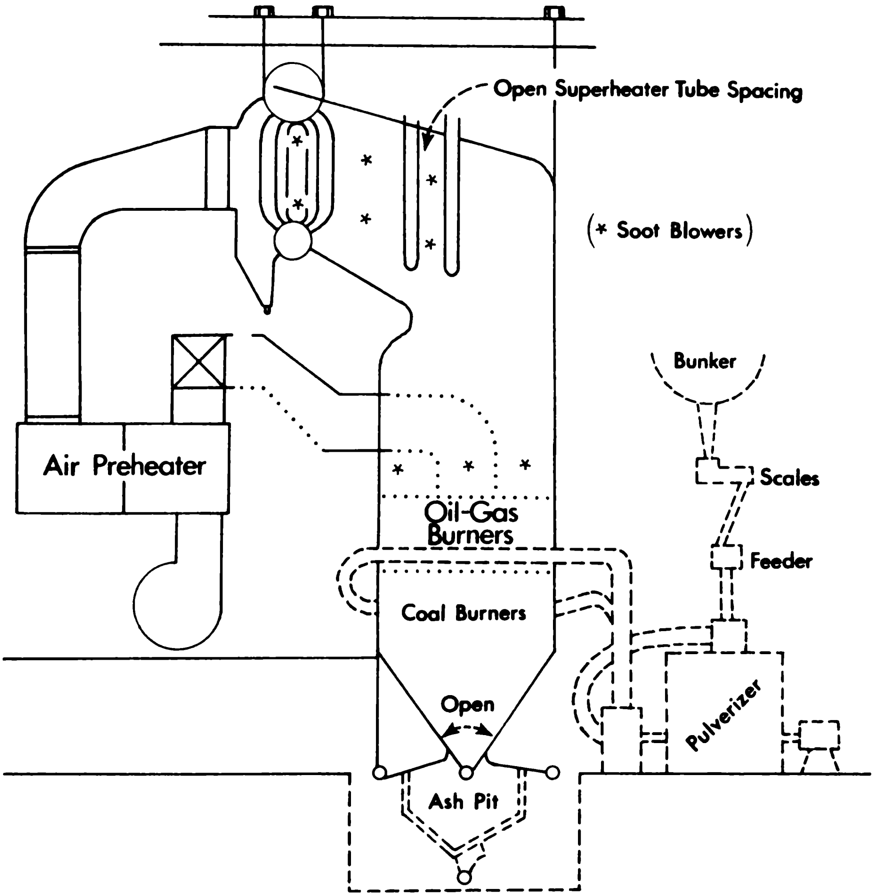

Fig. 2. Boiler and Flue-Gas Circulation Paths. From: University of Oklahoma, Science and Public Policy Program. 1975. Energy Alternatives: A Comparative Analysis. U.S. Government Printing Office, Washington, D.C. (Originally from Shields.)

Boiler

A coal-fired boiler can be either the water-tube or the fire-tube type. In a water-tube boiler, the water and steam are inside the tubes and the hot gases are outside. The opposite is the case with fire-tube boilers. Modern boilers are of the water-tube type because these boilers can be constructed for greater capacity and higher pressures than fire-tube boilers.

To maximize thermal efficiency, a power plant boiler generally contains the following components: superheater, reheater, economizer, and air preheater. The superheater is a system of tubes located at the top of the boiler in which saturated steam is superheated by combustion gases. The reheater is a system of tubes which reheats partially expanded steam that has passed through the turbine's initial stages; the reheated steam is then returned to the final stages of the turbine. The economizer transfers heat from the combustion gases (after the superheater and the reheater) to the boiler feedwater. The air preheater extracts additional heat from the flue gases (after the economizer) and transfers it to the combustion air before the air is fed into the furnace. In addition to these components, a boiler typically utilizes steam separators, fans, pumps, and fuel-handling equipment.

Turbine

The turbine converts heat energy from the boiler to mechanical energy. In the turbine, steam expands, exerting force on the turbine blades. This force turns the turbine shaft which is connected to the generator shaft. Basically, the turbine is a sophisticated, steam-driven windmill.

Generator

The generator converts mechanical energy from the turbine to electrical energy by utilizing a basic natural phenomenon--i.e., the movement of an electrical conductor relative to a magnetic field creates a voltage within the conductor. In the generator, the movement (rotation) is maintained by torque transmitted from the turbine. Power plant generators have energy conversion efficiencies ranging from 96 to 99%.

Water/Steam Cycle

The water/steam cycle in a coal-fired power plant is schematically presented in Figure 3. In the boiler, heat from coal combustion is transferred to water to produce steam. The steam does work (in the technical sense) against the turbine blades and emerges at lower temperature and lower pressure; it is then condensed into water and the water is returned to the boiler to complete the cycle. The heat extracted by the condenser is rejected to a lake, river, pond, or to the atmosphere.

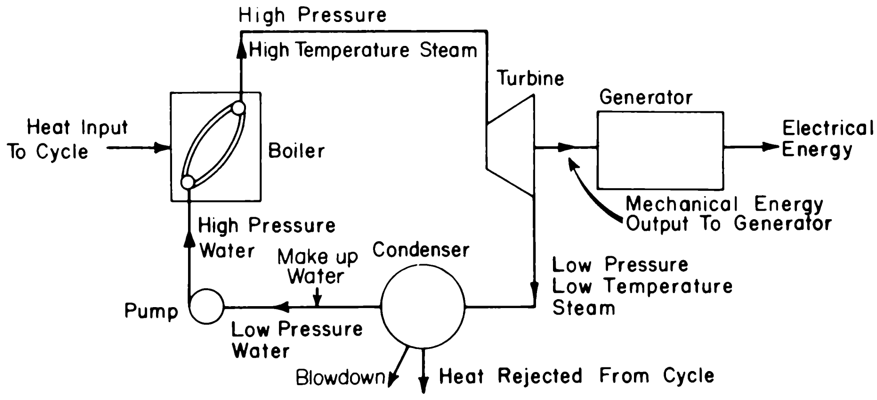

Fig. 3. The Water/Steam Cycle in a Coal-Fired Power Plant. Modified from: U.S. Atomic Energy Commission. 1974. Draft Environmental Statement: Liquid Metal Fast Breeder Reactor Program. U.S. Government Printing Office, Washington, D.C.

In a modern system, after passing through the early stages of the turbine, moderate-temperature/moderate-pressure steam is reheated in the boiler to make high-temperature/moderate-pressure steam, which is then returned to the final stages of the turbine. This is called reheat and it improves the efficiency of the heat-to-mechanical-energy conversion process. Some power plants have two reheat stages. (Figure 3 does not show a reheat cycle.)

The electrical power that a generating plant is capable of producing is measured in megawatts electric (MWe) (1 MWe = 10^6 watts = 10^3 kilowatts). The sizes of coal-burning power plants range from less than 10 MWe to more than 2000 MWe. Power plants do not operate continuously over long periods at full capacity. Averaging over a year, electrical energy output is typically 70% of capacity. The average output expressed as a percent of capacity is called the capacity factor or plant factor.

As indicated above, the power generating station rejects low-temperature heat; because of this and other losses, more than one kilowatt-hour (kW•h) of heat energy must be supplied by the coal for each kW•h of electrical energy output. In a modern coal-burning power plant, the numbers are typically 2.5-2.8 kW•h (8500-9500 Btu) of coal energy input per kW•h of electrical energy output. This corresponds to plant efficiencies of 36-40% (efficiency = kW•h of electrical output per kW•h of coal energy input).

Cooling Systems

All steam-electric power plants require cooling systems to reject heat. Cooling systems are thus not unique to coal-fired power plants and are omitted from discussion in the Manual.

Coal Storage and Handling

Coal storage. Coal is consumed continuously by the furnace, but is delivered in periodic bulk shipments of large tonnage which must be stored at the plant.

Coal handling. Coal is unloaded at the receiving facility and stored. From storage, coal is transported by conveyor to a crusher house, then to a surge bin, and finally to the silos or bunkers which feed the furnaces. The surge bin serves to smooth out the flow of coal to the burners. On the conveyor feeding the surge bin, coal samples are taken for measurement of the Btu content of the coal to determine how many metric tons/minute are needed by the furnace. Collectors in the surge bin remove dust, thereby reducing the possibility of explosion. The collected coal dust is conveyed to the bunkers and is subsequently burned in the furnace. For boilers utilizing pulverized coal burners, the feed system from each silo includes a pulverizer. The pulverized coal is mixed with a certain proportion of preheated air and delivered to the furnace for combustion. With pulverizers it is desirable to include a magnetic separator in the feed system. A coal-handling system for a large plant is shown in Figure 4.

Stack-Gas Cleaning

Coal combustion results in the emission of particulates, nitrogen oxides (NO_X), and sulfur oxides (SO_X) from power plant stacks. The U.S. Environmental Protection Agency (USEPA) has developed New Source Performance Standards (NSPS) which place limitations on particulates and oxides of sulfur and nitrogen emitted in the stack gases from power plants. The methods employed to meet these standards are summarized below.

Particulates. Particulate (fly ash) emissions are that part of the uncombustible residue which is carried out of the stack by the flue gas. With pulverized-coal firing (dry ash unit), 80% of the ash becomes entrained in the flue gas; the remaining 20% settles in hoppers (at the boiler base) from which it is removed for disposal. This fly ash level is relatively high (compared to stoker and cyclone-furnace firing) due to the fact that pulverized coal is burned in suspension. The fly ash level is reduced to about 50% for a pulverized-coal furnace with a slag-tap capability. With cyclone-furnace firing, only 20 to 30% of the total ash is carried away as fly ash.

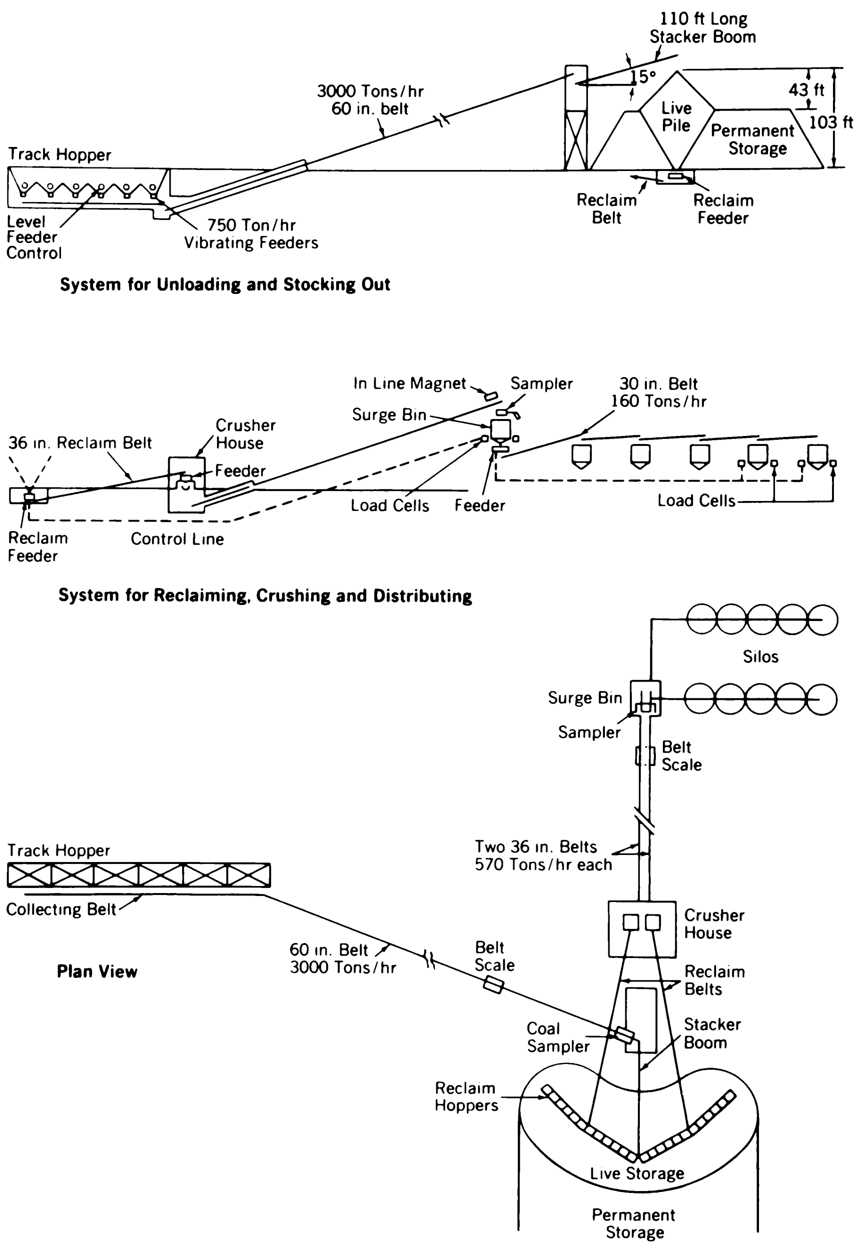

Fig. 4. Coal-Handling System for a 1000-MWe Power Plant. From: Babcock and Wilcox Co. 1972. Steam, Its Generation and Use, 38th ed. New York. (Reprinted with permission.)

There are four types of fly ash control systems: electrostatic precipitators, wet scrubbers, fabric filters, and mechanical collectors. These are described in APPENDIX A.

Nitrogen oxides. Combustion-generated nitrogen oxides (NO_x) are produced by two reactions: the combination of nitrogen from the combustion air with oxygen and the oxidation of nitrogen chemically bound in the coal. The formation of nitrogen oxides depends on combustion conditions in the primary flame zone of the boiler.

Four techniques are available to control NO_x emissions from coal-fired boilers: (1) modification of combustion conditions, (2) modification of the coal, (3) extraction of NO_x from the flue gas, and (4) utilization of an alternative, low NO_x combustion process (catalytic combustion, fluidized-bed combustion).

See APPENDIX A for additional discussion of NO_x control.

Sulfur oxides. Coal contains organic and inorganic compounds of sulfur at concentrations up to about 14% sulfur. Upon combustion, various oxides of sulfur are formed and are carried up the stack as flue gases. Methods for controlling emissions of SO_2 (flue-gas desulfurization) include lime or limestone scrubbing, double alkali scrubbing, magnesia scrubbing, and the Wellman-Lord process. These are described in APPENDIX A.

GENERAL SITING CONSIDERATIONS

The siting of a coal-fired electric generating station is a complex process involving social, economic, and environmental considerations and trade-offs. The screening process for site selection should take into account numerous environmental aspects such as water availability, water use and quality, air quality, aesthetics, public use areas, and movements and habitats of important animal species.[1] If the potential impacts are identified before a site is chosen, the impacts may be mitigated by proper design modifications, or another site can be selected.

There are no general power plant siting standards or criteria that have nationwide applicability. However, a number of States have agencies charged with responsibility for power plant siting; these agencies should be consulted for State siting criteria. In addition, Federal, State, and local laws and regulations pertaining to air and water pollution control apply.

In most cases to date, State and Federal agency biologists have been assigned to review ecosystem impacts only after a site has been selected. Review

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[1] A species is "important," for example, if a specific causal link can be identified between the power plant and the species, and if one or more of the following criteria apply: (a) the species is commercially or recreationally valuable; (b) the species is threatened or endangered; (c) the species affects the well-being of some important species within criteria (a) or (b); or (d) the species is critical to the structure and function of the ecological system. (Definition adapted from "Regulatory Guide 4.2 for the Preparation of Environmental Reports for Nuclear Power Stations," U.S. Nuclear Regulatory Commission, Office of Standards Development, July 1976, Revision 2.)

of alternative sites is usually a formality, unless the biologist can demonstrate that a severe impact is likely to occur at the designated site. However, there appears to be an increasing tendency for some power companies to obtain input from State and Federal agencies early in the site selection process, either in response to new State regulations or voluntarily to avoid later conflicts and delays. In many cases, early input from the biologist could be one of the most productive aspects of the environmental review process.

The siting factors that have the greatest influence on impacts to terrestrial and aquatic biota are water availability and land use. The potential severity of the impacts will depend, in part, on the nature of the existing atmospheric, terrestrial, and aquatic environments. These factors are briefly discussed below; because of regional differences which affect the importance given to these factors (e.g., water availability is of greater concern in the arid West than in the humid East), no attempt is made here to assign priorities to the siting factors.

Water Availability

The major water requirement of the steam-electric power plant is for waste heat dissipation. The amount of water needed will depend on the cooling system used; i.e., much greater amounts of water are required for once-through cooling systems than for a closed-cycle system which employs cooling towers or another offstream cooling system operating as a closed loop (see Table 1). Limestone scrubbing and ash sluicing account for 16-30% of the cooling water requirement. A majority of the existing water resources of the country have competing uses. The addition of a power plant to a system which already receives industrial and municipal wastes, which has impoundments, which is subjected to navigation and dredging, and which is also managed for fish and wildlife, compounds the burden to that aquatic system.

Land Use

Impacts to terrestrial and aquatic biota arise from removal or alteration of habitat. Table 2 provides examples of power plant land area requirements.

Land areas may be degraded, destroyed, or made totally or partially inaccessible to important species because of construction or operation of the station. As a result of this preemption or restriction of access to wildlife habitat, animal populations in affected areas will disperse to seek suitable habitat elsewhere, possibly resulting in competition with resident individuals.

Atmospheric Environment

Sulfur oxides, nitrogen oxides, particulates, and chemical elements are emitted into the atmosphere from coal-fired power plants. These effluents can affect terrestrial and aquatic ecosystems. The meteorology of the site influences the ultimate ground-level concentrations of these stack-gas effluents; likewise, ambient air quality influences the maximum 24-hour concentrations of air pollutants, and is thus a factor in the magnitude of pollutant effects on plants and animals.

Terrestrial Ecosystems

Impacts to terrestrial ecosystems include a reduction or loss in total available habitat, destruction or modifications of food webs, and changes in populations. In general, animal populations have the appropriate reproductive capacities to withstand losses of a few individuals without major changes in overall population densities. However, if these losses exceed reproductive capacities, shifts in the community structure may occur.

Siting a power plant close to wetlands may have adverse consequences, not only for such "quality of life" factors as diversity of species but also for conditions such as water level and quality which are essential to the survival of the overall wetland ecosystem itself.

Table 1. Estimated Water Requirements for Coal-Fired Power Plants

Cooling system	Water requirements (liters/kW·h) Through-put[a]	Consumptive use[b]
Once-through	150	0.95
Cooling ponds	150[c]	0.95
Wet cooling towers	150[c]	2.8

[a]Volume of water taken into the cooling system; most of this water is discharged back to the source.
[b]Portion of water taken into the system which is lost to evaporation and seepage.
[c]Water is recycled in these systems; once the tower or pond is filled with water, continued withdrawal from a natural water source will comprise approximately 10% of this figure.

Table 2. Approximate Area Requirements for Coal-Fired Power Plants of Various Sizes[a]

Component	Area requirements of coal-fired plants (ha) 100 MWe	350 MWe	700 MWe	2100 MWe
Coal storage, handling[b]				
Rail siding	0.3	0.5	0.8	2.1
Reserve storage	1.0	1.5	2.4	6.5
Live storage, crusher, surge bins	0.2	0.3	0.4	1.2
Subtotal	1.5	2.3	3.6	9.8
Power generation				
Boiler	0.3	0.3	0.4	1.1
Turbine/generator	0.3	0.3	0.4	1.1
Subtotal	0.6	0.6	0.8	2.2
Waste heat dispersal[c] (Cooling towers)	1.1	3.4	6.5	18.6
Waste handling[b]				
Ash ponds	0.4	0.8	1.5	4.5
Sludge ponds	0.4	0.8	1.5	4.5
Subtotal	0.8	1.6	3.0	9.0
TOTAL	4.0	7.9	13.9	39.6
Area permanently disturbed[d]	29.	57.	97.	283.

[a]Data compiled from references cited in the Report, Table 4.
[b]Data are annual estimates. Actual values are a function of the heat (Btu/lb), sulfur, and ash content of the coals being burned.
[c]Where cooling lakes are used, approximately 0.4-0.8 ha/MWe is required.
[d]Includes roads, parking areas, switchyards, landscaping, etc., not included in rest of table.

Other aspects of impacts to terrestrial ecosystems are discussed on pages 21-23.

Aquatic Ecosystems

Coal-fired power plants require water for operation. Like nuclear-, gas-, and oil-fired plants, the primary water use is for dissipation of waste heat. Aquatic ecosystem effects of cooling water use include impingement of fish on water intake screens, entrainment of plankton and larvae in the condenser cooling water, and thermal discharge effects on biota in the receiving stream. The consumptive use of water which is unique to coal-fired plants arises from material transport, e.g., movement of ash and scrubber sludge to disposal basins.

Natural lakes. A factor to be considered for lake sites is the volume of the lake relative to the amount of water required for plant operation. If the amount of water required by the power plant is a large fraction of the lake volume, then reductions in volume and surface area of the lake will result in several impacts to aquatic biota. First, lake drawdown will reduce the volume and quality of aquatic habitat available to biota. Pelagic species will become more concentrated, and species interactions will be increased due to a reduction in carrying capacity and the volume of the system. Second, the location of the littoral zone will change, and although this may not be serious in lakes which occupy gradually sloping basins, the littoral zone may be greatly reduced in lakes with limited shallow areas which then drop steeply. Since the littoral zone is highly productive in terms of aquatic macrophyte growth and associated epiphytes and invertebrates, reduction of this zone can have significant effects on the biota of this type of lake.

Temporary drawdown has been used as a management technique for enhancing bass populations in some impoundments. However, timing of drawdown is critical. For example, when drawdown occurs during the spawning season, nests and eggs of littoral spawners can incur a dessication mortality. During other times of the year, primarily fall or winter, temporary drawdown displaces prey species from refuge areas afforded in the littoral zone. Because available plant cover is reduced, prey species are more susceptible to predation. Reestablishing predrawdown water levels stimulates production and, in many cases, improves both fish production and yield. Cool-water percids (yellow perch, walleye, and sauger) occupy intermediate habitat between the shallow littoral zone and the deep profundal zone. Displacement or elimination of this sublittoral area would reduce the populations of these species.

Estuaries. The major siting considerations for power plants on estuaries are the location and type of cooling-water intake and discharge facilities, and other effects of plant construction and operation such as discharges from solid-waste-disposal areas, coal storage-pile runoff, and siltation. Additional factors to consider for estuarine siting are the tidal cycle and, when present, intrusion of a saltwater wedge. Variations in salinity affect distribution of estuarine species and their various life history stages.

Rivers. An important consideration of siting a power plant on a river is that any additions, such as silt from construction runoff or discharge effluents, are constantly diluted and carried downstream by the river. There is thus a potential for impacts downstream from a proposed site that should also be considered. The majority of the large rivers in the United States are not, however, free-flowing. Many impoundments have been created, primarily for flood control and navigation.

Siting power plants on smaller rivers may necessitate construction of impoundments in order to meet water requirements. An impoundment can have significant effects on the river system, both upstream and downstream. Construction impacts include siltation and habitat destruction. When the impoundment is built and filled, a new set of impacts will occur. The dam itself forms a physical barrier which blocks the movement of fish and invertebrates. The life cycles of migrant fish such as forage species (suckers and minnows) and game species (salmonids) can be interrupted. When this occurs, the populations of these and other species with similar life cycles could be impacted by reduced recruitment.

Other effects of impounding a river include the change from a lotic to a lentic habitat above the dam, with corresponding changes in biotic species occurrence and diversity. Land areas will be inundated, introducing new substrate for invertebrates and adding organic matter to the water. Downstream from the dam, water quality will usually improve because the impoundment serves as a settling basin for suspended matter carried by the river.

Artificial lakes. An alternative to siting power plants on existing aquatic resources is the construction of an artificial lake. The use of the lake would be primarily to provide cooling water. However, many artificial lakes are multipurpose in that they provide an additional resource for aquatic sports and fish and wildlife. Implementation of this alternative has both positive and negative attributes. Although a new aquatic resource is generated, terrestrial habitat is lost. If groundwater is used to fill and maintain water in the lake, water levels in neighboring wells and wetlands may be affected adversely.

SITE SELECTION

Siting of a power plant usually involves comparison of a number of alternative sites before a choice is made. Rather than attempt to quantify absolute impacts to biota, it is simpler and more reasonable to view impacts on a relative basis. This approach is especially useful when a single site is to be selected from among several alternative sites. For this purpose, information on specific aspects of each site is essential, and includes the items listed below. The list is not exhaustive; the biologist should add items that are important to the specific locality, or delete items that are irrelevant or unimportant to the site in question.

Information Required for Site Evaluation	Sources
Atmospheric environment: Topography Proximity of other point sources Ambient air quality (maximum predicted 24-hour and annual average concentrations of SO_2, NO_x, and TSP) PSD class designation	Site visit Topographic maps USEPA Regional Office State Air Quality Office
Site (terrestrial): Community type Land use Land capability class Importance to birds and mammals Vegetation sensitivity to SO_2 Proximity to transportation routes Critical habitats and rare, endangered, or protected species Proximity to major flight routes	Power plant operator Site visit District Soil Conservation Service In-house (FWS) State Fish and Game Department Literature
Site (aquatic): Proportion of water source required Water quality Water uses Critical habitats and rare, endangered, or protected species Important species and habitat	Power plant operator USEPA Regional Office District Corps of Engineers State Water Quality Office In-house (FWS) State Fish and Game Department
Transmission facilities: Length of rights-of-way Community types traversed Number of stream and wash crossings Raptor populations	Power plant operator Site visit In-house (FWS)
Waste disposal: Depth to water table Flooding hazard Soil limitations for ponds and reservoirs Proximity to wetlands and surface waters	District Soil Conservation Service Soil Survey Reports District Corps of Engineers Site visit Power plant operator

In most cases, when site selection is in progress, there is very little data available from the power plant operator regarding details of the terrestrial and aquatic ecosystems at each alternative site. The biologist must, therefore, rely on visual assessments during visits to the individual sites, on topographic maps and aerial photographs available from the power plant operator or the U.S. Geological Survey, and on expertise and knowledge of the region by the Fish and Wildlife Service. Consultation with appropriate State agencies (e.g., Fish and Game Department) and staff of local colleges and universities is crucial.

To aid in the evaluation of alternative sites, a table similar to Table 3 can be prepared. Alternative sites (A to ...) are listed across the top, and the factors to be used as criteria for ranking the sites are listed in the left-hand column. The values or description for each of the factors for which data are available are entered in the table under the appropriate column. When all such boxes for a given factor have been filled in, each site is ranked accordingly, using a ranking of 1 for the best site for the power plant, 2 for the second best, and so on. When the entire table has been completed, the rankings are averaged for each factor. The site with the lowest average rank is assumed to be the most suitable for a power plant, i.e., would have the least adverse effects on terrestrial and aquatic ecosystems in the locality or region.

A certain amount of subjectivity is obviously involved in ranking of the sites; such subjectivity cannot be avoided and is, in fact, desirable as long as the subjectivity is based primarily on professional judgment and opinion. An experienced individual can integrate a large number of quantities and unquantifiable aspects, a process that cannot presently be matched by any other methods. Independent, congruent rankings by two or more biologists would lend additional validity to the result.

The factors listed in Table 3 that can be considered as guides in ranking alternative sites are briefly discussed, as follows:

Table 3. Some Ecosystem Factors to be Considered in Evaluating Alternative Sites for a Coal-Fired Power Plant

Factors	Alternative Sites					
	A		B		C	
	Value or Description	Rank	Value or Description	Rank	Value or Description	Rank
Atmospheric Environment: Topography Proximity of other point sources Ambient air quality: SO_2 NO_x TSP PSD class designation						
Site (terrestrial): Habitat value Land use and capability class Importance to game birds and mammals Vegetation sensitivity to SO_2 Proximity to transportation routes and highways Critical habitats and rare, endangered, or protected species Proximity to major flight routes						
Site (aquatic): Proportion of water source required Water quality Water uses Endangered species or critical habitats Important species Important habitat						
Transmission Facilities: Length of rights-of-way Habitat types traversed Number of stream and wash crossings Raptor populations Water bird populations						
Waste Disposal: Depth to seasonally high water table Flooding hazard Soil limitations for ponds and reservoirs Proximity to wetlands						

Atmospheric Environment

The biologist should be cognizant of the factors that contribute to ground-level concentrations of air pollutants in order to deal intelligently with predictions of possible effects on biota. Of particular interest are the maximum 24-hour concentrations of pollutants and the maximum annual average concentrations. It is exposure to these maximum concentrations that tend to cause acute effects to vegetation and animals, particularly during fumigation conditions.

Topography. The topographical features at and near a site determine the dispersion and ultimate ground-level concentrations of the pollutants emitted from the stack of a power facility. In general, higher maximum concentrations result from mountainous terrain than from flat terrain because more concentrated portions of the plume contact the hillsides. Examples of ranking are:

1 - Flat, level terrain
2 - Gently rolling terrain
3 - Hills as tall as the plant stack
4 - Hills taller than the plant stack

Proximity of other point sources. The contributions of the plant, in conjunction with other nearby point sources, can have an adverse effect on the quality of the air. Other point sources, either upwind or downwind, can elevate the ground-level concentrations above what the proposed facility would produce. Examples of ranking are:

1 - No point sources within 50 km
2 - No point sources within 10 km
3 - No upwind or downwind point sources within 10 km
4 - Weak point sources upwind or downwind within 10 km
5 - Strong point sources upwind or downwind within 10 km

Ambient air quality. Background concentrations of air pollutants must be considered when determining the total effects of a proposed facility. High ambient concentrations when enhanced by the proposed facility may exceed standards. Generally, SO_2, NO_2, and total suspended particulates (TSP) are the pollutants of current concern. Examples of ranking are:

	Annual Average Concentrations (μg/m^3)		
Rank	SO_2	NO_x	TSP
1	≤ 10	≤ 20	≤ 10
2	10-30	20-40	10-25
3	30-60	40-60	25-50
4	60-80	60-100	50-75
5	> 80	> 100	> 75

The values for Rank 5 exceed Federal standards (see Appendix D).

Prevent significant deterioration (PSD) class designation. Areas that have been designated Class I have very strict limits as to the amounts of pollutants that can be added. Class II areas generally are acceptable for growth, whereas Class III areas may have pollutant loads near or exceeding standards. Examples of ranking are:

1 - Class II
2 - Class III
3 - Class I

Site Factors (Terrestrial)

Community type. The various vegetation community types on alternative sites can be evaluated with regard to capability for supporting wildlife. In general, habitat of good quality for supporting wildlife would be less preferred as a power plant site than a habitat of lower quality. The Handbook for Habitat Evaluation Procedures (Fish and Wildlife

Service Resource Publication No. 132) can provide guidance for ranking of alternative sites as wildlife habitat.

Land use and capability class. The U.S. Soil Conservation Service has devised a classification system that ranks soils into eight classes according to their ability to support agriculture. Economic constraints may preclude preempting farmland (Land Classes I through IV) from cultivation. Sites with soils of lower agricultural quality (Classes V through VIII) may be more suitable for wildlife habitat. From the standpoint of the wildlife biologist, siting a power station on cultivated or other disturbed lands would be preferable to siting it on lands of high wildlife quality. However, this view may be in conflict with the agricultural and socioeconomic needs of the locality.

Importance to birds and mammals. If the site provides a major proportion of forage or cover for important animal species in the region, the disturbance of the area may be of concern to the wildlife biologist. Such sites would be poor choices for power plant installations.

Sensitivity to air pollutants. Although the sensitivity of biota to pollutants is known for only a few species and pollutants, knowledge of the presence of a species known to be sensitive may play a large role in ranking alternative sites. This is particularly true if the species is a dominant, an important resource for wildlife, or an important game species. In this regard, offsite biota in the area of predicted maximum concentrations should be considered.

Proximity to transportation routes and highways. The proximity to major transportation routes will determine whether or not new roads need to be built to support the operation of the generating station. Increased use of existing roads would tend to have less of an impact on wildlife than construction of new ones.

Critical habitats and rare, endangered, or protected species. The presence of critical habitat for rare, endangered, or protected species at a given site would increase the undesirability of locating a generating station at that site. If the area contains a major proportion of the resources of an endangered species, siting of a generating station may be precluded.

Proximity to major flight routes and resting sites. Waste-disposal ponds pose a threat to birds, particularly water birds. Use of these ponds by water birds may result in the ingestion of potentially toxic material. A site removed from major flight routes would be less likely to pose this threat.

Site Factors (Aquatic)

Proportion of water source required. The magnitude of impacts to the aquatic ecosystem will depend in part on the volume and flow of the natural water body to be used as a source of cooling water. For example, a small free-flowing river may need to be impounded to provide sufficient water for power plant cooling requirements; such impoundment will have marked, long-term effects on the aquatic ecosystem. Ignoring other factors, a site on a small river would thus tend to be less desirable from the point of view of commitment of resources than a site on a larger river where, for example, less than 10% of the river water would be withdrawn for cooling.

Water quality. If the ambient concentrations of certain chemical elements in a water body are close to potentially toxic levels, the concentrations may become harmful by additions from the proposed power station. Heated discharges into such water bodies may also serve to aggravate the potential for adverse effects on the aquatic ecosystem. On the other hand, it may be less desirable to have a relatively clean river degraded in a particular locality than to have the power plant sited along a river already heavily polluted. Thus, ranking of a site according to water quality must take into account specific regional policy, as well as effects on aquatic biota.

Water uses. Desirability of a site for power plants will also depend on other competitive uses of the water, such as recreation, public and industrial use, fish and wildlife management, and navigation. For example, a river used for domestic water might be less preferred for power plant siting than a river used for navigation.

Endangered species or critical habitats. Areas with endangered species or critical habitat are less desirable for power plant installation than other sites; there may be cases where such sites should be rejected.

Other important species. The use of the alternative sites by sport and/or commercial fish species, and their potential to be adversely affected, should be considered. Ranking such sites for power plant use will be a controversial matter: one view holds that "islands of diversity" should be preserved, at the expense of other sites. Such a view would rank a water body with many species as less desirable for power plant siting than a river with few important commercial or sport fishes and low diversity. On the other hand, another view would maintain that degraded rivers with few indigenous sport and commercial species should not be further degraded, but rather upgraded to encourage establishment of a diverse fauna which can support sport and commercial species. During the process of ranking alternative sites, the individual biologist must consider several viewpoints, as well as the needs and desires of the specific region.

Important habitat. The potential for impacts to spawning or nursery grounds, feeding areas, rare or unusual habitat, and migration routes should be considered in ranking alternative sites. Obviously, a site where only a small percent of available habitat will be affected is more desirable than one where a major fraction of spawning habitat would be disrupted.

Transmission Facilities

Length and width of rights-of-way. In general, sites requiring shorter transmission routes are preferred, except where the routes traverse critical or unique habitats, or wetlands.

Community types to be traversed. The impact of the lines will depend upon community type. For example, forest will be cleared and maintained clear beneath a transmission line. An open scrubland, however, may be allowed to return to scrubland. Thus, rights-of-way through forest would generally be less desirable than rights-of-way through cropland or scrubland.

Number of streams and wash crossings. Construction of a power line may affect the hydrology of streams or washes that it traverses, thereby disrupting riparian habitats. Thus, the number of streams along a transmission corridor may influence the siting decision, i.e., the greater the number of stream crossings, the less desirable is the corridor (ignoring other factors).

Raptor and water bird populations. If the transmission lines from a site pass through areas where raptor densities are high, the towers may be used for perching. On one hand, this increases the chances for collision and electrocution, thereby decreasing a site's desirability. On the other hand, towers can provide valuable perching sites in areas where the terrain is flat, thus increasing a site's desirability. Wetland areas should be avoided to decrease the possibility of water birds colliding with the tower and lines.

Waste Disposal

Depth to seasonally high water table. The closer the water table is to the soil surface, the greater the likelihood that groundwater, surface waters, and soil will be contaminated with leachate from ash and sludge disposal ponds. Areas where the water table is less than 3 m from the soil surface would be poor sites for waste disposal.

Flooding hazard. A site with frequent or occasional flooding would be less suitable for waste disposal than a site with no or infrequent flooding.

Soil limitations for ponds or reservoirs. Sites with very slow soil permeabilities (< 0.1 cm/hour) would serve as better ash and sludge waste-disposal areas than those with rapid permeabilities (> 12 cm/hour); an evaluation of specific sites for ponding can be obtained from the district Soil Conservation Service.

Proximity to wetlands. The closer the ash and sludge disposal site is to wetlands, the less suitable is that site, particularly if the wetlands are down-gradient of the proposed pond area.

CONSTRUCTION CONSIDERATIONS

Construction of the power plant and associated facilities has the largest potential for acute, short-term impacts to terrestrial and aquatic ecosystems. The aspects of construction that directly affect ecosystems include removal of vegetation; excavation; earth moving; dewatering; dredging and/or impounding of streams and rivers; establishment of lay-down, borrow, and fill areas; influx of large vehicles; and increased human activity. Major adverse impacts arise from loss of habitat, soil erosion, and siltation of waterways.

Terrestrial Impacts

Construction of the power plant removes wildlife habitat permanently for at least the 40-year life of the station. Vegetation and small animals are destroyed, and food resources for birds and larger mammals are decreased, with an overall reduction of primary and secondary productivity. It is sometimes stated that the more mobile animals will move to undisturbed areas, but as suitable habitat becomes more scarce, population levels of affected species inevitably decline. In cases where cooling lakes or reservoirs are constructed, the amount of terrestrial habitat removed can encompass on the order of a thousand or more hectares.

Construction of transmission corridors does not permanently remove vegetation and wildlife habitat, but can alter the nature of the habitat with subsequent changes in the wildlife community structure. In many cases, species diversity will increase due to the establishment of "edge" habitats; habitat for forest-dependent wildlife, however, will decrease due to the necessity of permanently preventing the growth of trees.

The extent of impact to terrestrial ecosystems, and the acceptability of such impacts, will depend markedly on the nature of the particular vegetation community affected. Removal of scarce habitats from a given locality will reduce species diversity, whereas removal of relatively common habitat in the locality will affect numbers of specific wildlife but will not necessarily affect diversity.

A major impact of construction that does not usually receive much attention is the loss of the soil resource. Soil erosion is generally considered to be detrimental due to its effect on aquatic systems; sometimes ignored is the fact that the soil is a major component of the biosphere and requires hundreds to thousands of years to form from a parent material. Unlike vegetation, which can be reestablished within a short time given appropriate effort (and given the presence of soil as anchor for roots and source of nutrients and water), a soil cannot be returned to its "preconstruction" condition once it has been disrupted and its upper layers removed. Segregating and storing of "topsoil" can prevent total loss of the soil resource, but experience gained at reclamation sites on surface-mined land indicates that physical, chemical, and biological changes occur during storage that reduce the productivity of a soil. "Topsoil" storage should be encouraged (indeed, required), but this will not automatically assure that the resource will be completely preserved.

Other impacts to terrestrial systems due to construction arise from dust, noise, and increased human activity. These are temporary sources of impacts, however, and in some cases can be mitigated and controlled. A brief discussion of noise is provided in APPENDIX B.

Aquatic Impacts

The major source of impact to aquatic systems from power plant construction is increased sediment input. Construction practices expose soil to natural weathering. Wind and precipitation runoff carry sediment to aquatic resources. The effects on water quality of increasing the sediment load include increasing water temperature, suspended solids, turbidity, and nutrient loads. Effects on biota include reduced primary production, siltation of benthic habitat and spawning sites, smothering of benthic organisms, and clogging of gills.

Dredging operations that are associated with intake, discharge, and occasionally barge slip construction also impact aquatic biota. In addition to the effects related to sedimentation, dredging alters and disrupts benthic habitat and can thus impair or destroy associated benthic organisms and the organisms that feed upon them.

Removal of riparian vegetation can affect aquatic habitat through increased light and temperature, which tends to increase primary productivity. However, removal of riparian vegetation also promotes bank instability, with increased erosion potential and loss of shade and cover for fish.

Construction of a reservoir for cooling water on a river alters the nature of the aquatic habitat and may result in changes in species occurrence and diversity, both above and below the dam.

Evaluation of Construction Impacts

There is presently no satisfactory method to predict the impacts of construction on wildlife, nor to quantify specific apects of construction that can lead to such impacts. A general relationship that can be assumed is illustrated in Figure 5. The curve is not an infinite straight line because, in general, as power plant size increases, some aspects of construction do not necessarily change proportionately. For example, perhaps only one large haul road will be

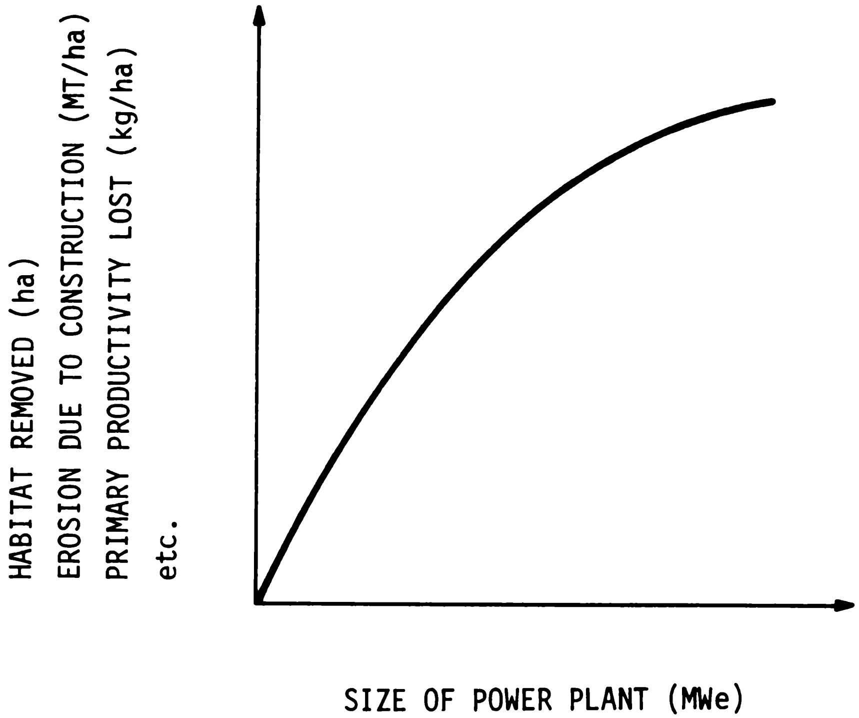

Fig. 5. Idealized Curve for Power Plant Construction Impacts

needed whether the power plant is 100 MWe or 1000 MWe in size, and perhaps only one new transmission line corridor will be needed whether the plant is 1000 MWe or 4000 MWe in size. The magnitude of construction impacts is, as with most other impacts, specific to the site, to plant design, and to practices of the particular contractors.

Items of information that can aid in evaluating construction effects are listed below.

Information Required for Evaluation of Construction Impacts	Sources
Site aerial photographs of a scale adequate to distinguish vegetation community types and clearly delineate the following: Land areas to be cleared Proposed building and parking lot areas Proposed waste-disposal sites Proposed borrow, lay-down, and fill areas Proposed and existing ponds, lakes, surface seeps, and wetlands Proposed and existing roads and railroad spurs Proposed switchyards	Power plant operator
Topographic maps (7-1/2 inches) on which are delineated the proposed site and transmission corridors (error of estimating the latter should be not more than 3.2 km)	U.S. Geol. Survey Power plant operator
Area of each habitat type or plant community to be cleared or disturbed on site and along the transmission rights-of-way	Power plant operator Site visit
Presence of critical habitat for endangered and threatened species	In-house (FWS) Site visit
Estimates of abundance of resident and migratory animals and birds within each habitat type on site and along the transmission corridors	Power plant operator Site visit
Power plant operator's plans for erosion control, herbicide and pesticide use, dewatering, clearing and disposal of clearing waste, and other construction practices	Power plant operator

Estimation of the area (ha) of specific habitat to be disturbed or removed from wildlife use is the simplest step in the evaluation process, but is only an initial step. The major question to be addressed is what direct and indirect effects such habitat disturbance or removal will have on wildlife populations in the locality and in the region. (A higher degree of assessment sophistication, which would address the question of secondary and long-term effects of such ecosystem perturbations on the national and global community of species, is beyond current capabilities).

The individual field biologist should be familiar with the respective region to the point that the data collected will allow an estimation of the effects of habitat removal on species distribution and abundance, nesting and feeding habits, patterns of migration, and other attributes of wildlife populations. The evaluation is limited by the lack of knowledge regarding wildlife population biology, regardless of the amount of site-specific data available. Given these limitations, a "best judgment" evaluation, supported by as much documentation as possible, is currently the state-of-the art.

The adequacy of the clearing, dewatering, and soil erosion control measures used by the power plant operator should also be evaluated. Unfortunately, despite the best intentions and sound proposals of a given operator, supervision of construction crews may, in many cases, be inadequate to assure consistent implementation of the proposals. The biologist has no control over this aspect, and can assume a "worst-case" approach (e.g., extreme soil erosion and heavy siltation of surface waters) as a basis of the assessment. Dewatering procedures become unusually important where there are wetlands on site or in the vicinity; the biologist should enlist the expertise of a hydrologist in evaluating the effects of the dewatering procedures on the wetlands or on wildlife watering sources. Specific measures associated with good construction practice can be found in the references on construction listed at the end of this section.

Construction of a cooling lake on site will replace terrestrial habitat with aquatic habitat; the biologist should evaluate the loss of terrestrial habitat in terms of wildlife populations as indicated previously, and describe the predicted characteristics of the new aquatic habitat.

Measures to replace portions of the natural habitat that are removed can also be suggested by the biologist. For example, clearing of natural nesting habitat for Wood Duck can be partially mitigated by placing Wood Duck nesting boxes at appropriate locations on site. Tree-planting programs can also be carried out to provide replacement habitat. In some cases, it will be simpler to suggest a different site plan (e.g., suggesting an alternative location for an ash pond), but for this to be feasible, the biologist must be familiar with the requirements of the particular power station and must have the cooperation of the power plant operator.

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COAL SLURRY PIPELINES

DESCRIPTION [23-24]

A coal slurry pipeline is a system of pipes which transport coal in the form of a slurry (pulverized coal and water in nearly equal proportions by weight) from a mine to a power plant. The pipelines are usually planned, constructed, and operated by companies independent of the power plant operator. In the United States, the single operating pipeline and four others in the planning stage are underground; all are in the West.

Major facilities associated with slurry pipelines are the slurry preparation plant; the pipeline, its associated pumping stations, and their water and slurry storage ponds; and the slurry dewatering plant. The slurry dewatering facilities make use of vacuum disc filters and/or thermal dryers to produce a filter cake of coal from the slurry. Filtrate from the disc filters goes to a clariflocculator where the clear water overflow may be used in power plant operations, such as for makeup water; the underflow is recycled to slurry storage tanks. Spent water that is not used for makeup water has to be stored in evaporation ponds or treated (e.g., if fine particles are in suspension) and discharged to receiving waters. The filter cake is sent to dryer feed bins, then to dryers, and finally to a coal storage area.

The chemical constituents of the slurry are determined by the chemical quality of the water and the chemical characteristics of the coal. Western coals are likely to cause increased hardness and alkalinity of the water; trace metals are, therefore, expected to remain as complexes with the coal particles or with suspended iron hydroxide particles, rather than as dissolved constituents in the transport water.

SUMMARY OF IMPACTS [53-54]

Terrestrial

The major impact to terrestrial biota from coal slurry handling is the removal of wildlife habitat. Land is required for rights-of-way, pumping stations, emergency storage ponds, dewatering facilities, and evaporation ponds. Evaporation ponds have the potential for adverse effects if they are used as watering sources by wildlife. Accidental spills of coal slurry may kill low-growing vegetation and small animals. Coal slurry mixed with soil can result in reduced soil porosity, water-holding capacity, and aeration. Additionally, spontaneous combustion of the coal fines can degrade air quality and initiate brush or forest fires.

Aquatic

Construction can result in erosion of soil, causing siltation of local waterways. Trenching and placing a pipe across streams will result in temporary destruction of benthic habitat and downstream turbidity and siltation.

The primary impacts that are possible from coal slurry operations are associated with consumptive use of water and accidental discharge of slurry into local waterways. Withdrawal of well water may cause groundwater aquifer drawdown (decrease in water volume) and reduced wetland habitat. If water is taken from a river or stream, drawdown may expose benthic communities in shallow reaches. Contamination of water bodies from accidental release of slurry from storage tanks and dewatering facilities can cause changes in pH (from eastern more than from western coals), introduction of toxic materials, and increases in turbidity. Runoff and wind erosion from exposed filter-cake and refuse piles can cause similar contamination.

STANDARDS AND CRITERIA

There are no standards or criteria specific to coal slurry pipelines. However, at the receiving end of the pipeline, effluent discharges to surface waters from dewatering of the slurry are subject to regulations governing power plant liquid effluents.

QUANTIFICATION [23-24]

The land required for rights-of-way for coal-slurry pipelines is about 1.5 to 3 ha/km of pipeline. Pumping stations, each with an emergency storage pond covering about 20 ha, are located every 100 to 130 km along the line. Thus, the pipeline would require approximately 170-320 ha/100 km. Evaporation ponds will vary in size with quantity of the slurry, which is a function of the coal requirements of the plant.

Water requirements for coal slurry transport can be estimated by assuming that 50% (by weight) of the slurry is water. For example, to transport 9 million metric tons of coal per year, at a 100% load factor, will require approximately 9 million m^3 of water per year (1 m^3 water weighs approximately 1 metric ton). This is equivalent to a water requirement of approximately 6.5 million gallons/day.

The concentrations of pollutants in runoff from slurry-spill areas can be estimated using mass balance calculations as outlined in the section LIQUID EFFLUENTS (subsection Quantification).

INFORMATION REQUIREMENTS AND SOURCES

Information Required	Sources
Slurry pipeline (if applicable): Rights-of-way Total length Width Habitat traversed	Pipeline operator State Geol. Survey State Conservation or Natural Resource Departments State Universities
Number and location of pumping stations	Pipeline operator
Area required for pumping stations and associated emergency holding ponds, and for habitat to be cleared	Pipeline operator
Habitat and area occupied by dewatering facility at station	Power plant operator Site visit
Method to contain surface and subsurface contamination from slurry dewatering pond	Pipeline operator
Fate of slurry water at terminal site	Power plant operator
Method to contain dust and runoff from slurry refuse and filter-cake piles	Power plant operator
Other facts related to slurry pipelines, e.g., chemical and physical characteristics of the slurry	Power plant operator Pipeline operator

IMPACT ANALYSIS

The land required for coal slurry pipelines will be disturbed, and the soil and vegetation in most cases will be removed. Land disturbance associated with the pipeline occurs for short periods while the pipe is being laid or repaired, and, in the case of pumping stations and ponds, will extend for the life of the pipeline.

In arid and semiarid regions, evaporation ponds are likely to be used to dispose of the supernatant or filtrate from slurry dewatering. These ponds will have the potential of being used as a source of water by wildlife. Because the water will contain dissolved or suspended trace elements that can be toxic, the wildlife may be adversely affected. This may be a particular problem in the case of waterfowl and other birds in arid lands where little open water is available. Knowledge of power plant location relative to watering and resting sites will aid in evaluating the potential magnitude of this problem.

Accidential spills of slurry will be localized in their initial impact. Areas of high precipitation are expected to recover sooner from accidental spills than are arid lands, due to dispersal and leaching of the contaminants by the rain and to more rapid recovery of vegetation. On the other hand, contamination of surface waters due to runoff will be greater in areas of high precipitation. The capacity for containment of slurry and dewatering ponds, as well as backup systems in case of accidental spills, should be reviewed to determine the potential for surface water and groundwater contamination.

To assess potential impacts from large-scale spills, it will be necessary to know the chemical and physical characteristics of the coal slurry, deslurried water, and receiving water. From these data, mass balance calculations can be made to estimate dissolved and suspended pollutant concentrations in the receiving stream after mixing with the slurry runoff (see LIQUID EFFLUENTS--Quantification). Results of the estimation can then be compared to toxicity data in the bioassay literature (for example, see Table F.1 of the Report), and/or to literature values for low-level, chronic effects.

Impacts from handling and storage of filter cake will be similar to those from coal storage (see the section on COAL STORAGE).

MITIGATIVE MEASURES

Safe operation of the pipeline will minimize the probability of accidental spills of coal slurry.

The attractiveness of evaporation ponds to wildlife can be avoided by using other means for disposing of the slurry water. For example, the water can be treated and discharged to local drainageways.

Pipeline route selection is the key to the prevention of severe construction impacts to terrestrial and aquatic habitat. Particularly sensitive areas such as lakes, reservoirs, streams, wetlands, and adjacent erodible areas should be avoided.

During pipeline construction, trenching activities should be confined to the narrowest possible corridor to reduce impacts of soil erosion. Construction activities near water bodies should coincide with dry periods to reduce potential siltation impacts due to erosion. Siltation barriers and rapid revegetation practices should be employed to further protect water resources.

In areas where pipelines must cross a stream, the pipe is placed in a trench and buried rather than bridged over the stream; this will minimize potential aquatic impacts if the pipe seals should leak or the pipe should break. General construction practice would be to divert half the stream flow with a cofferdam, trench and place the pipe in that half, and then repeat the process on the other half of the stream. Riprapping and revegetation will be required to prevent bank erosion.

Impacts occurring from consumptive use of water will be difficult to mitigate, especially in semiarid regions of the West, and may have to be considered as part of the total environmental cost of coal delivery. Methods to repair damage to vegetation from accidental releases of slurry will be similar to those for solid-waste and coal-cleaning disposal (see the respective sections). Excess water from the dewatering system may need to be treated before being discharged to local waterways.

ADDITIONAL DATA SOURCES

Energy Transportation Systems Inc. (ETSI)
P.O. Box 3965
San Francisco, Calif. 94119
(415) 764-7080/7081

Slurry Transport Association
490 L'Entant Plaza East, S.W., Suite 3210
Washington, D.C. 20024
(202) 554-4700

Black Mesa Pipeline
P.O. Box 1889
Flagstaff, Arizona 86001
(602) 774-5076

REFERENCES

Gray, W. S., and P. F. Mason. 1975. Slurry pipelines: what the coal man should know in the planning stages. Coal Age 80(8):58-62.

Ross, B. A., and P. D. Martinka. 1975. Western coal transportation--a challenge. Min. Congr. J. 61(4):40-45.

For a comprehensive list of articles, refer to: Slurry Transportation Bibliography (obtainable from the Slurry Transport Association--see ADDITIONAL DATA SOURCES for address).

COAL CLEANING

DESCRIPTION [24-28]

Coal cleaning (beneficiation) is a mechanical process used to reduce sulfur and unwanted noncombustible materials (ash). (See APPENDIX C for a description of the chemical constituents of coal.) Cleaning also increases uniformity of the physicochemical properties of coal and increases heating value. Cleaning is commonly practiced for deep-mined coal, especially those mined by continuous mining machines which do not discriminate between coal and roof or bottom slate. Less cleaning is done for strip- and auger-mined coal. Bituminous coal accounts for ∿ 95% of cleaned coal. Practically all anthracite is cleaned, but only small amounts of subbituminous and almost no lignite or western coals are cleaned. Coal cleaning equipment may be part of the ancillary facilities at mine-mouth power facilities. In other cases, coal is cleaned at the mine, resulting in less of a waste-disposal problem and a reduction in transportation costs.

Most conventional cleaning methods make use of the fact that slate, rock, and sulfur-containing pyrites and marcasites have higher specific gravities than coal. The methods employ centrifugal force or gravity to separate these wastes from coal.

Coal washability refers to the potential for reducing sulfur and ash components and depends upon the chemical and physical forms of impurities along with the acceptable percentage of coal loss during cleaning. Sulfur content of U.S. coals ranges from 0.2 to 7%, and averages 1 to 2%. The removable sulfur fraction is concentrated in high density pyritic materials, and thus the cleaning process for sulfur also reduces ash. Trace-element concentrations may also be reduced by conventional coal cleaning.

For cleaned coal, the average yield of raw coal averages 73%, with the remaining 27% disposed of as waste. Waste products are divided into two fractions: (1) gob, which is rock or large-sized fragments that are separated from coal by gravity, and (2) slurry, which is extremely small particles that are generally transported to a disposal site in slurry form and allowed to dewater in an impoundment. Consumptive use of water is relatively small, since the water is recycled throught the coal-cleaning "loop."

Most wastes are disposed of on or near the surface as fill in strip mine cuts, landfills, or valley fills, or are stored in surface piles. Due to economics, mine operation interferences, and health and safety reasons, cleaning wastes are disposed of in underground mines only to fill voids created by mining and to control ground subsidence. Cleaning wastes are also used in limited amounts for highway fill and for winter antiskid on highways. All waste piles must be stabilized through construction in compacted layers, including the use of noncombustible and impervious material if necessary. The waste pile must be contoured to blend with the natural surroundings and must be revegetated. [148]

SUMMARY OF IMPACTS [53-54]

The primary source of impacts from coal cleaning is coal refuse disposal. Impacts arise due to land use, seepage, and runoff. Refuse slurry ponds have poor water quality and thus have no utility for wildlife. Dust from dewatered slurry can deposit upon vegetation resulting in reduced production. Seepage or runoff from refuse ponds can carry chemical elements into surrounding soil, and the acidity of the slurry can affect the chemistry of soils with low buffering capacities.

Another source of impact from coal cleaning is noise (see APPENDIX B). Noise generated by the cleaning process may inhibit auditory communication in the mating or alarm behaviors of wildlife, and may cause the more mobile animals to move away from the site.

Oxidation of pyrite in coal-processing wastes will contribute sulfuric acid to drainage. In addition to low pH, drainage from coal-refuse piles can have high concentrations of sulfates and metals--i.e., iron, manganese, aluminum, and zinc. Sedimentation and turbidity can also result from runoff and erosion from waste storage areas. Spillage of slurry is a frequent source of coal fines and silt pollution which are common to some eastern and midwestern streams.

Ponds, marshes, and streambeds may be destroyed if coal refuse is disposed of in natural depressions or valleys. The degree of impact will depend upon quality and quantity of effluent, flow and quality of receiving stream, sensitivity of biota, and the dilution and buffering capacity of the receiving water. Impacts to groundwater will depend upon the amount of drainage infiltrating from the disposal area and the buffering capacity of groundwater and soils through which drainage water passes.

STANDARDS AND CRITERIA

Fugitive dust and runoff from coal cleaning areas are subject to the standards for air quality and liquid effluents, respectively. Disposal of coal-processing wastes is subject to the Surface Mining Control and Reclamation Act of 1977 (PL 95-87).

QUANTIFICATION [26-27]

Regional data on coal washability are summarized in the Report. The amounts of refuse from cleaning of Appalachian and Eastern Interior coals can be estimated using the data listed in Table 4. Western coals are not usually cleaned.

Table 4. Coal Refuse as Percentage of Raw Coal and Refuse/Clean Coal Ratios for Appalachian and Eastern Interior Coals[a]

	Refuse as percent of raw coal	Ratio of refuse to clean coal
Alabama	36	0.57
Illinois	23	0.30
Indiana	22	0.29
Kentucky (eastern)	27	0.36
Kentucky (western)	23	0.30
Ohio	25	0.33
Pennsylvania	27	0.38
Tennessee	27	0.38
Virginia	33	0.50
West Virginia	30	0.42
Average	27	0.38

[a]Data from: Dvorak, A. J., et al. 1977. The Environmental Effects of Using Coal for Generating Electricity. NUREG-0252. Prepared by Argonne Laboratory, Argonne, Ill., for the U.S. Nuclear Regulatory Commission.

Impacts from gob and slurry disposal will depend upon characteristics of the coal, and the size and location of the refuse piles. The size (MWe) of the plant, in addition to the type of coal and percentage yield of clean coal desired, will have a large role in determining the amount of gob and slurry produced. Finally, impacts to surface waters will depend on the amount of runoff that will actually reach the receiving water body, and the quantity and quality of receiving water available to dilute the refuse runoff. A method for estimating the resulting concentrations of contaminants in the receiving stream is described in the section LIQUID EFFLUENTS--Quantification.

Water requirements for coal cleaning vary with the geographic region, type of coal, and type of equipment. Data on the latter are listed in Table 5. As indicated previously, most of this water is recycled.

Table 5. Water Requirements for Various Coal Cleaning Methods[a]

Method	Water requirement (m^3 per metric ton raw coal)
Heavy medium washers	0.05 - 2.50
Jigs	2.3 - 5
Rheolaveurs	8 - 16

[a]Data from: Lucas, J. R., D. R. Maneval, and W. E. Foreman. 1968. Plant waste contaminants, pp. 17-1 to 17-58. In J. W. Leonard and D. R. Mitchell (eds.), Coal Preparation, 3rd ed. American Institute of Mining, Metallurgical, and Petroleum Engineers, Inc., New York.

INFORMATION REQUIREMENTS AND SOURCES

Information Required	Sources
Habitat and area for coal cleaning facilities, including description of water recycling area or "water loop"	Power plant or coal mine operator Site visit
Habitat and area for refuse disposal: Gob Slurry ponds	Power plant operator Site visit
Type of coal to be cleaned and percent yield of waste	Power plant operator
Amount and chemical characteristics of the refuse	Power plant operator
Method for containment of runoff and groundwater contamination	Power plant operator
Stabilization and reclamation and time frame for refuse disposal area	Power plant operator
Flow and quality of water in receiving stream	State Water Quality Office

IMPACT ANALYSIS

In addition to estimating loss of wildlife habitat and its effect on wildlife populations, impacts from gob and slurry disposal must be assessed, particularly with regard to effluents from those wastes. Ideally, the quality and quantity of effluent from individual gob and slurry areas should be known. However, in most cases, such data will not be available, and estimates will have to be based on general knowledge of coal wastes. Using a method similar to that outlined in the section LIQUID EFFLUENTS--Quantification, the final concentrations of dissolved and suspended solids in the receiving stream, after mixing, can be estimated. Determinations of coal cleaning impacts to aquatic systems are then based on comparison of these concentrations with known toxicity data and water quality criteria.

Refuse from coal cleaning is most often disposed of in surface-mine pits and in lowland areas for underground mines; thus, in general, little new land will be withdrawn from wildlife use. Estimation of terrestrial effects should be directed toward the effects on soils and vegetation of runoff and seepage from the refuse areas, in terms of chemical additions to the plant growth medium. The approach will be similar to that used for ash and scrubber sludge disposal (see the section SOLID WASTES).

Seepage and runoff from slurry ponds and gob disposal areas should be evaluated. If the slurry impoundment is not large enough, maximum rainfall or flood conditions could overflow the dikes. Thus, for the same amount of waste, larger impoundments are required in areas of high rainfall than in areas where such events are unlikely. Seepage from waste ponds will be a function of the permeability of the material underlying the pond (see the section SOLID WASTES). The magnitude of the impacts due to material released from waste ponds will be a function of soil properties. Because most gob effluents are acidic, soils with low buffering capacities will be most markedly affected.

Nutrient availability to plants will either increase or decrease, depending upon the element; trace-metal availability will tend to increase, with possible toxic effects on vegetation. Soils in regions where coal cleaning is practiced tend to be acidic, because these are usually regions of high precipitation, i.e., eastern regions.

MITIGATIVE MEASURES [139-152]

Proper disposal site preparation and revegetation practices seem to be the best methods to mitigate impacts from gob and slurry disposal. Site preparation includes lining the impoundment and installing drainage ditches. As the impoundment is filled, compaction of the wastes improves stability and reduces aeration, thus limiting acid production and preventing spontaneous combustion. Proper contouring of the waste-disposal site will reduce erosion. Revegetation will reduce the threat of combustion, decrease erosion and runoff, reduce acid drainage, and beautify the landscape. However, there are a number of unresolved problems in direct revegetation of gob and slurry areas due to the hostile nature of the material in terms of seed germination and plant growth. Successful vegetation of these areas will involve extensive pretreatment and amendment of the waste material unless a suitable earth cover is placed over the waste.

Measures for mitigating aquatic impacts are in large part identical with those to reduce terrestrial impacts. In addition to the procedures mentioned in the prior paragraph, impermeable liners and bases in slurry ponds and gob areas will minimize infiltration to groundwater. Mixing fly ash with gob and/or slurry (at mine-mouth facilities) prior to disposal has been reported to bring the pH of drainage to near-neutral and keep water-soluble metal concentrations at relatively low levels. Other methods in common use to mitigate the effects of acid drainage include treatment with lime, limestone, caustic soda, or soda ash.

ADDITIONAL DATA SOURCES

Land Reclamation Laboratory
Argonne National Laboratory
9700 S. Cass Avenue
Argonne, Ill. 60439

Civil Engineer
U.S. Environmental Protection Agency
National Environmental Research Center
Cincinnati, Ohio 45268

State Land Reclamation Agencies

REFERENCES

D'Appolonia Consulting Engineers, Inc. 1974. Coal Refuse Disposal Facilities; Engineering and Design Manual. Prepared for the U.S. Department of the Interior, Mining Enforcement and Safety Administration. 1 v. (various pagings).

Leonard, J. W., and D. R. Mitchell (eds.). 1968. Coal Preparation. The American Institute of Mining, Metallurgical, and Petroleum Engineers, Inc., N. Y.

National Coal Association. 1974-present. Annual Symposium on Coal Mine and Preparation Plant Refuse Disposal. Louisville, Ky.

Nunenkamp, D. C. 1976. Coal Preparation Environmental Engineering Manual. EPA-600/2-76-138; PB-262 716. J. J. Davis Associates, McLean, Va. Prepared for U.S. Environmental Protection Agency. 726 pp.

Wewerka, E. M., J. M. Williams, P. L. Wanek, and J. D. Olsen. 1976. Environmental Contamination from Trace Elements in Coal Preparation Wastes. A Literature Review and Assessment. ERDA LA-6600-MS; EPA-600/7-76-007. Los Alamos Scientific Laboratory, University of California, Los Alamos. Prepared for U.S. Environmental Protection Agency and U.S. Energy Research and Development Administration. 61 pp.

COAL STORAGE

DESCRIPTION [28]

The two types of coal storage at a power plant are live storage and reserve storage.

Live storage serves as a buffer between the continuous requirement of the furnace and the intermittent arrivals of bulk coal shipments. The coal at the surface of the pile can oxidize upon contact with air and evolve heat, which may build up and cause spontaneous combustion. To avoid this, the coal can be kept in small piles; the surface/ volume ratio of small piles will maximize heat dissipation but will also maximize exposure to air, thus reducing the Btu content of the coal.

Reserve storage serves as a buffer for periodic interruptions of shipments due to, for example, labor problems, mine disasters, derailments, and inclement weather. Reserve storage piles usually contain a 100-day supply, although mine-mouth plants may stockpile only a 30-day supply. Reserve stockpiles are checked daily for "hot spots", which are removed and sent to the boilers.

SUMMARY OF IMPACTS

Terrestrial [54-55]

The major impact of coal storage is the preemption of land from other uses. The land is cleared and covered with coal, preventing the reestablishment of suitable wildlife habitat. If a portion of the area around a power station is removed from use by wildlife, there can be an increase in competitive pressures in the habitat into which the wildlife are forced. Fugitive dust from storage piles can affect air quality and can deposit on vegetation, reducing photosynthetic activity and palatability. Other impacts can result from noise production during unloading and piling of the coal, from leaching of elements and ions such as sulfate into the soil from the storage pile, and from fire in the storage pile.

Aquatic

Impacts to aquatic systems associated with coal storage arise from runoff that may introduce coal fines, minerals, and trace elements into surface waters. High-sulfur coals can produce acid-mine-type drainage with low pH, high concentrations of metals and sulfates, and iron hydroxide precipitates. Runoff from low-sulfur coal storage areas also contains dissolved constituents.

STANDARDS AND CRITERIA

Fugitive dust and runoff from coal storage areas are subject to the standards for air quality and liquid effluents (see APPENDICES D and F).

QUANTIFICATION

The area preempted by coal storage piles is a direct function of the size and coal consumption of a power plant. Figure 6 provides the means to estimate the land area required from these two factors.

Noise generated in unloading and handling the coal will also increase as the plant size increases and coal deliveries increase; an approach to noise quantification is described in APPENDIX B. Dusting from coal piles is increased in areas of low rainfall, high evaporation potential, and frequent wind gusts. Rather than attempt to quantify dust levels from coal storage areas, it is more reasonable to recommend mitigative measures for dust control.

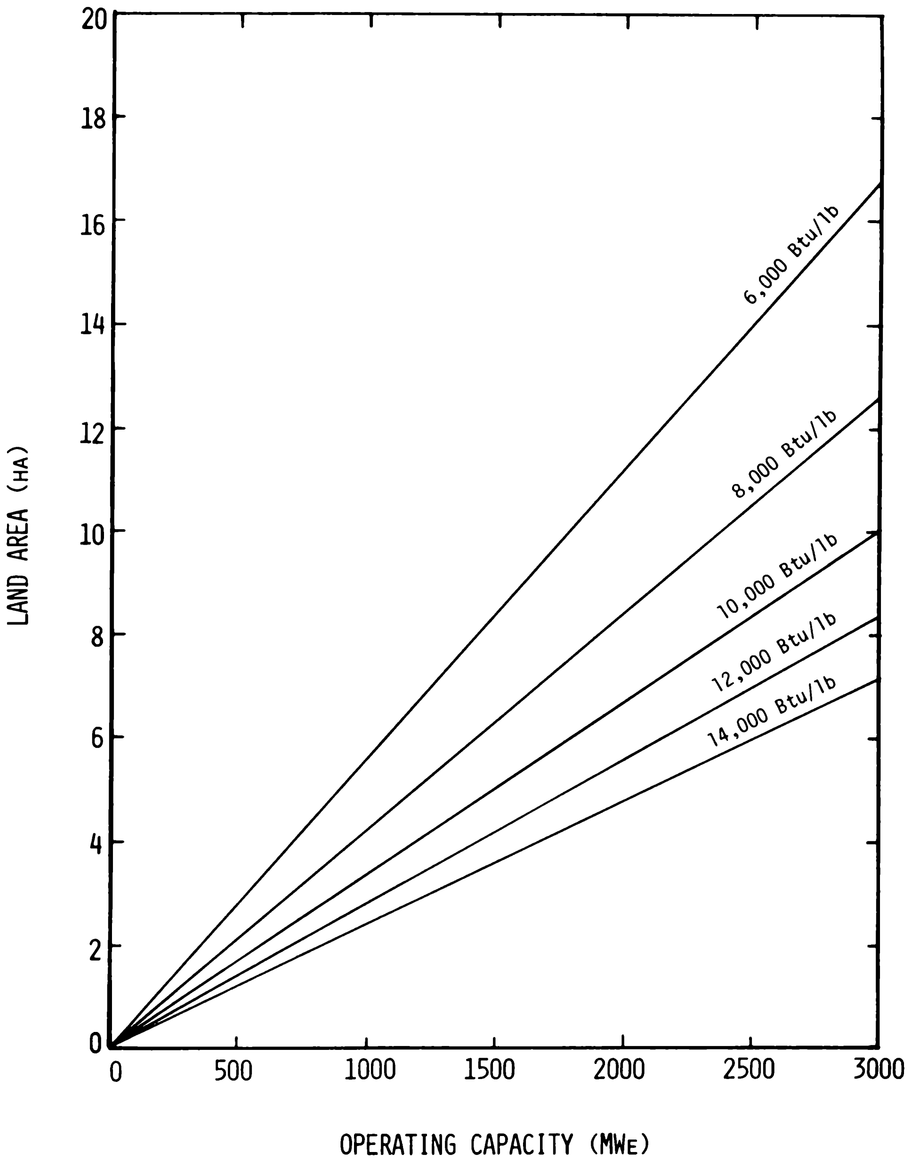

Fig. 6. Land Area Required for Coal Storage at Power Plants Using Coal of Various Heat Contents.

Estimation of chemical pollutants in runoff from coal storage areas can be calculated from mass balance equations, as outlined in the section LIQUID EFFLUENTS--Quantification.

Seepage from coal storage areas can be evaluated using an approach similar to that outlined in the section SOLID WASTES.

INFORMATION REQUIREMENTS AND SOURCES

Information Required	Sources
Location and size (ha) of storage piles: Live storage Reserve storage	Power plant operator
Habitat to be disturbed for storage piles and soil profile characteristics	Power plant operator Site visit
Proximity to surface waters	Power plant operator Site visit
Methods to contain surface runoff and seepage	Power plant operator
Other facts related to coal storage, e.g., quantity and quality of runoff during periods of precipitation	Power plant operator Literature

IMPACT ANALYSIS

The impact of runoff from coal storage piles is related to periods of precipitation, and quality and quantity of runoff. In turn, the quality of runoff is related to the size of the pile and type of coal. Impact analysis is based on the amount of runoff and its chemical constituents entering a receiving water body and the concentrations of these constituents after dilution, compared to water quality criteria and/or toxicity levels for aquatic biota (e.g., see Table F.1 of the Report). Similarly, effects on vegetation and biota of seepage or leachate from coal storage areas can be assessed, based on estimations of pollutant concentrations in the soil and vegetation.

The wildlife biologist must decide whether the land required for coal storage is important for the maintenance of the endemic wildlife. This decision must be based upon knowledge regarding the species using the site, the dependence of wildlife on the site's habitat, and the availability of alternative habitat in the vicinity of the plant.

The effects of dust, noise, and spontaneous combustion of the coal are addressed using approaches similar to those described in the sections on COAL CLEANING and on LIMESTONE STORAGE AND PREPARATION.

MITIGATIVE MEASURES

Good coal-pile management techniques will decrease contact of water with coal and reduce both leaching and the potential for spontaneous ignition. Good management techniques include laying the pile on a dry and relatively impervious foundation and sealing the pile surface by compaction or other means. The reserve stockpile should be checked daily for hot spots, and any found should be removed to the boilers.

Dikes or berms can be used to prevent surface runoff from reaching surface waters. Drainage ditches can divert runoff toward a receiving (settling) pond and away from natural water bodies.

ADDITIONAL DATA SOURCES

Civil Engineer
U.S. Environmental Protection Agency
National Environmental Research Center
Cincinnati, Ohio 45268

REFERENCES

Leonard, J. W., and D. R. Mitchell (eds.). 1968. Coal Preparation. The American Institute of Mining, Metallurgical, and Petroleum Engineers, Inc., N.Y.

Nunenkamp, D. C. 1976. Coal Preparation Environmental Engineering Manual. EPA-600/2-76-138; PB-262 716. J. J. Davis Associates, McLean, Va. Prepared for U.S. Environmental Protection Agency. 726 pp.

LIMESTONE PREPARATION AND STORAGE

DESCRIPTION [28-29]

Lime and limestone are raw materials required for the lime, limestone, and double alkali scrubbing methods of flue-gas desulfurization. (A more recently developed technique for reducing sulfur emissions--fluidized bed combustion--also requires limestone.) Lime sold for desulfurization may be either quicklime or hydrated lime. Limestone is the cheapest to purchase, but requires the largest volume and must be crushed for use in desulfurization. Quicklime costs less per metric ton than hydrated lime; when used in desulfurization, it is changed to the hydrated form by slurrying. The choice between using limestone or lime ultimately depends on the availabilty of the raw material, transportation distances, the size of available storage facilities, and whether the size of the operation warrants the expense of any crushing or slaking machinery required to use the less expensive raw materials.

Limestone Preparation

Limestone stockpiled at a power plant site has gone through a primary crushing prior to transport. When needed, it is moved by conveyor from the storage to a silo from which it feeds by gravity into a ball mill. Water is added in the ball mill and the stone is crushed to about the 320 mesh size. The slurry is then discharged to a classifer where the oversize particles are separated for recycle through the mill. The remaining slurry contains about 20% solids by weight and is injected into the scrubbing stream.

Lime Preparation

Lime is a calcined or burned form of limestone. When calcite ($CaCO_3$, the principal mineral in limestone) is heated to about 1093°C, it breaks down to quicklime (CaO) and releases carbon dioxide. Hydrated or slaked lime is quicklime to which water has been added to form $CaO \cdot H_2O$ or $Ca(OH_2)$. About 2 metric tons of limestone are needed to produce 1 metric ton of lime. Lime is usually produced in plants near the limestone quarries. Lime is made into a slurry at the power plant site.

Storage

When the limestone delivered to a power plant is coarse enough that it can withstand the weather, limestone may be stockpiled in uncovered heaps. The size of the stockpiles is commonly maintained by a conveyor or gravity feed system. Generally the areas are not lined, but could be if necessary for environmental protection. If the limestone arriving at a power plant has already passed through secondary crushers and contains too many fines that would blow if stockpiled outside, it is stored in silos. Conveyor systems bring limestone to and from silos. Hydrated lime and quicklime are also stored in silos.

A variation of the limestone (calcium carbonate) scrubbing technique employs sodium carbonate. This material, especially if obtained as a waste product of some other industry, may be stored in open ponds.

SUMMARY OF IMPACTS [55-56]

Terrestrial

Limestone storage can result in loss of primary productivity and wildlife habitat from the areas covered by limestone. Noise generated at the pile during unloading could also disturb the wildlife (see APPENDIX B). More importantly, limestone dusting has been shown to reduce the growth of trees and alter the species composition of forests near limestone processing plants. In areas of high relative humidity, limestone dust can encrust vegetation causing leaf mortality and depressed photosynthetic activity. Runoff from limestone storage piles can result in excess calcium input into the soil and in increases in soil pH, altering the availability of soil nutrients to vegetation. Increase in soil pH may also exceed the tolerance limit of the vegetation species.

Sodium carbonate storage ponds can pose hazards to water birds and other wildlife. For example, the high pH (> pH 9) of the sodium carbonate liquor appears to have a detergent-like effect on water birds, i.e., the birds' natural coating of oil is removed. Also, accumulation of carbonate salts between the birds' feathers may cause the feathers to separate, exposing their skin to the weather.

Aquatic

Major concerns associated with limestone storage are dust and runoff impacts. Impacts can be caused by increases in sedimentation, turbidity, and calcium. Calcium additions to water can raise hardness, alkalinity, and total dissolved solids (TDS). Theoretically, increased TDS may bring about ionic imbalances in organisms, but this is not expected to occur, except in very rare cases. Calcium inputs may be beneficial in that certain levels are needed for primary production and maintenance of snail populations. Increased hardness decreases solubility of heavy metals. Increased alkalinity would aid in buffering acid inputs from coal storage and stack-emission fallout, but could also increase the solubility of some potentially toxic elements, such as selenium.

STANDARDS AND CRITERIA

Each State is responsible for establishing its own allowable limits for particulate matter and fugitive dust from limestone processing plants or stockpiles. Although there are no specific Federal regulations, State limits must be approved by the USEPA and are listed in the State regulations section of the Environment Reporter (Bureau of National Affairs).

Leaching and runoff from limestone stockpiles are regulated by the Federal Water Pollution Control Act Amendments of 1972 (PL 92-500) and the Clean Water Act Amendments of 1977 (PL 95-217). Limestone stockpiles are considered point sources. (See APPENDIX F.)

QUANTIFICATION [14-15]

The daily lime or limestone requirement for lime, limestone, or double alkali scrubbers can be calculated from equations in the Report or estimated using Figure 7.

The volumes of 30-day lime or limestone stockpiles for each scrubbing system are plotted in Figure 8. The storage area requirements will vary with the degree to which the limestone or lime has been ground prior to being shipped to the plant. Finely ground limestone is stored in silos with relatively small basal areas; coarsely ground limestone is stored in outdoor stockpiles with relatively large basal areas. If it is assumed that the stockpiles fall out in approximately the shape of a cone (with an apical angle of 120°), the land area requirement for lime or limestone stockpiles with a 30-day supply may be roughly estimated from the volume of the pile as:

$$\text{Land required } (m^2) = \pi \times (1.65 \times m^3 \text{ per pile})^{2/3} \quad (1)$$

Water requirements for flue-gas desulfurization systems are dependent on the operating conditions of the power plant; in general, about 14-17% of the cooling water requirement is consumed by sulfur control processes. Losses are mainly due to evaporation and sludge disposal. If the SO_2 removal system also removes fly ash, the water requirement may be as high as 30% of the power plant's cooling water requirement.

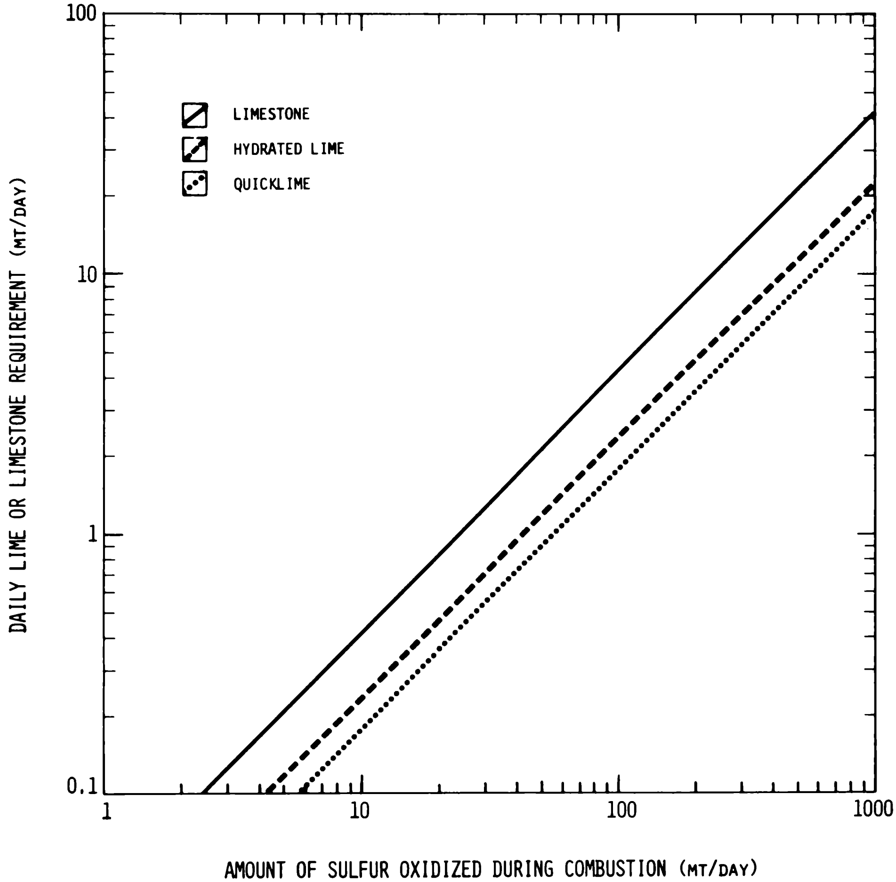

Fig. 7. Daily Lime or Limestone Requirement for Flue-Gas Desulfurization. Scrubber efficiencies are assumed to be 85% for lime or limestone scrubbing and 90% for double alkali scrubbing. The amount of sulfur oxidized was determined by multiplying the daily coal requirement (Fig. 10) by the % sulfur in the coal.

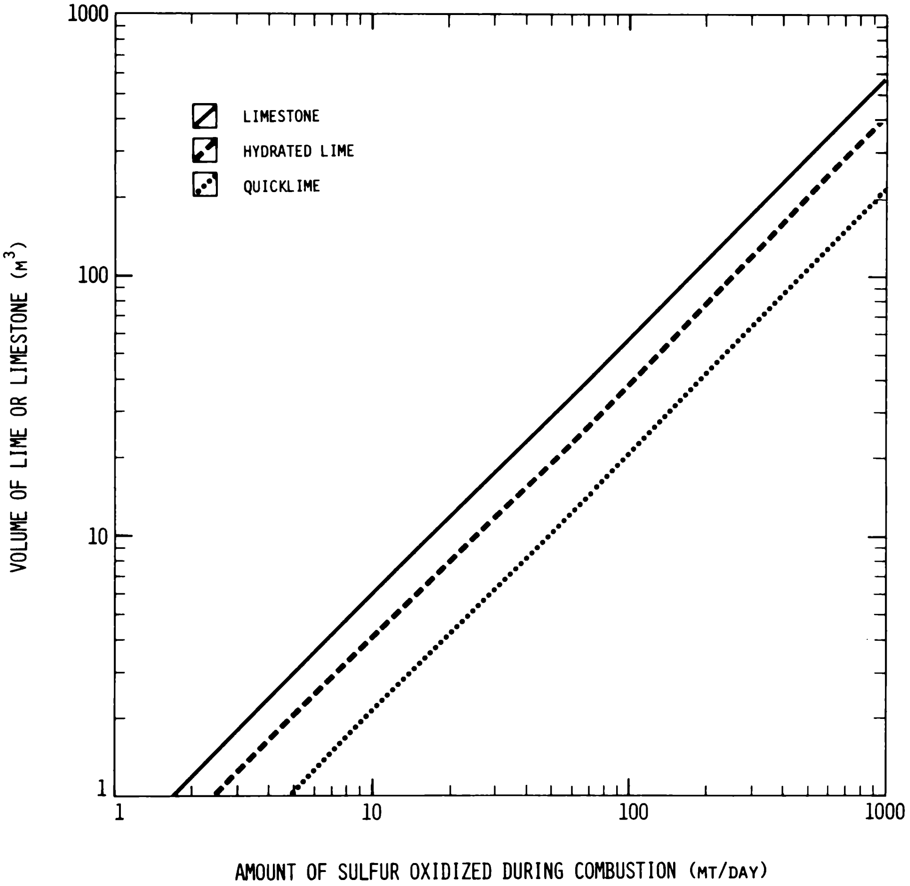

Fig. 8. Volume of a 30-Day-Supply Stockpile of Lime or Limestone Required for Flue-Gas Desulfurization. The volumes of quicklime and hydrated lime are virtually the same whether a lime or double alkali scrubbing process is used; therefore, these lines have been superimposed on the graph. The amount of sulfur oxidized was determined by multiplying the daily coal requirement (Fig. 10) by the % sulfur in the coal.

INFORMATION REQUIREMENTS AND SOURCES

Information Required	Sources
Precipitation Potential evaporation Wind velocity and direction	Natl. Weather Service Power plant operator
Soil pH and buffering capacity	District Soil Conservation Office Agricultural Extension Service
Habitat and area for: Lime or limestone storage Lime or limestone slurry preparation facilities	Power plant operator Site visit
Method to reduce dust and runoff from the storage area	Power plant operator
Receiving water use and quality	State Water Quality Agency

IMPACT ANALYSIS

Terrestrial

Limestone requirements of a power plant are a function of the amount of coal consumed and the sulfur content of the coal [Fig. 7 (see Quantification)]. Thus, plants burning low-sulfur coal from the West would require little or no land for limestone storage and processing, whereas large plants burning high-sulfur eastern coal would require a considerable area for limestone storage and processing. Estimates of land required by a given plant can be derived from Equation 1.

The impacts of lime or limestone dusting and leaching depend upon a number of site-specific variables. Limestone dusting will most likely occur under conditions of low rainfall, high evaporation, and high winds. However, in areas where dew forms and relative humidity exceeds 60%, limestone crusts can form on vegetation. Impacts on vegetation have been noted for deposition rates of about 1 g/m^2 per day. A higher risk of leaching and erosion of materials from limestone storage piles occurs in areas of high rainfall. Erosion could be a particular problem in areas where it is likely that intense rainfall events may occur. Humid areas also tend to have more acidic soils which are more sensitive to alkaline leachate due to their low buffering capacity.

Aquatic

Quantification of impacts will be site-specific depending upon (1) dilution capabilities and chemistry of receiving water, (2) organisms present, (3) size of storage and preparation facilities, (4) containment potential for runoff and dust, and (5) frequency of inputs. Impacts from limestone preparation may be masked by impacts due to, for example, coal storage and liquid waste effluents. Analysis of limestone impacts can best be derived from information on the quantity of dust and runoff material anticipated to enter a receiving water body. From the dilution capabilities of the water body (based on ambient concentrations and flow or volume), an anticipated range of concentrations for calcium and total dissolved solids (TDS) from limestone inputs can be calculated and then compared to toxicity levels for aquatic biota [e.g., see Appendix F of "Toxicity of Power Plant Chemicals to Aquatic Life" (Becker and Thatcher 1973)].

MITIGATIVE MEASURES

Mitigation of dusting problems may take two approaches: (1) preventing wind from reaching the storage pile, and (2) watering the pile so that the particles are too heavy to be picked up by the wind. Windrows or fences are used to divert wind away from the pile. Watering the piles is the most common method of dust suppression, but in arid lands this may not be practical. Compaction and surface contouring are also used to reduce the impacts of dusting. Storage in silos prevents runoff from the stored material and dust blowing.

Combining the alkaline runoff and seepage from lime or limestone storage areas with the acidic liquid effluents from coal storage areas can result in neutralized discharges that would be less harmful to land and receiving waters than the uncombined discharges. Fortuitous placement of waste basins to intercept runoff from these storage areas is recommended.

ADDITIONAL DATA SOURCES

Indiana Limestone Institute of America
Stone City Bank Bldg., Suite 400
Bedford, Indiana 47421
(812) 275-4426

National Lime Association
5010 Wisconsin Ave., N.W.
Washington, D.C. 20016
(202) 966-3418

National Limestone Institute
3251 Old Lee Highway, Suite 501
Fairfax, Virginia 22030
(703) 273-8517

Pulverized Limestone Association
Georgia Marble Co.
3460 Cumberland Pky.
Atlanta, Georgia 30339
(404) 432-0131

REFERENCES

Becker, C. D., and T. O. Thatcher. 1973. Toxicity of Power Plant Chemicals to Aquatic Life, WASH-1249. Prepared by Battelle Pacific Northwest Laboratories, Richland, Washington, for the U.S. Atomic Energy Commission. 1 v. (various pagings).

Boyton, R. S. 1968. Chemistry and Technology of Lime and Limestone. Interscience Publishers, New York. 520 pp.

National Coal Association. 1974. Coal Utilization Symposium Focus on SO_2 Emission Control. Proceedings of Coal and the Environment Technical Conference, Oct. 22-24, Louisville, Ky. Washington, D.C. 220 pp.

DESCRIPTION [33-43]

The dispersion and ground-level concentrations of SO_x, NO_x, particulates, and other emissions from a coal-fired power plant are determined by the complex interaction of the (1) physical characteristics of the plant stack, (2) physical and chemical properties of the emitted effluents, (3) meteorological conditions at and near the site during the time the effluent travels from stack to ground-level receptor, and (4) nature of the vegetation--i.e., plant heights and percent cover, and (5) topography of the power plant site and surrounding areas. By determining applicable values of each of these variables, estimates of ground-level concentrations resulting from power plant operations can be made using suitable models.

Particulates are defined as dispersed matter existing in the condensed phase (either solid or liquid) in which individual particle units range in size from 0.005 to 500 μm in diameter. The combustion of coal in conventional power plants generally produces particulates in the size range of 0.01 to 100 μm. Particulate emission control devices, particularly electrostatic precipitators (see APPENDIX A), are extremely efficient (> 99% when properly maintained) in removing particulates from the stack gases. However, the percent efficiency ratings of particulate emission-control devices are misleading because they are based on particulate mass. In reality, the larger particles are efficiently removed, whereas the finer particles and gases are much less efficiently removed. Unfortunately, it is the smaller particulates which can be transported the greatest distances in the atmosphere and which are most likely to be inhaled into the deeper regions of the animal respiratory system or to penetrate into the stomata of higher plants.

A secondary effect of gaseous emissions from coal-fired power plants is acid precipitation. Acid precipitation forms in the atmosphere from chemical conversion of sulfur and nitrogen compounds under the influence of oxygen, water, and sunlight to form sulfuric acid (for SO_x) and nitrous and nitric acids (for NO_x). Hydrochloric acid accounts for a third component of strong acids in precipitation, partly owing to combustion of coals containing chlorine. [64-70]

Acid precipitation impacts are more of a regional than local problem due to the multitude of industrial and municipal SO_x and NO_x sources, dispersal, residence time in air, etc. Most acid precipitation (pH 4-4.5) in North America is in eastern Canada and the northeastern United States--especially New England, New York, and Pennsylvania--due to SO_x and NO_x emissions within the area and to being downwind of the Chicago-Pittsburgh industrial area (see Fig. 9). The geographical range of acid precipitation is spreading west and south and intensifying at the center. Areas impacted by acid precipitation or having potential to be impacted--e.g., Washington, Oregon, and Idaho--have water characterized by low acid-neutralizing capacity and drainage systems in crystalline or metamorphic bedrock with shallow, acid soils of low buffer capacity.

In the eastern United States, increased sulfur in precipitation occurs in summer due to rain possibly being more efficient than snow in removing sulfur compounds and/or greater electrical power generation in summer. Acid precipitation can present greater impacts to aquatic and terrestrial systems when optimal growth and reproduction are occurring.

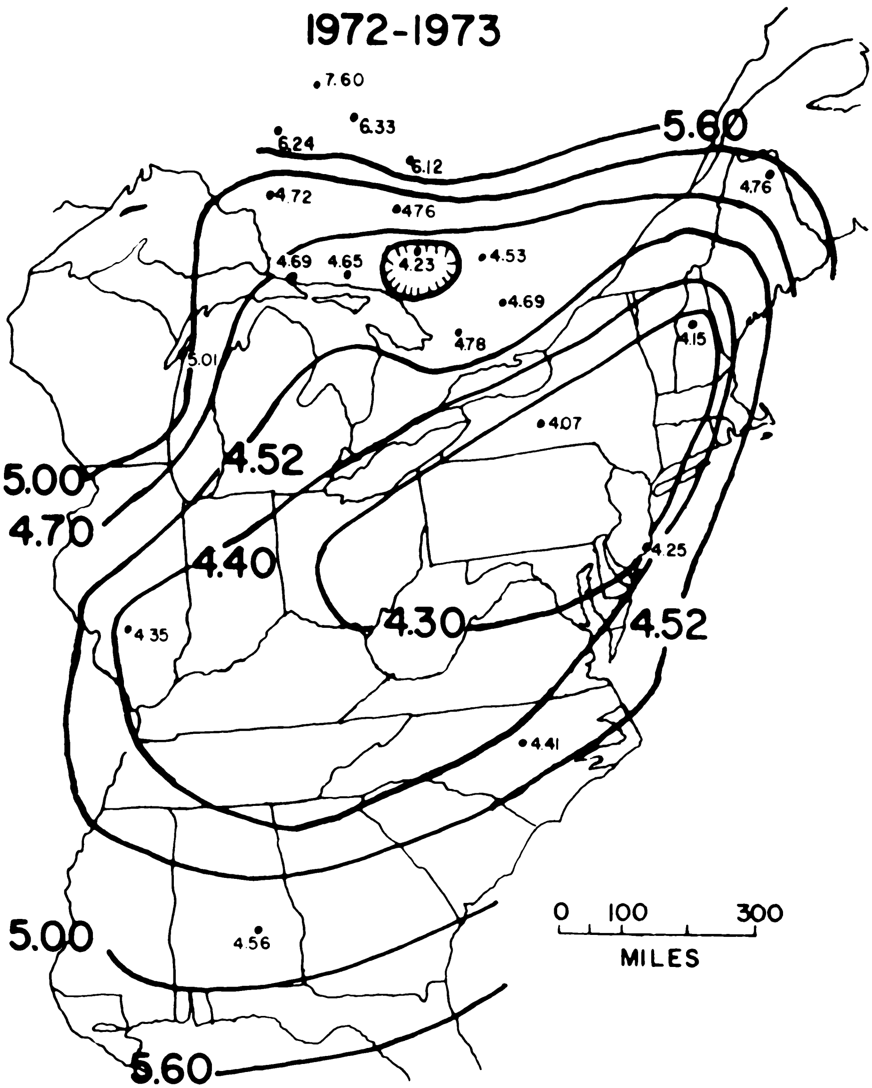

Fig. 9. Distribution Isopleths of Rainfall pH in the Eastern Half of the United States. From: Cogbill, C. V. 1976. The history and character of acid precipitation in eastern North America. Water Air Soil Pollut. 6:407-413 (reprinted with permission).

SUMMARY OF IMPACTS

Terrestrial [56-88]

Biota exhibit varied thresholds for responses to SO_2 exposure. Plants have been shown to have threshold levels for injury from chronic levels of exposure ranging down to 130 $\mu g/m^3$ annual average, whereas some mammals do not exhibit toxic reponses below about 1300 $\mu g/m^3$. The many interactions of SO_2 with other pollutants, as well as environmental and genetic factors, make it difficult to predict responses of biota in the field. Native plant species tend to be more tolerant of SO_2 than crop or ornamental species. Nonvascular plants are highly sensitive to SO_2, exhibiting injury at concentrations as low as 40 $\mu g/m^3$.

Plants and animals have been found to have injury threshold levels down to 1000 $\mu g/m^3$ for chronic exposure to NO_2. The major effects of nitrogen oxides in air pollution result from their reactions with hydrocarbons and other airborne photochemical oxidants to produce secondary pollutants. Thus, nitrogen oxides contribute primarily to regional pollution problems.

Acid precipitation is a regional problem that cannot be attributed to a single point source of pollutant emission. Areas with low soil buffering capacity and high annual rainfall are susceptible to impacts from acid precipitation.

Particulate emissions from power plants can have direct effects on vegetation by deposition. Particles can block stomata, interfere with gaseous exchange, and disrupt heat-exchange pathways. Inhalation of particulates by animals can lead to pulmonary disfunction. The chemical nature of the fly ash is varied, and includes a number of trace elements. Most of these elements are toxic to biota if they reach sufficient concentrations in the environment. The fate and potential toxicity of trace elements is affected by several factors. Availability of elements to vegetation is a function of the solubility of the elements and the cation exchange capacity of the soil. Other factors which affect the fate of trace elements in soils include precipitation by other ions, reactions with organic matter, drainage, activity of microorganisms, and effects of plant roots upon the soil. Trace-element deposition is most critical when the soils of a particular site contain concentrations of one or more elements that approach the threshold levels for toxicity.

Radioactive Emissions [107-108]

The radiation dose to animals due to emissions from a 1000-MWe coal-fired plant is expected to be much lower than the dose from natural background. This estimate is based on calculations for man and may not be accurate for fish and some species of animals, especially those higher up the trophic chain. However, considering the low doses involved, the only health effect that might be observed would be an increase in the cancer rate, and then only after a long latent period that extends into decades. Assuming that the latent period in animals is as long as in man, any carcinogenic effect of the low doses would have minimal impact because the latent periods exceed the life spans of most animals.

Aquatic [67-70, 88-107]

Both direct precipitation and watershed runoff of acidic water can affect aquatic systems. Impacts are not solely due to acid. Metal and organic toxins may accompany acidic inputs. Also, the reduced pH can mobilize trace elements from binding sites on organic and inorganic complexes. For example, aluminum leached from soil by nitric acid in rainfall has been identified as the main toxicant affecting trout species in lakes of the Adirondack Mountains.

Under certain conditions, moderate acid precipitation can supply beneficial nutrients (sulfur and nitrogen); however, toxic components are also expected to be associated with the nutrients. In most cases, detrimental impacts to aquatic ecosystems occur from acid precipitation, and organisms of all trophic levels are affected. The overall results are reduced productivity, disruption of natural cycles, and simplification of food webs. Organisms may be eliminated by toxic effects, either directly or indirectly (e.g., zooplankton may be reduced or eliminated by limited algal food). The direct effects of acid precipitation are usually first evident by reduced reproductive capabilities or efficiency (e.g., for fish) or by reduced organism development (e.g., reduced insect emergence and abnormal embryo development in amphibians). The tolerance of organisms to acid loadings will vary from species to species. For instance, the following pH ranges have adverse effects on various fish species in the lakes of the La Cloche Mountains in Canada:

pH	Species
6.0 to 5.5	Smallmouth bass, walleye, burbot
5.5 to 5.2	Lake trout, trout-perch
5.2 to 4.7	Brown bullhead, white sucker, rock bass
4.7 to 4.5	Lake herring, yellow perch, lake chub

Trace-element enrichment of surface waters due to emissions from coal-fired power plants has been estimated for several model cases. In one case, arsenic, cadmium, cobalt, copper, lead, molybdenum, nickel, and vanadium enriched background concentrations by less than 5%; barium, chromium, manganese, and zinc by 5-20%; and mercury and selenium by more than 100%. In none of the cases were water quality criteria exceeded, nor were the toxicity thresholds of most aquatic biota exceeded. The results of these and other modeling studies have yet to be verified by field sampling; they suggest, however, that additions to surface waters of trace elements due to stack releases from a single large coal-burning plant will cause no acute toxicities. Cumulative, long-term, or more subtle effects cannot presently be evaluated without appropriate experimental observations.

STANDARDS AND CRITERIA

Ambient air quality standards and New Source Performance Standards apply. The 1977 Amendments to the Clean Air Act include air quality designations for wilderness and other areas. (See APPENDIX D.)

QUANTIFICATION

Prediction of impacts to biota are partly based on the accurate estimation of the dispersion and subsequent ground-level concentrations of pollutants emitted from a facility. Requirements for this estimation include good meteorological and air quality data, applicable dispersion techniques, competent engineering design, and proper interpretation of the results. However, the high variances associated with input parameters attaches wide confidence limits to the predicted patterns of pollutant dispersal.

Gaseous Emissions

The daily coal requirement (DCR) of a power plant can be estimated from Figure 10. The DCR can be used to estimate quantities of SO_2 and fly ash emitted by the power plant. Figure 11 illustrates the relationship between the emissions of SO_2 or fly ash to the amount of sulfur dioxides or total ash produced during combustion. The values on the abscissa can be obtained by multiplying the daily coal requirement of the power plant by the percent of sulfur or ash in the coal to be used (available in the "Keystone Coal Industry Manual," or see APPENDIX C). Assuming complete oxidation to SO_2, the amount of sulfur oxidized daily must be multiplied by 2 to obtain daily SO_2 formation (the molecular weight of SO_2 is twice the atomic weight of sulfur). The curves for fly ash emissions have been calculated assuming that 0.35% of the total ash produced is released to the atmosphere (70% of total ash is fly ash; 99.5% of fly ash is captured by precipitators). Sulfur emissions are calculated assuming 85% efficiency for the flue-gas desulfurization equipment. Any decrease in the efficiency of these pollution-abatement devices will result in proportionate increases in emissions.

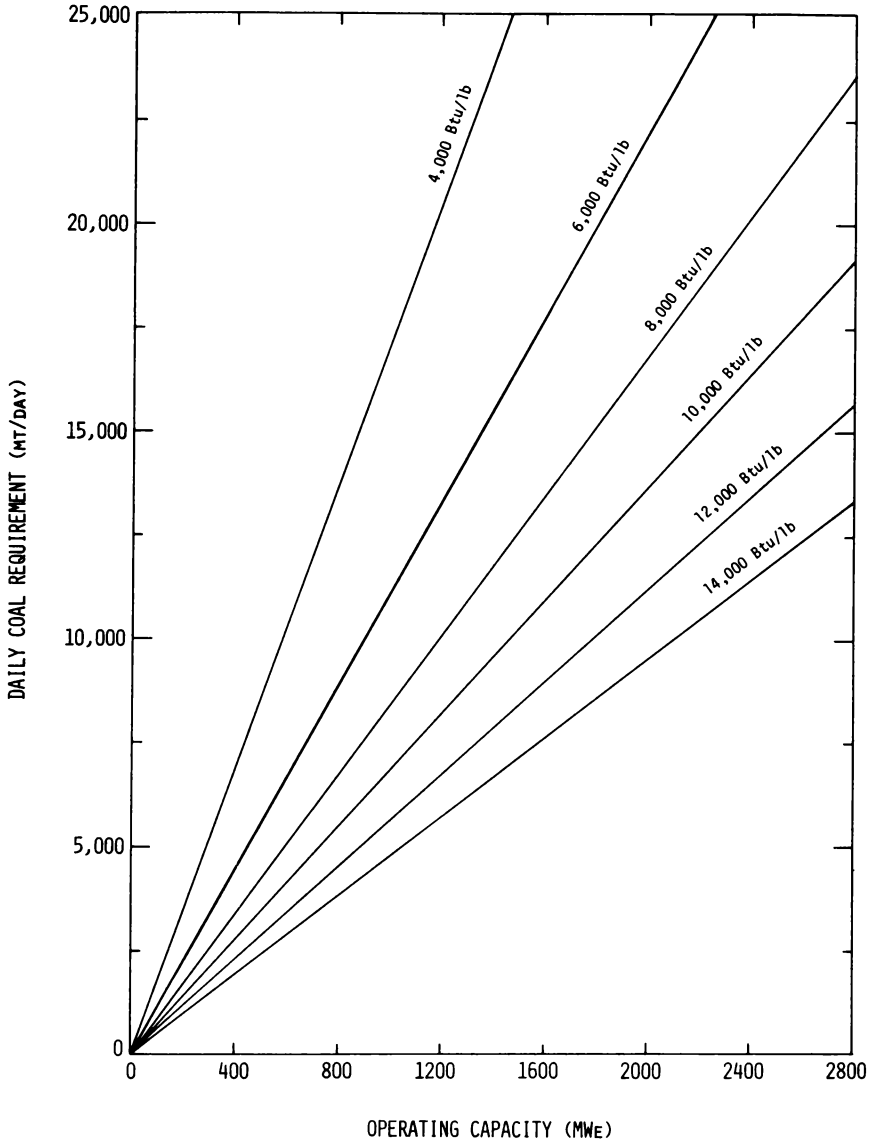

Fig. 10. Daily Coal Requirement for Power Plants of Various Capacities. The operating capacity is expressed as: plant rated capacity (MWe) × capacity factor (%).

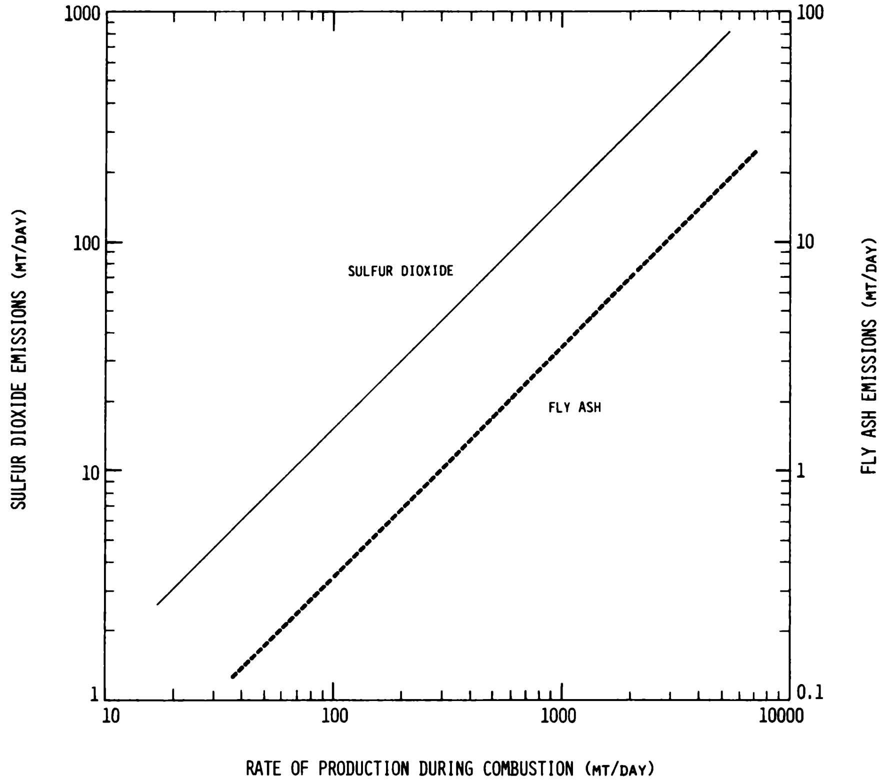

Fig. 11. Emission Rates of Sulfur Dioxide and Fly Ash as a Function of Quantities Produced during Combustion.

Since NO_X formation is due to the thermal fixation of atmospheric nitrogen and the conversion of chemically bound nitrogen in coal, there is no practical way to relate NO_X emissions to the type or chemical composition of the coal burned. For the purpose of calculating the amount of NO_X formed, an emission figure of 758 lb $NO_X/10^9$ Btu of heat input can be assumed for an average coal with a heating value of 11,867 Btu/lb. This figure does not include the effect of emission controls. Thus,

$$NO_X(\text{MT/day}) = 0.052 \times C \;, \qquad (2)$$

where C is the rated generating capacity of the power plant in MWe. If excess air is controlled or staged combustion is practiced, leading to a 50% reduction in NO_X formed, the emission rate for a 1000-MWe coal-fired unit (operating at 70% capacity with a thermal efficiency of 40%), is estimated to be 27.2 tons NO_X/day. Assuming a linear relationship between plant size and NO_X emissions, and correcting for a reduction in thermal efficiency from 40% to 38%, each 100 MWe of rated capacity would result in 2.47 MT (2.72 tons) of NO_X emitted per day. Thus, with emission controls,

$$NO_X(\text{MT/day}) = 0.025 \times C \;. \qquad (3)$$

Trace-Element Deposition

Stack height is one of the most important factors affecting the quantity of particulate deposition per unit area. Much larger quantities of particulates are deposited closer to plants with short stacks (such as those of many older oil- and gas-fired units which may be converted to coal) than plants with tall stacks. The tall stacks allow greater dispersal and dilution of particulates in the air, and thus may contribute to regional trace-element loadings. Meteorological factors and topography can also affect deposition.

If predicted trace-element emissions and deposition rates for the power plant in question are available, conservative estimates of resultant trace-element concentrations in soils and plants may be estimated.

Calculations for conservative soil concentrations are as follows:

$$\text{Deposition } (g/m^2) \times \frac{1\ m^2}{10^4\ cm^2} \times \frac{1}{d} \times \frac{10^6\ \mu g}{1\ g} \times \frac{1}{D_b}$$

$$= \text{Total added soil conc. } (\mu g/g) \text{ per unit time} \qquad (4)$$

where: deposition (g/m^2) = deposition (not aerial concentration) per unit time,

d = soil depth (cm) in which the element is assumed to be retained, and

D_b = soil bulk density (g/cm^3).

Use of this calculation without modification assumes that (1) all of the deposition in a given area is retained by an assumed surface layer of soil (of depth d), (2) none of the element is lost from this volume of soil by leaching, surface runoff, or erosion, and (3) the deposited element is distributed equally throughout the assumed soil volume.

Bulk density (D_b) of the soil can be either measured or estimated by consulting with Soil Survey Reports for the area, local Soil Conservation Service Offices, or University Agricultural Experiment Stations or Cooperative Extension Services. Bulk densities generally range from 1.0 to 2.0 g soil/cm^3. Bulk density is a weight measurement which considers the entire soil volume, both solid particles and pore spaces. Thus, bulk density is dependent upon soil texture and structure as well as the degree of soil compaction. Sandy soils generally have higher bulk densities than well-granulated, finer-textured surface soils such as silt loams, clay loams, and clays (unless the clays are compacted). Very compact subsoils may have bulk densities $\geq$ 2.0 g/cm^3 regardless of texture. If bulk density data are not available, the assumption of 1.5 g/cm^3 for a loamy soil is a reasonable estimate.

The following figures (Figs. 12-15) and tables (Tables 6-11) are to be used with the subsection Impact Analysis.

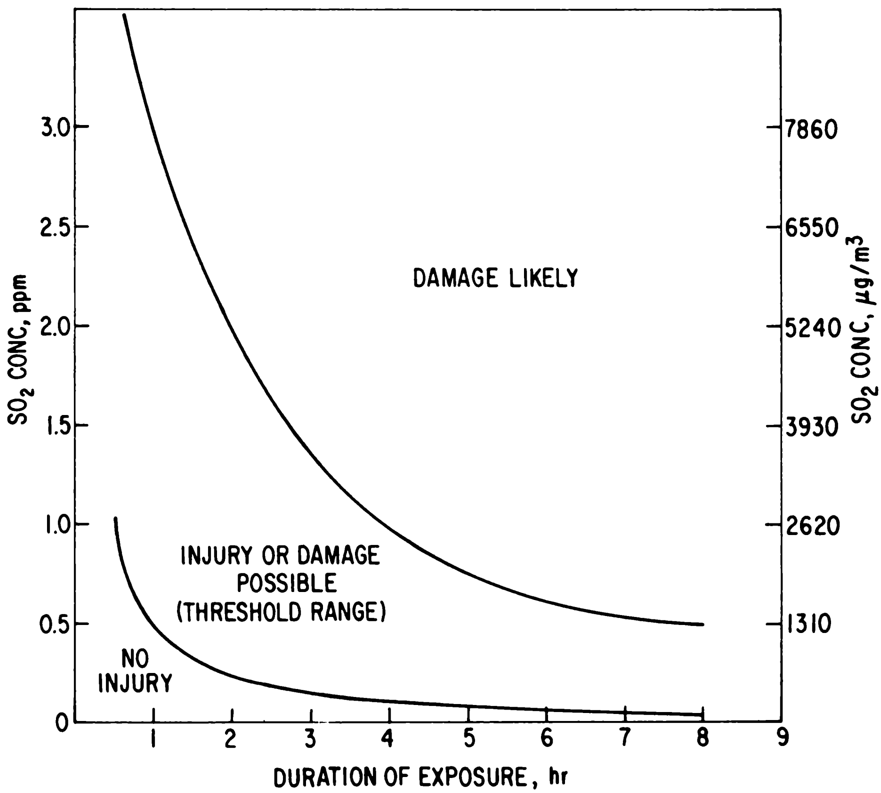

Fig. 12. Dose-Injury Curves for SO_2-Sensitive Plant Species. Adapted from: U.S. Environmental Protection Agency. 1973. Effects of Sulfur Oxides in the Atmosphere on Vegetation. Rev. Chap. 5 for Air Quality Criteria for Sulfur Oxides. EPA-R3-73-030; PB-226 314.

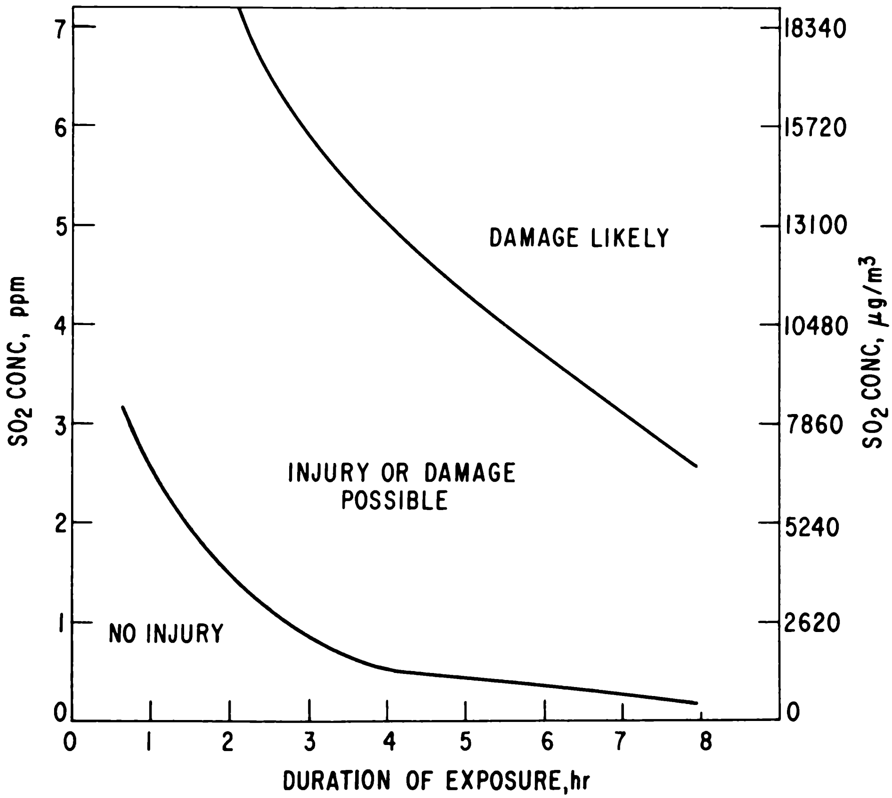

Fig. 13. Dose-Injury Curves for Plant Species of Intermediate SO_2 Sensitivity. Adapted from: USEPA 1973 (see Fig. 12 for citation).

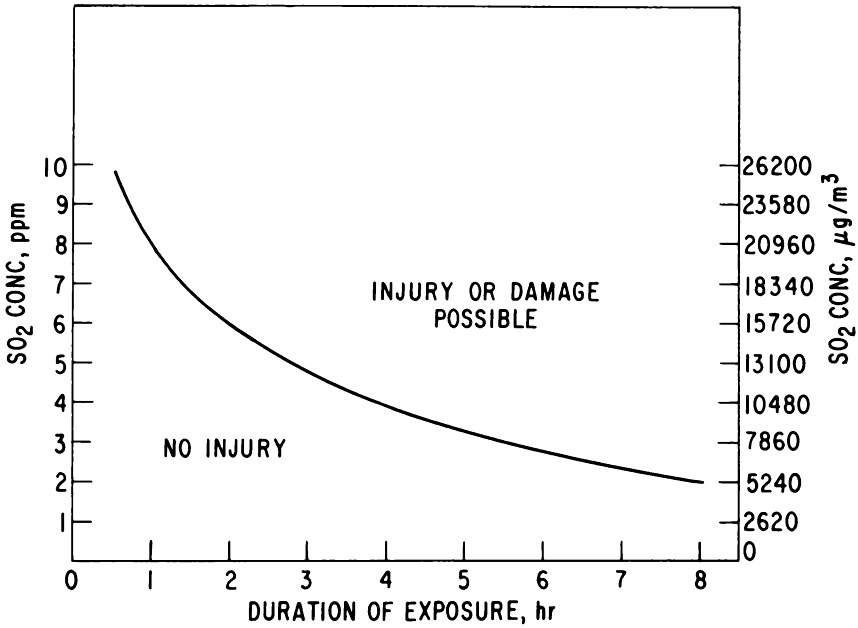

Fig. 14. Dose-Injury Curve for SO_2-Resistant Plant Species. Adapted from: USEPA 1973 (see Fig. 12 for citation).

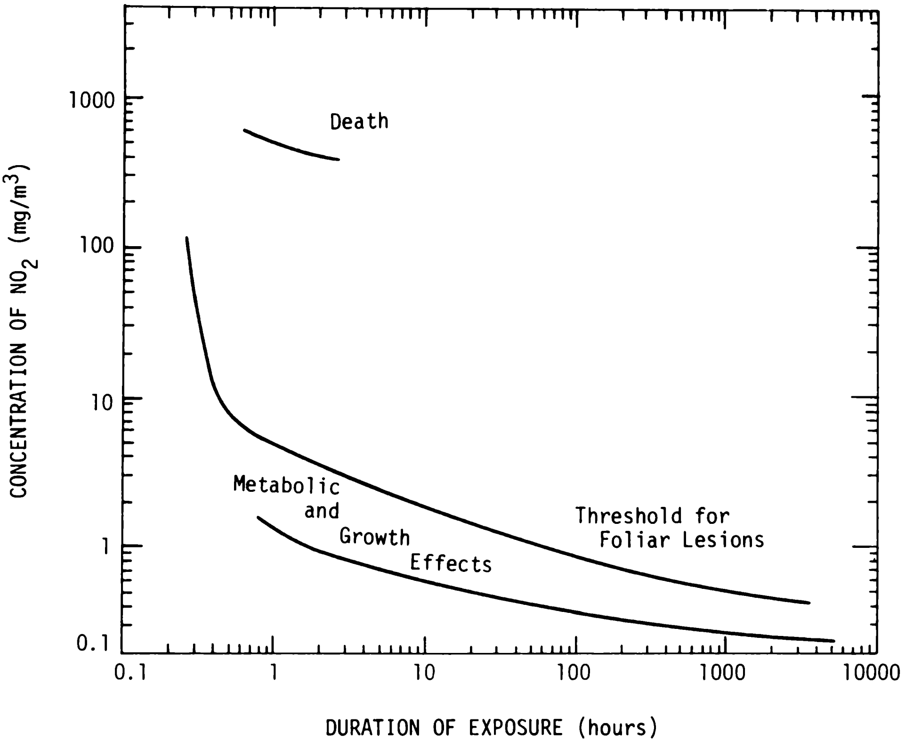

Fig. 15. Threshold Curves for the Death of Vascular Plants, Foliar Lesions, and Metabolic or Growth Effects as Related to the Nitrogen Dioxide Concentration and the Duration of Exposure. Adapted from: National Research Council, Committee on Medical and Biological Effects of Environmental Pollution. 1977. Nitrogen Oxides. National Academy of Sciences, Washington, D.C. (originally from MacLean 1975).

Table 6. Plant:Soil Concentration Ratios

Element	Concentration ratio[a]
Arsenic	0.14
Barium	0.03
Beryllium	0.02
Boron	5.3
Cadmium	10.7
Chromium	0.02
Cobalt	0.11
Copper	0.47
Fluorine	0.03
Lead	0.45
Manganese	0.066
Mercury	0.02-0.5
Molybdenum	0.57
Nickel	0.045
Selenium	1.0
Vanadium	0.01
Zinc	0.64

[a]This is a generalized approximation of the ability of plants to accumulate trace elements. The concentration ratio is the ratio of the average concentration of each trace element in plants to the average concentration of each trace element in soils. (Data compiled from references cited in the Report, Table 27.)

Table 7. General Summary of Trace-Element Concentrations Known to be Toxic to Animals[a]

Trace Element	Concentration
Fluorine	100-300 ppm in diet
Mercury	20-50 mg/kg body weight
Manganese	500-5000 ppm in diet
Selenium	5-30 ppm in diet
Arsenic	3 ppm in plants toxic to sheep
Vanadium	10-500 ppm in diet
Beryllium	Very toxic[b]
Copper	20-30 ppm in diet
Nickel	1000 ppm in diet
Zinc	500-1000 ppm in diet
Lead	80-150 ppm in diet
Chromium	500 ppm in water
Boron	1-5 g/kg body weight
Cobalt	1-3 ppm in diet
Cadmium	15 ppm in diet

[a]Information summarized from references cited in the Report, Table D.2.

[b]Major hazard to humans, and presumably to animals, is through inhalation. Average short-term (24-hour) or monthly concentrations of beryllium must not exceed 0.01 $\mu g/m^3$ in ambient air. Toxicity data on the ingestion hazard are meager.

Table 8. Total Endogenous Soil Concentrations of Selected Elements[a]

Element	Soil Range (μg/g)	Average Soil Concentration (μg/g)
Arsenic	0.1 - 40	6.0
Barium	100 - 3000	500
Beryllium	1 - 40	6.0
Boron	2 - 100	10.0
Cadmium	0.01 - 7.0	0.06
Chromium	5 - 3000	100
Cobalt	1 - 40	8
Copper	2 - 100	20
Fluorine	30 - 300	200
Lead	2 - 100	10
Manganese	100 - 4000	850
Mercury	0.01 - 4(?)	-
Molybdenum	0.2 - 5	2
Nickel	10 - 1000	40
Selenium	0.01 - 80	0.5
Vanadium	20 - 500	100
Zinc	10 - 300	50

[a]Data compiled from references cited in the Report, Table 26.

Table 9. Average Emission Rates of Uranium and Thorium Series Isotopes and Radon for Four Model Plants and Three Standard Coal Types[a]

Plant size (MWe)	Coal type	Emission rates (Ci/yr)			
		U	Rn-222	Th	Rn-220
100	Western	3.1×10^{-4}	0.08	1.9×10^{-4}	0.07
	Northern Appalachian	2.6×10^{-4}	0.1	1.8×10^{-4}	0.09
	Eastern Interior	6.4×10^{-4}	0.14	1.8×10^{-4}	0.05
350	Western	1.1×10^{-3}	0.28	6.5×10^{-4}	0.25
	Northern Appalachian	9.7×10^{-4}	0.35	6.7×10^{-4}	0.32
	Eastern Interior	2.2×10^{-3}	0.49	6.2×10^{-4}	0.18
700	Western	2.2×10^{-3}	0.56	1.3×10^{-3}	0.49
	Northern Appalachian	1.9×10^{-3}	0.7	1.3×10^{-3}	0.63
	Eastern Interior	4.6×10^{-3}	0.98	1.3×10^{-3}	0.35
2100	Western	6.6×10^{-3}	1.68	4.0×10^{-3}	1.47
	Northern Appalachian	5.6×10^{-3}	2.1	3.9×10^{-3}	1.89
	Eastern Interior	1.4×10^{-2}	2.94	3.8×10^{-3}	1.05

[a]Each model plant is assumed to be equipped with an electrostatic precipitator for fly ash removal, operating at 99.5% efficiency.

Table 10. Comparison of Dose Rate to Man Between Emissions from a 1000-MWe Coal-Fired Plant and Natural Background Radiation

	Dose rate (mrem/year)	
	Coal-fired plant[a]	Natural background[b]
Whole body	1.9	80
Lung	1.9	180
Bone	18.2	120

[a]Data from: McBride, J. P., et al. 1977. Radiological Impact of Airborne Effluents of Coal-Fired and Nuclear Power Plants. ORNL-5315. Oak Ridge National Laboratory, Oak Ridge, Tenn.

[b]The natural background dose to animals is actually 5 to 10% higher since animals live in the open without the benefit of shielding afforded by housing structures.

Table 11. Effects of pH on Selected Fish Species[a]

pH range	Comments
3.0-3.5	Toxic to most fish; some plants and invertebrates survive.
3.5-4.0	Lethal to salmonids. Roach, tench, perch, and pike survive.
4.0-4.5	Harmful to salmonids, tench, bream, roach, goldfish, and common carp; resistance increases with age. Pike can breed, but perch, bream, and roach cannot.
4.5-5.0	Harmful to salmonid eggs and fry; harmful to common carp.
5.0-6.0	Not harmful unless > 20 ppm CO_2, or high concentrations of iron hydroxides present.
6.0-6.5	Not harmful unless > 100 ppm CO_2.
6.5-9.0	Harmless to most fish.

[a]Data from: European Inland Fisheries Advisory Committee. 1969. Water quality criteria for European freshwater fish--extreme pH values and inland fisheries. Water Res. 3:593-611.

INFORMATION REQUIREMENTS AND SOURCES

Air Quality and Meteorology [33-40]

Ordinarily, the biologist is not responsible for obtaining or evaluating air quality and meteorological information. However, the biologist should be cognizant of this aspect of the assessment, and a brief description is therefore included.

The meteorological data should be collected from the site, using instruments with sufficient precision to detect the scales of motion under study. The instruments should be located so as to be free from obstacles that might disturb the flow of air. As a general rule, instruments should be sited no closer than 10 times the vertical height of an upwind obstacle. Because wind directions, wind speeds, and atmospheric stability can have great seasonal variations, at least one full year of data should be collected. If no data are available from the site, data from nearby facilities such as power plants, mining facilities, or National Weather Service (NWS) stations can be used. However, care must be used when comparing the sites, for local effects may dominate the dispersion of effluents. In particular, river valleys, hills, or ridges may dramatically modify the wind regime at even nearby sites. The NWS data are available from the National Climatic Center, Asheville, N.C., for all NWS facilities.

Air quality data should be taken at the site, using techniques approved by the USEPA. At least one year of records are necessary to make a true determination of the ambient air quality of a site. Air quality data are available from the USEPA, state air quality agencies, many universities, and other facilities. As with all non site-specific data, care must be taken to determine the applicability of results obtained at other locations. Local effluent emitters may bias data to the point of unusability.

Terrestrial

Information Required	Sources
Type of coal to be used: Btu/lb, ash, and sulfur content	Power plant operator Literature
Size of plant and stack height	Power plant operator
Trace elements: Threshold levels for toxicity Plant:soil concentrations	Literature Report, Appendix D
Deposition rates of particulates	USEPA meteorological models
Presence of SO_2-sensitive vegetation	Site visit Literature

Aquatic

Information Required	Sources
Proximity of water bodies, especially lakes, to plant relative to wind conditions	Power plant operator Class A Station of Natl. Weather Serv. Climatic atlas
Current acid precipitation and quality of surface waters in the area	Power plant operator State Geol. Survey State EPA or Dept. of Water Resources
Potential of effluents to cause or add to acid precipitation of the region	Power plant operator State Geol. Survey State EPA or Dept. of Water Resources
Buffering capacity of drainage basin (water and soil)	Power plant operator State Geol. Survey State Dept. of Water Resources

IMPACT ANALYSIS

Air Quality

[36-38, 56-58]

The meteorological data and emission inventory will be used as input for a dispersion analysis technique. Various models have been developed to predict concentrations resulting from the emission of pollutants, both on an annual basis and for short-term, worst-case situations. Models that have been tested and shown to produce reasonable results are available from the USEPA, Office of Research and Monitoring. Techniques other than those approved by the USEPA should have sufficient validation with independent data before results obtained from them enter into a decision-making process. The concentrations predicted by the models are added to the known background concentrations to determine the possible impacts to biota as well as compliance with Federal, State, and local ordinances. Models used with excellent site-specific data, known source strengths and characteristics--such as stack height and diameter, emission velocity, and effluent temperature--will give accuracy within a factor of from 4 to 10. Poor quality data, inappropriate analysis techniques, and fluctuating source strengths will introduce additional variability in the predictions.

Facilities in complex terrain--such as river valleys, lake areas, sea shores, or mountainous regions--require special attention. Proven analytical techniques are not available, because conventional models do not yield reliable results. The services of a competent meteorologist, experienced in complex dispersion analysis, may be required.

When concentrations resulting from both annual operation and short-term, worst-case episodes have been calculated and added to background concentrations, compliance with applicable standards must be determined. Present standards deal not only with control strategies, emission levels, and ambient concentrations, but also consider additions to present levels of concentrations. The emissions and resulting concentrations must be analyzed for their possible impacts to air quality, biota, and aesthetic resources.

Terrestrial [58-67]

The rate at which gases from coal combustion are emitted is a function of the size of the power plant and its fuel consumption, the sulfur content of the coal, the manner of combustion, and the efficiency of flue-gas desulfurization [Fig. 11 (see Quantification)]. Meteorological phenomena and stack height influence the ground-level patterns of distribution of the gases. Figure 11 and Equations 2 and 3 present expected rates of emissions of SO_2 and NO_X. The curves are based upon the assumption of 85% efficiency for desulfurization of the flue gases. Lower scrubber efficiency will result in emissions of SO_2 proportionately higher than estimates from the curves. Values extracted from these curves and equations can provide input to the models discussed previously. Other input into the models would include local meteorological data, topographic data, and proposed stack height. The output of these models can provide worst-case, ground-level concentrations of pollutants in the vicinity of a model generating station. When using these predictions, it must be remembered that the assumptions are conservative and the input parameters may have high variances. Therefore, they should serve as a guide, not a rule.

If it is not feasible to utilize a model to predict site-specific pollutant concentrations, then a much more qualitative approach is required. Obviously, the larger the emissions from a generating station, the greater is the potential for air quality degradation. The height of the stack will affect dispersal of the emissions--the taller the stack, the greater the likelihood of dispersal and dilution. In addition, topography influences the patterns of distribution and the concentrations of airborne emissions. Hills and mountains upwind from the plant may alter wind patterns causing downwash, whereas downwind hills and mountains may intercept a plume of concentrated pollutants decreasing dispersal. Valleys and canyons decrease air circulation, increasing pollutant concentrations within the valley or canyon. Thus, flat open sites offer a greater likelihood of dispersal and dilution of airborne emissions. Winds affect the patterns of dispersion of airborne pollutants. High and frequent winds can result in rapid dispersal and dilution of airborne emissions. By integrating the meteorological, topographic, and emission characteristics of the site and the proposed station, the wildlife biologist may be able to arrive at a qualitative judgment of the effects of the station upon wildlife and their habitat.

A generalized relationship of injury to plants and the duration of exposure to various levels of SO_2 is shown in Figures 12, 13, and 14 (see Quantification). The relationships are shown for three categories of plants: SO_2-sensitive species, species of intermediate SO_2 sensitivity, and SO_2-resistant species. These curves represent responses of the most sensitive stages of plants. Vegetation species that have been classified according to these three sensitivity categories are listed in APPENDIX E. These lists are incomplete and will undoubtedly grow in length as new research is carried out. These classes are somewhat arbitrary, and sensitivity may vary among varieties of a single species. Also, one cannot readily extrapolate from one taxon to another, for no taxonomic patterns of sensitivity are revealed in the data.

Figure 15 (see Quantification) relates injury of sensitive vascular plants to duration of exposure to various levels of NO_2. This information is presented in a manner similar to that for responses to SO_2, and the same caveats hold for both sets of information. Sufficient information on North American species is not available to formulate a species listing for sensitivity to NO_2.

Responses to SO_2 and NO_2 have been studied for several laboratory animals (see the Report, Tables 24 and 25). Threshold levels for response vary among experiments and animals. The minimum concentrations of

SO_2 and NO_2 for which deleterious responses have been found in laboratory animals are:

	SO_2	NO_2
Acute exposure	18 mg/m^3	2 mg/m^3
Chronic exposure	13 mg/m^3	1 mg/m^3

Extrapolation of this information to wildlife is questionable. However, these values can serve as a general guide.

The data on threshold or minimum levels of SO_2 and NO_2 required to elicit a deleterious response in biota can be compared to the predicted maximum ground-level concentrations due to emissions from model plants. If predicted levels approach threshold levels, a potential problem may exist.

Particulate Emissions [70-88]

Particulate emissions from power plants are a function of plant size, rate of coal consumption, type of coal burned, and the efficiency of emission control devices [see Fig. 11 (Quantification)]. The distribution of particulate fallout is dependent upon stack height; smaller stacks result in particulate deposition closer to the plant. In addition, meteorological conditions greatly affect patterns of particulate dispersion.

Fly ash deposition rates are highly site-specific. The complex of factors that influence deposition rates makes the prediction of their levels very imprecise. Indeed, measurement of fallout from coal combustion exhibits a high variance among samples at the same site. Little more than a qualitative guide can be provided to estimate the impact of particulate fallout. Deposition rates will, to some extent, be a direct function of the emission rates shown in Figure 11. If predictions of deposition rates are available, Equation 4 (Quantification) can be used to estimate rates of particulate accumulation in soil. Individual trace elements will be emitted approximately according to their concentrations in fly ash, although there will be some partitioning due to differences in volatility of the elements. Mercury, chlorine, and bromine, for example, remain almost completely in the gas phase. Generalized concentrations of trace elements in fly ash are given in APPENDIX C. It must be emphasized, however, that trace-element composition varies among coals, and precipitators do not necessarily remove these elements in proportion to their concentration in fly ash. Using Figures 11 (Quantification) and C.2 (APPENDIX C), a qualitative estimate can be developed of which elements are more likely to be accumulated in soil.

The depth to which trace elements penetrate the soil is a function of the chemical and physical properties of the soil and a direct function of the amount of leaching due to rainfall. In general, elements will penetrate further in sandy soils (low in organic material) than in clay soils (high in organic material). Because the ion exchange capacities of clay soils tend to be higher than those of sandy soils, trace elements are more likely to be retained in the former and become available for uptake by vegetation.

Trace-element uptake and accumulation by plants cannot be defined by a single index. Uptake and accumulation vary with soil properties, species and variety of plant, environmental conditions, and other variables. A general guide to plant:soil concentration ratios is given in Table 6 (see Quantification).

The potential impacts from increased soil elemental content can be evaluated to some degree using known threshold levels for toxic effects. Some of these values are given in Table 7 (see Quantification) and Table 14 (see the section SOLID WASTES). Again, the information provided here must serve only as a guide for evaluating impacts; the outcome of these evaluations is highly sensitive to the assumptions or estimates made for particulate emissions and deposition patterns, soil penetration, elemental availability, and assimilation rates of vegetation.

Endogenous concentrations of trace elements within a soil will play a major role in determining the impacts of elemental fallout from a power plant. The addition of an element to a soil in which concentrations are already high can result in exceeding the thresholds for toxicity. Small input of an element into a soil which is deficient in that element may promote increased productivity by the vegetation. Data on elements deficient or in surplus in local soils may be obtained from local Soil Survey Reports, Soil Conservation Offices, Agricultural Experimental Stations, or Cooperative Extension Services. If local data are unavailable, Table 8 (see Quantification) may be used as a guide.

Radioactive Emissions [107-108]

It is unlikely that radioactive releases pose a hazard to wildlife [see Tables 9 and 10 (Quantification), which were derived using conservative assumptions]. The regional office of the USEPA may be consulted for a site-specific evaluation.

Aquatic [67-70]

The acid precipitation impacts resulting from a single power plant are impossible to isolate due to the regional nature of acid precipitation. At best, the only analysis that can be made is whether a power plant can potentially add to the acid precipitation of the region. This will be based on past history of acid precipitation in the area, sulfur content of coal (see APPENDIX C), efficiency of SO_x removal by scrubbers, buffering capacity of water bodies, and so forth.

The maximum trace-element enrichment of local surface waters from the proposed power plant can be estimated by applying a trace-element deposition model to the site, using site parameters. The values can be compared to water quality criteria and toxicity tables to determine if any acute effects can be expected. Ordinarily, none would be expected. The biologist should attempt to extend the analysis to include chronic, long-term secondary effects, but should realize that information on these effects is almost nonexistent.

MITIGATIVE MEASURES [139]

Techniques that have been developed to meet Federal and State standards for emissions and ambient ground-level concentrations of harmful pollutants include using low-sulfur, low-ash coal; installing and operating pollution-abatement equipment; increasing stack height or plume rise, and implementing emission-limitation programs.

Pollution-abatement devices include precipitators and baghouses to control particulate emissions, and scrubbers to control sulfur oxide emissions. Nitrogen oxide emissions can be controlled by limiting excess oxygen and maintaining low temperatures during combustion.

Tall stacks will reduce the actual ground-level concentrations in the vicinity of the plant, although the areas affected by low concentrations are increased. The USEPA no longer gives credit for tall stacks in calculating concentrations resulting from plant operations. By reheating the flue gas after passage through the scrubbing system, and by incorporating a smaller diameter stack outlet, the rise of the effluent plume above the actual stack is increased, resulting in a higher effective release height. Engineering design can match the plant and stack characteristics to the specific site, resulting in fewer incidences of high ground-level concentrations.

Because biota are most affected by the short-term, high ground-level concentrations that occur during periods of unusual meteorological conditions (which occur only a small fraction of the total operating time), methods are available to reduce these high ground-level concentrations. One method is to utilize a sulfur dioxide emission-limitation program. During periods of predicted or observed adverse meteorological conditions, electrical generation is decreased, thereby lowering SO_2 emissions during a time when higher emission rates could exceed ambient SO_2 standards. Power plants in areas not affected by the adverse meteorological conditions can be operated at full capacity to meet demand.

Another method to lower emissions during periods of high pollution potential is to substitute low-sulfur coal for high-sulfur coal, thereby maintaining generating capacity but reducing SO_X emissions. At other times when the pollution potential is lower, less expensive high-sulfur coal can be burned. Any technique relying upon modification of generating capacity or fuel usage is highly site-specific and requires the services of a competent meteorologist, with strategically located pollution monitors, to determine those periods during which mitigative measures should be taken and if such measures are effective. [173]

Although any or all of these techniques may be used on occasion, it is expected that the use of flue-gas cleaning devices will be the primary method for reducing ground-level concentrations of combustion emission products. However, other steps can be suggested by wildlife biologists. In habitats where the impacts of emissions are marked, it may be possible to replace sensitive flora with resistant varieties or species. Care must be taken to ensure that the replacement flora retains the same qualities for supporting wildlife as did the original flora. Unfortunately, this option is only open to the wildlife biologist in select cases because of insufficient knowledge concerning which varieties and species are resistant to these pollutants. In addition, this option is also faced with the same difficulties found in reclamation of other disturbed lands.

ADDITIONAL DATA SOURCES

Electric Power Research Institute
4312 Hillview Ave.
Palo Alto, Calif. 94304

Governmental Air Pollution Agencies
Air Pollution Control Association
4400 Fifth Ave.
Pittsburgh, Pa. 14213

National Climatic Center
Federal Building
Asheville, N.C. 28801

U.S. Environmental Protection Agency
Office of Air and Waste Management
Office of Air Quality Planning and Standards
Research Triangle Park, N.C. 27711

Soil Conservation Service District Offices

University Agricultural Experiment Stations

University Cooperative Extension Services

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Committee on Medical and Biological Effects of Environmental Pollution. 1977. Nitrogen oxides. National Academy of Sciences, Washington, D.C. 333 pp.

Colucci, A. V. 1976. Sulfur Oxides: Current Status of Knowledge. EPRI EA-316. Prepared by Greenfield, Attaway, and Tyler, Inc., San Rafael, Calif., for the Electric Power Research Institute, Palo Alto, Calif. 1 v. (various pagings).

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Turner, D. B., and A. D. Busse. 1973. Users' Guides to the Interactive Versions of Three Point Source Dispersion Programs: PTMAX, PTDIS, and PTMTP. U.S. Environmental Protection Agency, Office of Research and Monitoring, National Environmental Research Center, Research Triangle Park, N.C. (Draft report).

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Clean Air Act, PL 90-148, as amended by PL 95-95, August 7, 1977.

Comments on the Clean Air Act Amendment of 1977, PL 95-95. The NUSLETTER, Vol. 13, No. 1, Winter, 1978.

LIQUID EFFLUENTS

DESCRIPTION [118-120]

Liquid effluents from coal-fired power plants include discharges from the cooling water system, sanitary wastes, and combustion waste transport water. Only the latter is addressed in this section. Combustion wastes (fly ash, bottom ash, and scrubber sludge) are usually discharged to onsite disposal areas, and may be combined or handled individually. The dewatering of the disposal areas creates a discharge except when wastes are dewatered by evaporation. The effluents may contain significant amounts of trace elements and particulates, or have extreme pH, and may cause impacts to aquatic biota and their habitat.

During heavy storms, it may be possible for the waste-disposal basins to overflow (most basins are designed to contain a 10-year storm runoff), with subsequent discharge to the surface waters. The composition of this overflow would be similar to the normal dissolved and suspended contents of the disposal basin but would be more dilute due to the increased volume of water. Overflow is rare, and proper construction practices--which include a retaining berm, dike, or dam around the basin--would probably preclude the possibility of severe surface-water contamination by basin overflow.

Solid waste-disposal areas may also be sources of seepage. Water infiltration of the disposal area may leach trace elements and carry them to surface waters. In most cases the volume of seepage is small, although the concentrations of materials may be high.

SUMMARY OF IMPACTS [88-107]

The constituents of waste-disposal basin discharges that have the potential for adverse impacts are trace elements. Although trace elements occur naturally in water, the amounts are very small. In high concentrations, trace elements can adversely affect aquatic biota.

Trace elements can have direct lethal (acute) effects when concentrations are high, and indirect sublethal effects when concentrations or exposures are low or chronic. Direct lethal effects of certain trace elements can be caused by physiological actions of trace elements in different organs or tissues. In many cases, death is caused by interference of the trace element with enzyme systems. Death can also be caused by anoxia, especially if the trace elements disrupt gill function.

Only rarely will a single potential toxicant be present; discharges and most surface waters can be expected to contain a number of potential toxicants. The combined effects--whether additive, synergistic or antagonistic--of the constituents in the water will be of concern.

Sublethal or chronic effects include inhibition or interference with neurophysiological activity and/or enzyme activity; hormonal imbalance; increased susceptibility to disease and parasitism; and teratogenic, carcinogenic, and mutagenic effects. Additional effects can include reduced growth, behavioral modification, reduced survival, reduced reproductive capability, reduced fitness, and reduced feeding.

STANDARDS AND CRITERIA [173-174]

Effluent guidelines established by the USEPA regulate the amount of total suspended solids and oil and grease contained in bottom ash or fly ash transport water discharges and restrict pH to an acceptable range (see APPENDIX F). The composition of such effluents, including trace elements and PCB's, is usually controlled by individual State requirements such as National Pollution Discharge Elimination System (NPDES) permits. State water quality regulations must be consulted. If the receiving water body has other uses--e.g., drinking water, stock watering, irrigation, or industrial--the State health department may have additional water quality standards which must be met. Usually the most stringent regulations, either Federal or State, take precedent.

QUANTIFICATION

A simple analysis can be used to quantify final concentrations of given pollutants in receiving waters from any discharge. The model described here uses a few assumptions to simplify calculations of values which can then be compared with bioassay literature on concentrations toxic to aquatic organisms, and literature on sublethal effects due to chronic, low-level exposures. The approach is applicable to effluents from waste-disposal areas, coal storage areas, limestone storage areas, and runoff from coal slurry spills. In each case, the volume of rainfall expected, the area of land occupied by the storage material, the chemical composition of the material (particularly potentially toxic elements), and the volume or flow of the receiving waters must be known or estimated. The model assumes the following:

1. Composition of the runoff from the subject land area is the same as the material wetted; e.g., if the material contains 1 ppm copper and 2 ppm zinc, the runoff will contain 1 ppm copper and 2 ppm zinc.

2. All runoff reaches the aquatic resource, with no losses or gains in either water or dissolved and suspended materials.

The final concentrations of a given pollutant or pollutants in the receiving stream, after mixing, are then calculated according to the equations given below.

Rivers

Assumptions:

1. A constant flow which is equal to the 7-day/10-year low flow.

2. Complete mixing of the discharge or runoff with river flow.

3. No losses of materials to sedimentation, precipitation, or other similar processes.

The calculation determines the final concentration of the material in the river as a function of flow rate.

$$\frac{\left(\frac{V_r}{t} \times C_r\right) + \left(\frac{V_d}{t} \times C_d\right)}{\frac{V_r}{t} + \frac{V_d}{t}} = \text{Final Concentration} \qquad (5)$$

where:

$\frac{V_r}{t}$ = River flow rate, liters/second (L/s)

C_r = Background concentration of the pollutant in the river, mg/liter (mg/L)

$\frac{V_d}{t}$ = Discharge flow rate, liters/second (L/s)

C_d = Concentration of the pollutant in the discharge, mg/liter (mg/L)

Example:

The 7-day/10-year low flow of the receiving river is 10,000 L/s and the background concentration of iron is 0.5 mg/L. The discharge rate is 10 L/s and its iron concentration is 1.0 mg/L.

$$\frac{(10{,}000\ \text{L/s} \times 0.5\ \text{mg/L}) + (10\ \text{L/s} \times 1.0\ \text{mg/L})}{10{,}000\ \text{L/s} + 10\ \text{L/s}} = 0.5005\ \text{mg/L}$$

Impoundments and Lakes

Usually the volume of water available in large lakes and impoundments is sufficient for dilution of discharges. The calculations of final concentrations are only generally approximate because of the behavior of trace elements in water.

The approach used is to determine the total amount of material entering during a period of time--i.e., for a lake, the time period is the life of the plant; for an impoundment, the time period is the flushing time.

Assumptions:

1. A constant lake volume.
2. Complete mixing of discharged materials within the lake.
3. No losses of materials to sedimentation or precipitation.

The calculation determines the final concentration of a pollutant at the end of the time period.

$$\frac{\left(\frac{V_d}{t} \times C_d \times T\right) + \left(V_l \times C_l\right)}{V_l} = \text{Final Conc.} \qquad (6)$$

where:

$\frac{V_d}{t}$ = Discharge flow rate, liters/second (L/s)

C_d = Concentration of the pollutant in the discharge, mg/liter (mg/L)

T = Life of power plant, years; conversion factor: 1 year = 3.15×10^7 seconds.

V_l = Volume of the lake, liters (L)

C_l = Background concentration of the pollutant in the lake, mg/liter (mg/L)

Example:

The effluent is discharged to a lake with 10^{10} L of water and background iron at 0.01 mg/L. Iron will be discharged at 10 L/s and 0.1 mg/L for the life of the plant (typically 40 years).

$$\frac{(10\ \text{L/s} \times 0.1\ \text{mg/L} \times 40\ \text{years}) + (10^{10}\ \text{L} \times 0.01\ \text{mg/L})}{10^{10}\ \text{L}} = 0.136\ \text{mg/L}$$

The quantifications are only approximate and should be viewed as relative indices, not absolutes.

Given the concentrations of specific elements in waters receiving, for example, ash basin effluent, the resulting concentrations in fish and other aquatic biota can presently only be surmised, unless actual analyses are carried out. The data from a field study are presented in Table 12 and provide some order-of-magnitude estimates. The values in the table provide some estimate of the relative concentrations of specific trace elements that could accumulate in various trophic levels. If the concentrations of elements in a given discharge are known, concentrations in the receiving stream, after mixing, can be calculated from Equations 5 or 6. Using the relative ratios calculated from Table 12, some estimate of the metal concentrations in various biotic components of the particular surface water can be obtained and compared to toxicity tables. Obviously, this method cannot replace actual field sampling and analysis of the particular aquatic ecosystem; however, in the absence of such site-specific data, order-of-magnitude estimates may suffice.

Table 12. Concentrations of Trace Elements in Abiotic and Biotic Components of a Stream Receiving Ash Basin Effluent[a]

Trace element	Concentration (ppm)				
	Abiotic	Biotic			
	Water	Benthos	Plants	Invertebrates	Fish
Aluminum	13.0	40,657.0	3,985.1	1,199.3	215.5
Iron	16.9	20,912.4	1,113.2	1,202.6	154.7
Potassium	6.1	8,149.2	1,803.6	2,666.2	1,946.2
Calcium	9.2	1,844.8	850.1	2,656.4	5,752.9
Magnesium	4.1	5,460.8	656.2	369.4	307.2
Titanium	0.9	2,388.5	109.4	71.5	15.1
Sodium	7.7	688.0	267.9	703.8	309.8
Chlorine	3.8	84.1	198.2	364.9	131.4
Barium	0.7	294.2	36.3	50.2	20.0
Strontium	0.3	236.0	60.3	48.4	36.3
Manganese	0.07	46.2	70.2	21.5	10.0
Cerium	0.2	129.7	9.7	4.3	1.6
Tin	0.1	85.0	18.0	20.7	3.4
Rubidium	0.4	51.6	8.2	29.0	8.5
Vanadium	0.04	63.9	4.7	4.4	0.6
Chromium	0.2	38.4	5.7	9.7	2.8
Zinc	0.4	6.4	5.0	14.9	11.8
Arsenic	0.06	19.7	4.2	2.1	0.5
Lanthanum	< 0.01	20.3	1.4	1.4	0.1
Thorium	0.03	15.3	1.3	1.7	0.3
Bromine	0.1	1.2	3.0	10.1	2.9
Selenium	0.1	6.1	1.8	2.6	9.4
Cobalt	0.1	10.6	1.7	1.7	0.5
Iodine	0.1	4.6	1.3	3.4	0.4
Uranium	0.01	8.0	0.7	0.3	0.1
Cadmium	0.1	1.7	1.5	4.0	1.3
Cesium	< 0.01	3.9	0.6	0.7	0.5
Antimony	0.07	1.0	0.8	2.1	0.7
Mercury	0.03	0.8	0.5	0.5	0.2

[a]Adapted from: Guthrie, R. K., and D. S. Cherry. 1976. Pollutant removal from coal-ash basin effluent. Water Res. Bull. 12:889-902.

INFORMATION REQUIREMENTS AND SOURCES

Information Required	Sources
River (discharge data): 7-day/10-year low flow Average annual flow	U.S. Geol. Survey State hydrologist District Corps of Engineers
Lake or impoundment: Area Volume Flushing time for impoundment	State hydrologist District Corps of Engineers
Water quality (background) of the receiving water body: Trace-element concentrations pH Hardness	U.S. Geol. Survey U.S. Environmental Protection Agency
Discharge: Rate Water quality data including pH, temperature, and trace-element concentrations	Power plant operator

IMPACT ANALYSIS [91-107]

Impact analysis is only partially based on projections of water quality. The calculated values (from Equations 5 and 6), which can be used as indicators of potential problems, will usually overestimate the concentrations that will occur due to the assumptions made to simplify the calculations. The calculated final concentrations of contaminants in the receiving water should be compared to USEPA water quality criteria for various uses--e.g., drinking water, livestock watering, aquatic biota--and any values which exceed such criteria should be reported as potential problems.

The discharge will form a plume which consists almost entirely of discharge effluent. The discharge plume will expose a relatively small area to the maximum concentration of given contaminant in the discharge. Concentrations of potentially toxic materials in the discharge should be compared with bioassay data (e.g., see Report, Appendix F) to determine if levels toxic to aquatic biota are exceeded. The effluent plume will usually be rapidly diluted as distance from the discharge source increases. Discharge plume models are available for use in determining the rate of dilution and the area of the plume. However, the use of any model is restricted by the assumptions involved, and results from plume dispersion models should be interpreted as indications of what may occur, not as absolute descriptions.

MITIGATIVE MEASURES

Mitigation of impacts from liquid effluents can be accomplished by either physical or chemical means. Physical methods to increase the dilution or mixing rate of the effluent with the receiving waters include the use of various types of discharge structures. Chemical treatment of an effluent can be used to reduce the concentrations of potentially toxic materials. In most cases, compliance with discharge effluent standards will ensure that acutely toxic conditions from effluents will not occur.

The use of pond liners, either clay or synthetic, can reduce the rate of seepage from combustion waste-disposal ponds (see section on SOLID WASTES).

ADDITIONAL DATA SOURCES

Cooperative Instream Flow Service Group
Biological Services Program
U.S. Fish and Wildlife Service
Ft. Collins, Colorado 80521

State Water Quality Agencies

U.S. Environmental Protection Agency Regional Offices

U.S. Geological Survey:

Regional Offices

Water Data Reports [Water Resources Data for (state)____, Water Year (19XX)]

STORET - Water Quality Data

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Kopp, J. F., and R. C. Kroner. 1970. Trace Metals in the Waters of the United States. Federal Water Quality Administration, Cincinnati, Ohio.

U.S. Environmental Protection Agency. 1976. Quality Criteria for Water. Office of Water and Hazardous Materials, Washington, D.C. 256 pp.

SOLID WASTES (ASH AND FGD SLUDGE)

DESCRIPTION [40-48]

Solid wastes generated by burning coal in power plants and by pollution-abatement processes include slag, bottom ash, fly ash, and flue-gas desulfurization (FGD) sludge (if a "throw-away" system is used).

Slag

Slag ("boiler slag," "Black Beauty") is that portion of the coal ash that melts to a viscous fluid at burner operating temperatures. It is usually recovered from the bottom of the boiler by tapping the slag from the furnace in a molten state into a tank of water. Slag is a glassy, angular material that is predominantly one-sized, usually ranging from #30 to #4 mesh.

Bottom Ash

Bottom ash ("cinders") is dry ash that does not melt but is too heavy to be entrained in the flue gas. It is recovered from the bottom of the boiler through a grate into an ash hopper filled with water. Slag and bottom ash are usually combined, and together are called "power plant aggregate."

Fly Ash

Fly ash is the portion of the coal ash carried up the flue; it is assumed here that 99.5% of the ash is retained by pollution-abatement equipment.

Flue-Gas Desulfurization Sludge

Flue-gas desulfurization (or scrubber) sludge is material generated by "throw away" flue-gas desulfurization methods (lime or limestone scrubbing). These sludges consist mainly of calcium sulfite, calcium sulfate, and calcium carbonate. The proportion of solids and water in these sludges can vary from 30% to 70% water by weight, depending on the process used for dewatering.

The major impacts of ash and scrubber sludge disposal arise in part from the physical and chemical nature of the materials, which contain several dozen elements and compounds including potentially toxic elements and radioactivity. The severity of impact is influenced by the method of disposal and the characteristics of the disposal site. Current practice includes wet-sluicing of fly ash and bottom ash to temporary onsite impoundments, separate disposal of fly ash and bottom ash, ash disposal in mined-out pits, combined FGD sludge and ash disposal, and ash and sludge utilization. Often, fly ash and scrubber sludge are hauled or sluiced to offsite permanent disposal sites. Ponds are usually about 3 m deep, and may be lined with clay or a synthetic liner. At the end of the useful life of the pond, it can be covered with a layer of earth and seeded or allowed to revegetate naturally. Lime and limestone scrubber sludge is usually unsuitable for deposit in landfills; due to the thixotropic nature of the material, it furnishes poor support for buildings or roads. Addition of chemical fixatives can reduce some of the undesirable properties, but does not eliminate them completely. Examples of such chemical treatment are processes developed by I.U. Conversion Systems, Inc. (IUCS); Dravo, Inc.; and Chemfix.

SUMMARY OF IMPACTS

Terrestrial [109-118]

Impacts to soils, vegetation, and animal life arise from preemption of land, use of active disposal ponds by water birds, and runoff and seepage from disposal sites.

Preemption of land. Onsite disposal of waste removes that area from further use for the lifetime of the plant. Disposal in mined-out pits or natural ravines, which frequently serve as catch basins for precipitation and runoff, eliminates use of such areas for aquatic habitat or for human recreation. Use of wetlands or swampy areas for disposal sites will remove those sites from use for nesting and feeding habitat by water birds, and may be critical to migrating or resident endangered species.

Use of active disposal ponds by water birds. The presence of a large body of standing water can sometimes be attractive to water birds, particularly if there are sources of food (e.g., farmland) nearby. Use of these ponds for resting and feeding can expose the birds to ingestion of particulate matter (slag) and potentially toxic chemical elements and ions. Attraction of birds to the ponds may also expose them to the hazard of collision with transmission towers and lines, if any are situated across or close to the ponds.

Runoff and seepage. Runoff from the onsite waste impoundments is unlikely if dikes are properly constructed, with sufficient freeboard (the height of the embankment above the water surface). Accidental releases due to excessive rains and/or poor dike construction can occur, which will add waste constituents to the soils immediately adjacent to the break, but are unlikely to affect offsite areas. Vertical and lateral seepage from the disposal sites can occur, particularly if the waste is deposited as a slurry. The major impact of seepage is the addition of potentially toxic chemical elements and ions to groundwater and soil. Contamination of groundwater results in eventual contamination of animal and human drinking water sources. Contamination of soil can result in uptake and accumulation of potentially toxic elements in vegetation, with subsequent ingestion by herbivores.

Groundwater

Sites which may need to be protected from seepage are those located in or near wetlands, on floodplains, on karst topography (irregular topography developed by solution of limestone in surface water and groundwater), or on any other permeable or fractured strata, or where the water table is near the surface. Wastewater impounded in an ash or sludge pond, and leachate from either, may contain high concentrations of potentially toxic elements. If the waste storage facility is not adequately lined by an impermeable material, effluent seepage may contaminate the subsoil and the groundwater. The extent of potential contamination is strongly influenced by the underlying soil and rock stratigraphies and by the local geohydrology. Unless deflected, flow through unsaturated strata is predominantly vertical with a minimum of lateral dispersion. Unsaturated flow rates may be relatively slow, which facilitates the sorption of cations onto the soil. As a result, the front of contamination may lag behind the seepage front. Depending upon the capacity of the soil to sorb ions, the depth of the aquifer, the duration of seepage, and the dilution potential in the aquifer, the groundwater may or may not be significantly contaminated. If trace elements from seepage do pollute the groundwater, their principal direction of movement will be lateral with the gradient of the water table. Lesser concentrations will disperse in all other directions.

Aquatic [118-120]

Procedures for disposal of fly ash and scrubber sludge can cause impacts to aquatic systems from consumptive water use, direct discharge, and seepage overflow from waste disposal basins.

Consumptive water use. The amount of water used will depend on the waste-disposal method. Large volumes of water will be used if each product is handled separately and slurried or sluiced to a settling basin or disposal pond and no water is recycled. Large quantities are also used if wastes are combined and transported to the basin.

Impacts from consumptive water use are due to water loss. This can be important on a site-specific basis, and, particularly in smaller watersheds, will result in reduction in the size of that system. Draw-down results in reduction of available habitat, change in size and/or location of productive littoral zone (in lakes and ponds), and increase in density of organisms present. In many cases, no readily obvious effect of consumptive water use will occur; the present state of knowledge on instream-flow needs is not sufficient to evaluate effects of minor reduction in water volume on the physical, chemical, and biological complex in aquatic ecosystems.

Direct discharges. The composition of untreated waters which have been used for solid waste disposal can contain significant amounts of potentially toxic elements in solution. During extreme storm precipitation events, it may be possible for the waste-disposal basins to overflow (most basins are designed to contain runoff from a once-in-ten-year precipitation event), with subsequent discharge to the surface waters. The composition of this overflow would be similar to the normal dissolved and suspended contents of the disposal basin but would be more dilute due to the increased volume of water.

Radioactivity [42-43]

Most of the natural radioactivity in coal (see APPENDIX C) will remain in fly ash, most of which is collected and stored in surface impoundments. Fly ash contains 2 to 7 times as much radioactivity as rocks and soils. Although the radioactivity concentrations in coal ash can be several times higher than concentrations in the original coal, fly ash is not considered to be a significant radiological health hazard. The gamma radiation from fly ash has been computed to be a negligible source of radiation to the general population, and would presumably be the same to wildlife. The state of knowledge regarding low-level radiation effects on wildlife is insufficient to allow an accurate evaluation. The emanation power of radon (the ratio of the radon released to that produced) for fly ash has been found to be less than 1%, compared to about 20% for uranium mill tailings, and about 70% for some soils. This, combined with the fact that the concentration of radium in fly ash is only marginally above background, results in a radon release rate from fly ash impoundments that is expected to be lower than that from soil. This conclusion remains to be confirmed, since there have been few published data on measurements of gamma radiation and radon emanation from fly ash impoundments.

STANDARDS AND CRITERIA

On 6 February 1978,[1] the U.S. Environmental Protection Agency published in the Federal Register "Proposed Criteria for Classification of Solid Waste Disposal Facilities" (40 CFR Part 257). Solid waste as defined in the proposed rules includes (but is not limited to) solid, semisolid, or liquid waste generated by air pollution control facilities and other discarded material from industrial operations. Disposal of such wastes must comply with criteria for "environmentally sensitive areas" such as wetlands, floodplains, permafrost areas, critical habitats, and sole-source aquifers. These rules and criteria should be used to evaluate suitability of a proposed site for disposal of ash and FGD sludge from coal combustion. (See also LIQUID EFFLUENTS--Standards.)

There are presently no standards for wildlife drinking water sources or chemical-element concentration in forage. A compilation of data from the literature is given in Tables 13 and 14, and can serve as approximate general criteria until more definitive values are established. The tables should be used with caution because of the variation that exists among vegetation and animal species regarding uptake, accumulation, and tolerance to a particular chemical element, or combinations of elements.

Effluent guidelines established by the USEPA regulate the amount of total suspended solids and oil

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[1]Too recent to have been included in the Report.

Table 13. Recommended Limits for Concentrations of Elements and Ions in Livestock Drinking-Water Sources Above Which Toxic Effects May Occur[a]

Element or ion	Recommended limit (mg/liter)
Aluminum	5
Arsenic	0.2
Boron	5.0
Cadmium	0.05
Chromium	1.0
Copper	0.5
Fluorine	2.0
Lead	0.1
Mercury	0.01
Molybdenum	uncertain[b]
Nitrate	100
Nitrite	10
Selenium	0.05
Vanadium	0.1
Zinc	25
Total soluble salts	5000

[a]Compiled from: National Academy of Sciences-National Academy of Engineering, Committee on Water Quality Criteria. 1974. Water Quality Criteria 1972. EPA-R3-73-033. U.S. Environmental Protection Agency.

[b]Toxicity influenced by many factors. Natural surface waters rarely contain over 1 mg/liter.

Table 14. Normal Range and Suggested Maximum Concentrations of Chemical Elements in Plant Leaves[a]

Element	Concentration (ppm, dry wt) Range	Maximum
Arsenic	0.1-1.0	2
Barium	10-100	200
Boron	7-75	150
Cadmium	0.05-0.20	3
Cobalt	0.01-0.30	5
Copper	3-40	150
Chromium	0.1-0.5	2
Fluorine	1-5	10
Iodine	0.1-0.5	1
Iron	20-300	750
Manganese	15-150	300
Molybdenum	0.2-1	3
Nickel	0.1-1.0	3
Lead	0.1-5.0	10
Mercury	0.001-0.01	0.04
Selenium	0.05-2.0	3
Vanadium	0.1-1.0	2
Zinc	15-150	300

[a]Data of: Melsted, S. W. 1973. Proc. Joint Conf. Recycling Municipal Sludges Effluents Land, pp. 121-128. (As cited by: Baker, D. E. and L. Chesnin. 1975. Chemical Monitoring of Soils for Environmental Quality and Animal and Human Health. Adv. Agron. 27:305-374.)

and grease contained in bottom ash or fly ash transport water discharges and restrict pH to an acceptable range (see APPENDIX F). The composition of such effluents is usually controlled by individual State requirements.

QUANTIFICATION

The quantity of ash and sludge produced at a power plant is a function of the initial percentages of ash or sulfur in the coal that is burned, the quantity of coal consumed, and the efficiencies and capacities of both the combustion and the solid waste collection systems. Data on daily or yearly quantities of ash and sludge produced at a given installation can usually be obtained from the power plant operator. In cases where such data are not available, or to verify the data supplied, procedures for calculating ash and sludge quantities are provided here. The calculations are based on plant capacity (MWe), the heat content of the coal (Btu/lb), the sulfur content of the coal (%), and the ash content of the coal (%). The daily coal requirement of a plant (Fig. 10, AIR EMISSIONS) depends upon the heat content of the coal:

$$\text{DCR(MT/day)} = \frac{P}{100} \times C(\text{MWe}) \times 10^3\ \text{kW/MW} \times 24\ \text{hr/day} \times 3412\ \text{Btu/kW·h} \times \frac{100}{E} \times \frac{1}{B_C(\text{Btu/lb})} \times 0.907\ \text{MT/ton} \times \text{ton/2000 lb}$$

where: DCR = daily coal requirement,

P = plant capacity factor (70% is a common figure),

C = rated plant capacity,

E = plant efficiency (36-40% is a common range), and

B_C = heat content of the coal.

The quantity of ash and sludge produced are directly proportional to the respective percentages of ash and sulfur in the coal that is consumed--i.e., DCR × % ash or DCR × % sulfur. All of the accompanying solid waste graphs (Figs. 16-19) are based on these quantities.

Example:

If: Plant rated capacity = 700 MWe
Plant capacity factor = 70%
Plant efficiency = 38%
Heat content of coal = 11,400 Btu/lb
Ash content of coal (by wt) = 10%
Sulfur content of coal (by wt) = 3.5%

Then: Daily coal requirement = 4200 MT/day
Ash in coal consumed = 420 MT/day
Sulfur in coal consumed = 147 MT/day

Except for the direct impacts of land use, assessment of solid-waste-disposal impacts involves the quantification of seepage, runoff, and erosion. These are all site-specific and are best assessed by a qualified geologist or hydrologist. Appropriate geological and hydrological information is available from the U.S. Geological Survey, State geological surveys, water resource research centers, and from the Department of Housing and Urban Development. In the case of seepage quantification, however, data in the literature are not a real substitute for the information obtained by logging drill holes and running hydraulic conductivity or pump tests on the soils at the proposed disposal site. An estimate of the seepage rate of an impoundment can be made from a water budget calculation (water entering the impoundment equals water leaving) if the rate of discharge, evaporation-precipitation rates, hydraulic conductivities and hydraulic gradients are known. Seepage follows Darcy's Law: [114-115]

$$Q = kA \frac{dH}{dL}$$

where: Q = seepage rate (volume per unit time),

k = hydraulic conductivity (determined experimentally, usually on undisturbed core samples),

A = area through which the seepage occurs, and

$\frac{dH}{dL}$ = the hydraulic gradient (decrease in hydraulic head per unit distance through the soil).

Knowledge of the sorptive characteristics of the soil, the quality of leaking effluents, and the position and gradient of groundwater can be used to estimate the extent of contamination of groundwater by waste-pond leachate. Hydrologic expertise will be needed to make these determinations.

The quantification of the impacts of a waste impoundment or waste pile on surface water includes estimation of the runoff from drainage basins above the facility for storms of various intensities. The increase in pond water levels and freeboard necessary to contain storm runoff are relatively easy to quantify. More difficult to estimate is the erosional effect of turbulent streams on waste facility embankments. The Department of Housing and Urban Development, the U.S. Army Corps of Engineers, and the U.S. Geological Survey have mapped the floodplains for 100-year floods for many areas of the country. Where previous mapping does not exist, there are techniques for floodplain determinations.

The blowing of fine-grained ash particles and consequent reduction in air quality due to dust can be predicted if data on the particle-size distribution and water content of the ash, and an appropriate model are available. It is simpler, however, to recommend that mitigative measures be taken to prevent blowing dust.

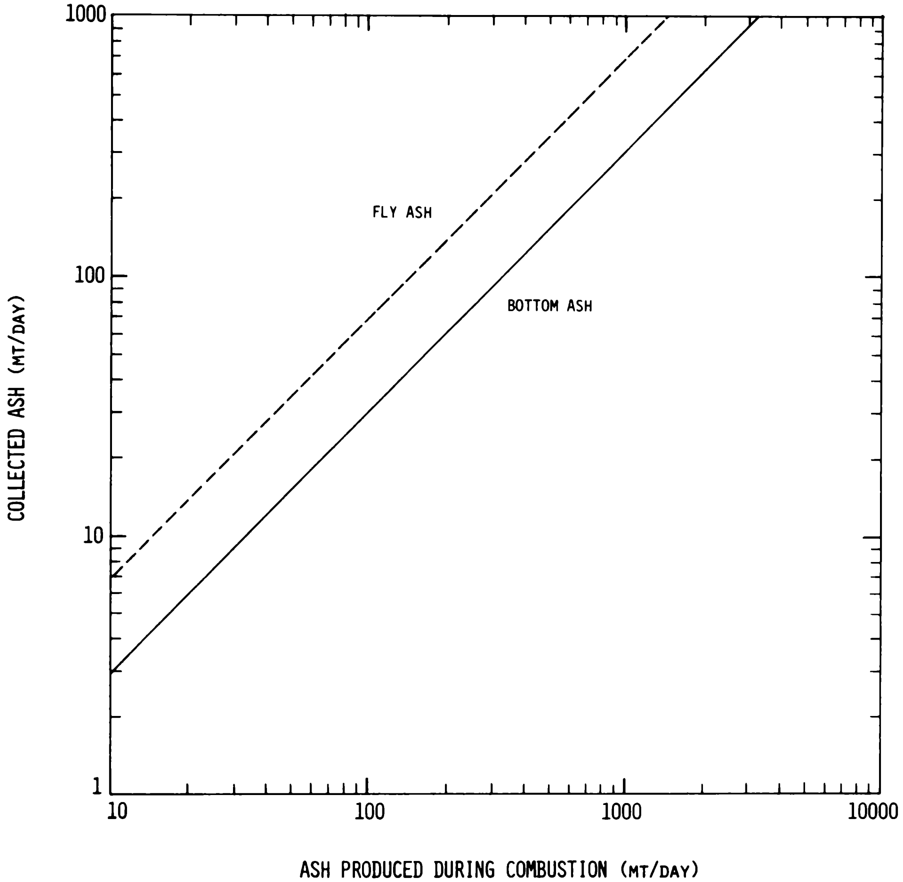

Fig. 16. Bottom Ash and Fly Ash Collected with Electrostatic Precipitators. Assumptions: 30% of the ash is bottom ash, 70% of the ash is fly ash, and the precipitator has 99.5% efficiency. The amount of ash in coal consumed was determined by multiplying the daily coal requirement (Fig. 10) by the % ash in the coal used.

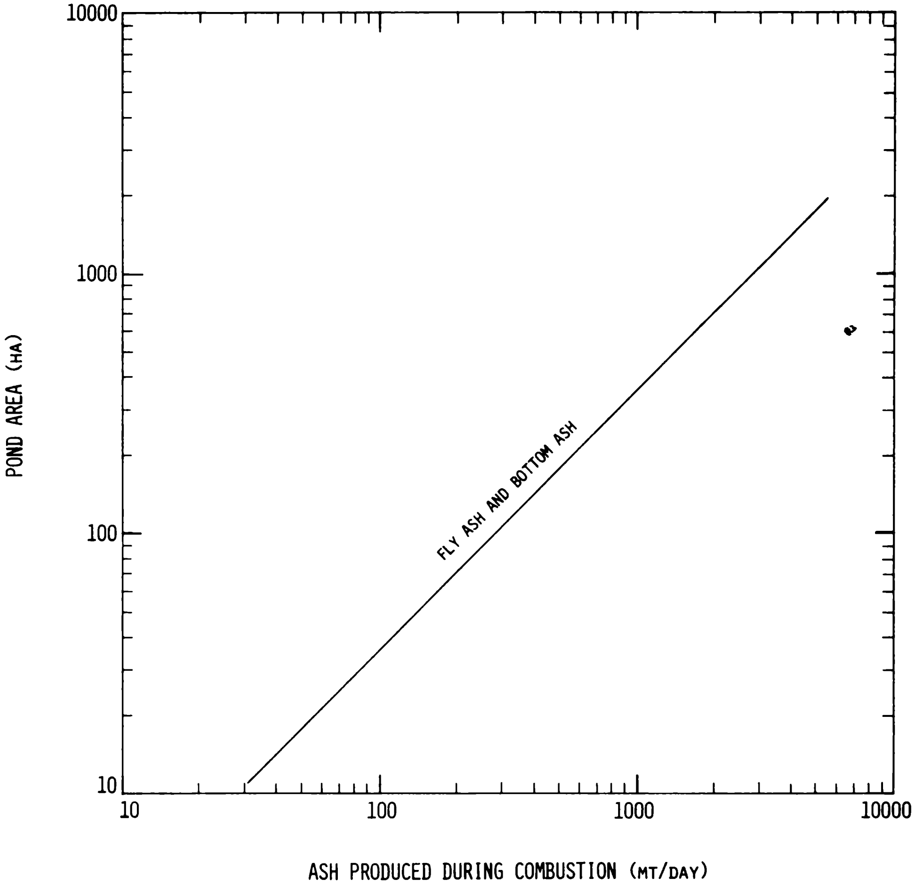

Fig. 17. Land Area Required for Ash Disposal. Assumptions: power plant has been operating for 40 years, and the ash is stored in a pond 3.3 m deep. The land area does not include embankments. The amount of ash in coal consumed was determined by multiplying the daily coal requirement (Fig. 10) by the % ash in the coal used.

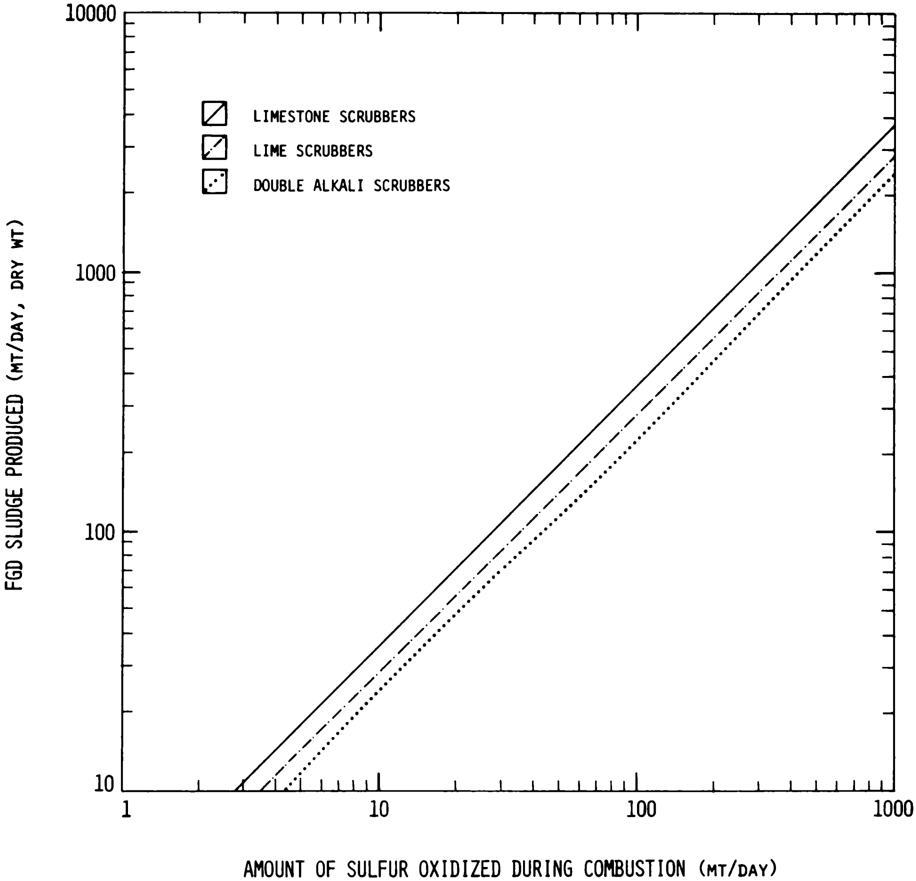

Fig. 18. Flue-Gas Desulfurization (FGD) Sludge Produced from Lime or Limestone and Double Alkali Scrubbers. Scrubber efficiencies are assumed to be 85% for lime or limestone scrubbing and 90% for double alkali scrubbing. The amount of sulfur oxidized was determined by multiplying the daily coal requirement (Fig. 10) by the % sulfur in the coal used.

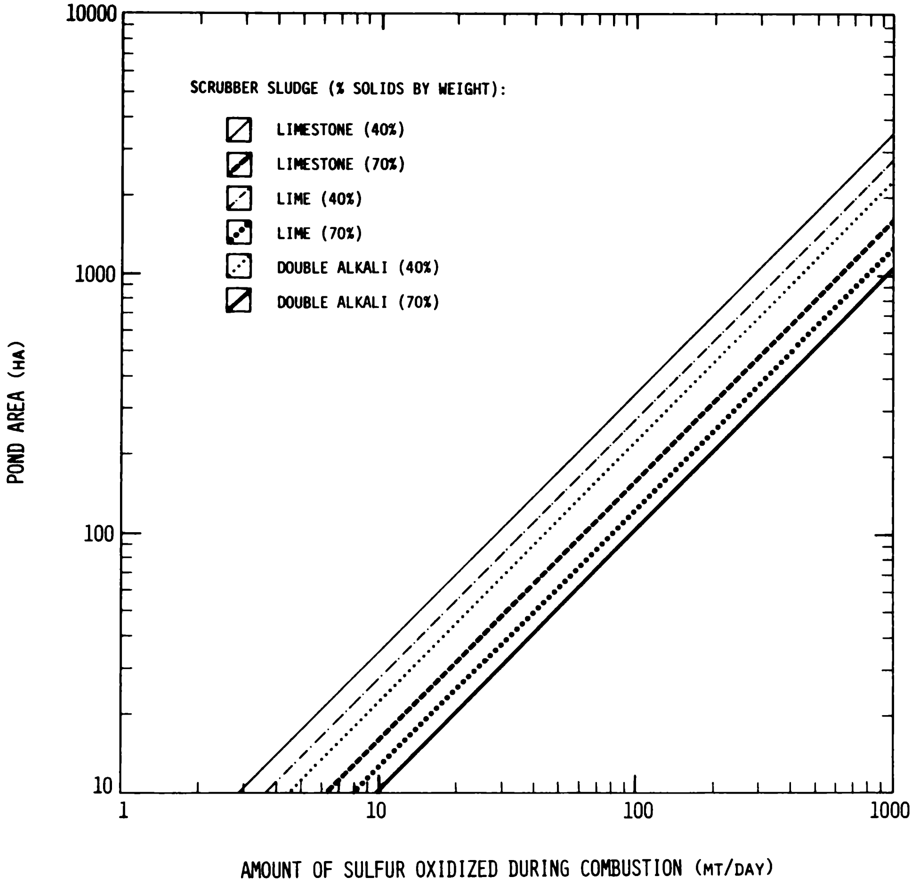

Fig. 19. Land Area Required for Flue-Gas Desulfurization Sludge Disposal. Assumptions: power plant has been operating for 40 years, sludge is stored in a pond 3.3 m deep, and the density of sludge is 2050 kg/m^3 (128 lb/ft^3). The amount of sulfur oxidized was determined by multiplying the daily coal requirement (Fig. 10) by the % sulfur in the coal used.

Consumptive use of water will be greatest if dewatering of ash and sludge is by evaporation, least if supernatant water is discharged to surface water, and intermediate if recycled. Water requirements for waste disposal at a coal-fired power plant are presented in Table 15.

Table 15. Water Requirements for Waste Disposal at a Coal-Fired Power Plant[a]

Waste		Water (liters/MW•h)	
Type	Weight (kg/MW•h as dry waste)	No recycling	Recycling
Bottom ash	5.1	20.4[b]	2.2[d]
Fly ash	20.0	79.5[b]	8.5[d]
Lime sludge	27.3	63.6[c]	11.6[d]
Limestone sludge	33.9	79.5[c]	14.6[d]

[a] Assumes 70% plant capacity.
[b] Assumes slurry with 30% solids by weight.
[c] Assumes sludge with 30% solids by weight.
[d] Assumes 70% solids by weight.

Quantification of runoff from waste-disposal basins will have to be determined for each precipitation event, and will be primarily dependent on the amount of precipitation and the type of basin retaining structures. The amount of overflow and its quality reaching a receiving water body will need to be determined and compared to the quantity and quality of receiving water available for dilution.

The Soil Conservation Service has developed simple equations and graphical solutions for quantification of runoff for a range of soils, moisture, and cover conditions after nonthunderstorm rainfalls.

INFORMATION REQUIREMENTS AND SOURCES

Information Required	Sources
Preemption of land: Area (ha) of proposed disposal site Current land use and productivity	Power plant operator Site visit Land Quality Office or U.S. Dept. of Agriculture In-house (FWS Energy and Land Use Groups)
Use by water birds and other birds: Proximity to flight routes Bird species expected in area Current and projected land use of the area surrounding the disposal site Location of existing and proposed transmission facilities, relative to the pond site	Power plant operator Site visit
Runoff and seepage: Depth of the seasonally high water table Type of liner (if any) and permeability Physical and chemical nature of the waste material Maximum probable flood Maximum precipitation Terrestrial habitats downgradient of the pond site Soil Conservation Service rating of site for reservoirs and embankments, or physical and chemical nature of soils and underlaying strata in the area of the disposal site	District Soil Conservation Service Soil Survey Reports Power plant operator U.S. Geol. Survey District Corps of Engineers Site visit

(continued)

Information Required	Sources
Waste disposal: Habitat and area for sludge and ash ponds Distance from aquatic habitats Methods to contain dust, erosion, and runoff Type of stabilization and reclamation and time frame Ultimate disposal site for sanitary wastes Other facts related to disposal	Site visit Power plant operator
Quantities of waste: Power plant capacity (MWe) Type of coal to be used--Btu/lb, ash, and sulfur content Ash and sludge production, daily or yearly	Power plant operator

IMPACT ANALYSIS

Preemption of Land [109-110]

The approximate land area required for ash and sludge waste disposal and the location of the disposal area can be determined from (1) information gathered during the site visit, (2) the environmental report (if available), and (3) quantification estimates. The current and projected use of the area, productivity, importance as wildlife habitat, and uniqueness of the area in terms of the surrounding county, State, and region should be described, and the loss to land productivity and/or wildlife habitat estimated.

Use of Ponds by Water Birds and Shorebirds [110]

Using the information collected, a prediction can be made regarding use of the pond by water birds and shorebirds. This will be highly speculative, since a number of unknown factors are involved, and there are few studies related to this question. There are data (see the Report) which indicate that surface-feeding species of water birds tend to ingest more slag than diving species. Adverse effects of such ingestion can only be speculated upon, until studies identifying mortality due to slag ingestion have been documented. Water birds can be expected to be killed every year due to collisions with transmission lines and towers if these facilities cross the area used by water birds. This effect has been documented.

Runoff and Seepage [110-118]

The adequacy of the impoundment design in terms of accidental overflow, breaching of the embankments, and seepage are best determined by dam engineers and hydrologists. Ordinarily, the field biologist is not expected to make this determination. Verification of impoundment storage capacity can be obtained by consultation with the district Soil Conservation Service or district Corps of Engineers. The expected effects to soils and biota of accidential embankment breaks or overflow should be described.

A semiquantitative evaluation of seepage can be made using a model for seepage, with coefficients appropriate for the given site. Models are, by necessity, only an approximation of real behavior and are developed using simplified assumptions that may not be applicable to the site. Models should be used with caution, particularly when they have not been validated for a particular site.

In the absence of modeling capability and/or site-applicable coefficients, a qualitative appraisal can be made. In some respects, a qualitative appraisal is a better method for impact prediction, since it does not pretend to be quantitative and thus forces the parties involved to proceed with caution in making decisions regarding waste disposal. APPENDIX G provides a qualitative measure of the suitability of a given area for ash and sludge disposal.

A simpler method is to refer to published information on soil limitations for pond reservoir areas and embankments. This information can be found in county Soil Survey Reports, or obtained by consultation with the district Soil Conservation Service. Each soil series in a given county is rated on the basis of soil permeability, depth to the seasonally high water table, slope, compaction characteristics, resistance to piping, and other soil properties. These ratings can provide some idea of the limitation for ash and sludge disposal.

In the absence of quantitative estimates of seepage and concentrations of trace elements in seepage, the biologist cannot make an estimate of the eventual concentrations of potentially toxic elements or ions in vegetation or in surface seeps that may be used by wildlife as drinking water, and thus cannot begin to assess the hazard to plants and animals. A qualitative prediction of the potential for adverse effects is about the best that can be made, using methods similar to those outlined in APPENDIX G.

If the biologist can obtain from hydrologists or soil scientists a quantitative estimate of trace-element concentrations in seepage, an assessment can be made by assuming that such concentrations will occur in the surface seeps. By comparison of those values with the values in the table of recommended criteria [Table 13 (Standards and Criteria)], the hazard to animal life through drinking water can be evaluated.

An assessment of the hazard to vegetation, and to wildlife and livestock consuming contaminated vegetation, is much more difficult to make, due to the many unquantifiable factors involved in plant availability of chemical elements in the soil and species response to given elements in the growth medium and in tissues. One method of estimation is to assume that at equilibrium, the concentration of a given element in the soil as a result of seepage will be the same as the concentration in the seepage, and will be in a form available for plant uptake (losses through leaching and soil binding are ignored). Using the plant:soil concentration ratios listed in Table 6, the approximate concentration in the plant can be calculated. The result can be multiplied by 10 to provide some safety margin. The final result can then be compared to the values in Table 14.

Example:

Data provided by the hydrologist indicates that seepage from a certain ash pond will contain arsenic at a concentration of 1 mg/liter (this may be a high value; some ash pond effluent and sludge pond liquors have been found to contain arsenic at concentrations ranging from less than 0.01 mg/liter to less than 0.1 mg/liter). From Table 6, the plant:soil concentration ratio for arsenic is 0.14. Concentration in the plant will thus be 1 ppm × 0.14 = 0.14 ppm (dry weight). Multiplying by a safety factor of 10, a value of 1.4 ppm arsenic in the plant is obtained. Comparison with the value for arsenic in Table 14 (Standards and Criteria) indicates that the value of 1.4 is above the normal range in most plants, but below the suggested maximum concentration that would produce toxic effects. Comparison with Table 7 indicates that arsenic is toxic to sheep at 3 ppm in vegetation. It can thus be predicted that it is unlikely that herbivores whose physiology is similar to sheep will suffer from arsenic toxicity through consumption of this vegetation, particularly since the literature indicates that arsenic is rapidly excreted from the body. Comparison with the values in Table 13, however, indicates that surface seeps containing 1 ppm arsenic will likely produce toxic effects in animals using those seeps for drinking water.

A number of deficiencies in this method can be cited. In addition to the uncertainties in estimating concentrations in vegetation (particularly cumulative concentrations in perennials), there are uncertainties in estimating toxic levels in different animal species due to differences in excretion rates, quantity of the particular vegetation species consumed, quantity of other food in the diet, physiological response to a given concentration in the diet, and effects of long-term consumption of supposedly non-toxic concentrations. There will be times, however, when it is the responsibility of the biologist to provide a quantitative estimate; in such cases, some method of estimation similar to that described above is appropriate, but must be accompanied by literature citations and a discussion emphasizing the limitations of the estimation. There will also be objections to the use of an arbitrary "safety factor"; safety factors are used routinely in engineering calculations, and may have some utility for biological calculations as well. The magnitude of the safety factor is, of course, subject to wide disagreement and should be included only at the discretion of the individual biologist.

Analysis of impacts to aquatic ecosystems will require identification and quantification of the chemical and physical constituents contained in waste-disposal basin overflow. The degree to which this overflow will be diluted upon mixing with the receiving water body will have to be determined. Reference can then be made to known toxicity values, and final determinations of potential impacts made. Overflow events are rare, and with proper construction practices, the possiblity of severe surface-water contamination by basin overflow would be precluded.

Analysis of consumptive use of water will require determination of the percentage of stream or lake water needed to meet waste-disposal needs. Unless the quantities needed would result in an observable reduction of the watershed size, impact analysis will be limited to an evaluation of water intake effects. (See also the section on LIQUID EFFLUENTS.)

MITIGATIVE MEASURES [140-150]

Steps can be taken to prevent or modify the impacts of seepage (i.e., soil and groundwater contamination), runoff (soil and surface-water contamination), and embankment erosion. The properties of the disposal site have a marked influence on what mitigative measures must be taken. Waste-disposal facilities are not to be located in areas described as environmentally sensitive by criteria proposed to supplement the Solid Waste Disposal Act (see subsection on Standards and Criteria) unless no other alternatives are feasible and it can be demonstrated that no significant adverse impact will result. Often the facilities located in these areas require some kind of engineered device or design such as liners, drains, diversion ditches, interception of contaminated water, and various types of stabilization.

If it is expected that chemical-element concentrations will exceed the allowable limits in the groundwater and soil around a disposal facility, then that facility should be lined. APPENDIX H is a guide for the selection of the most suitable liner.

Windblown dust from ash and sludge disposal sites can be prevented by keeping the surface of the material moist. Bottom ash, being of larger size, can enhance surface permeability of water if layered over fly ash. At the end of the useful life of the pond, it can be graded, covered with earth material, and revegetated.

ADDITIONAL DATA SOURCES

District Offices of the U.S. Geological Survey, Water Resources Division

State Agencies for Land Reclamation and Environmental Protection

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CONVERSION TO COAL

DESCRIPTION [153-163]

Differences between coal-fired and oil- or gas-fired electric generating plants occur mainly in (1) handling and storage of the fuel, (2) boiler size, and (3) quantity and type of combustion products. There are usually no major differences in other environmentally important aspects of power stations. For example, siting requirements are, in general, similar for all three types of power plants because all require a source of cooling water; land for power plant facilities, fuel storage, and waste disposal (the latter with the exception of gas-fired stations); proximity to major transportation routes; and electric-power transmission lines. The following discussion, therefore, concerns only the three major differences enumerated above.

Fuel Handling

Oil usually arrives at an oil-burning plant by barge. It is heated to reduce its viscosity and then pumped from the barge to surge tanks, and then to the boilers. The oil must also be heated when it is in the pipes.

Natural gas arrives at a gas-burning plant by pipe and is fed by the onsite piping system to the boilers at a controlled rate.

In comparison, at a large coal-burning plant, the coal is moved by conveyor from the plant's receiving facility to live storage, and again by conveyor from live storage to crusher to surge bin and thence to the silos feeding the boiler. With pulverized-coal firing, the coal from the silos is pulverized, mixed with air (the primary air), and pumped as a fluid to the boiler burners. Dust is removed from the coal in the surge bin. Due mainly to coal dust, coal-fired plants are relatively dirty compared to their oil- or gas-burning equivalents.

Fuel Storage

Fuel oil is stored in large aboveground or underground tanks at the plant site. Natural gas is similarly stored, although many gas-burning plants do not have storage tanks but rely instead on the storage capabilities of the pipeline system which delivers gas to the plant. Coal is stored in a large pile, sometimes 15 m (50 ft) high and extending over many hectares.

Boiler Design

Fuel--whether oil, gas, or pulverized coal--enters the furnace via the burner. Circular and cell burners, the most widely used types, can be equipped to fire any one, any two, or all three of these fuels.

For the same output in kilograms per hour of hot steam at a given temperature per hour, a pulverized-coal boiler must be significantly larger than an oil- or gas-fired unit.

Sootblowing equipment is unnecessary in gas-fired boilers, but must be utilized in boilers fired with oil or pulverized coal. The spacing of the superheater tubes may be greater in a pulverized-coal boiler than in an oil- or gas-fired unit.

Combustion Products

Ash. In contrast to gas burning which produces no ash and oil burning which produces a little ash, coal-burning power plants produce large quantities of bottom ash and fly ash.

Nitrogen oxides. Oxides of nitrogen are produced by gas-, oil-, and coal-fired power plants, with the NO_x emission rate being lowest for gas and highest for coal.

Sulfur dioxide. Generally, natural gas from U.S. wells contains negligible sulfur. Hence, gas-fired plants produce little, if any, SO_2.

Fuel oil can have a fairly high sulfur content--up to 3.5%. Oil-fired plants must either burn oil with a low sulfur content or utilize flue-gas desulfurization (FGD) systems. The most widely used FGD systems are similar to those used for coal-fired power plants.

SUMMARY OF IMPACTS

Terrestrial [161-162]

Previous sections have dealt with the impacts of burning coal in an existing or newly constructed electrical generating station. When the engineering aspects of conversion to coal are complete, the impacts of operation are not anticipated to be different from those already discussed. Areas for coal, and possibly limestone, storage and for disposal of combustion and emission control wastes are required at a coal-fired generating station. Preemption of new land for these purposes is the largest threat to wildlife and their habitat from the conversion of oil- or gas-fired plants to coal.

Impacts to wildlife also occur due to movement of men and machines when some support facilities for oil-fired power plants are dismantled. Adverse effects arise from dust, noise, and soil erosion; but with sufficient forethought and adequate supervision of construction crews, these unavoidable effects can be minimized and are temporary.

Aquatic

Adverse impacts to fish and other aquatic life may occur if residual oil contaminates land and water when oil handling facilities, storage tanks, and pipes and plumbing facilities are dismantled. Oil spills can be detrimental to all groups of aquatic organisms. Soluble components of oil can coat fish gills and interfere or prohibit oxygen exchange. In waters with marginal oxygen content, both gill-coating effects and increased biological oxygen demands from oil spills may cause fish death by suffocation. Heavier components of oil will sink and may smother benthos and/or adversely affect invertebrates by reducing their food sources. Algae can be killed due to interference with photosynthesis and the direct toxic effects of some oil components, including naphthenic acids, mercaptans, and phenols.

Barge facilities designed for oil may have to be modified to handle coal. This may require dredging and associated work, which can result in siltation and turbidity. Most impacts will be site-specific and can range from temporary disturbance to permanent modification or elimination of biota and habitat.

If existing facilities cannot be modified or dismantled economically, more land preemption and intrusion of waterways will occur for a gas- or oil-fired plant converted to coal than for a plant originally designed for coal.

STANDARDS AND CRITERIA

There are presently no standards specific to coal conversion which are different from those applicable to facilities designed originally to burn coal.

QUANTIFICATION

Land requirements for coal storage can be estimated from the daily coal requirements of the generating station (Fig. 6, COAL STORAGE). Requirements for lime/limestone storage can be estimated from fuel consumption and sulfur content of the fuel (Fig. 7, LIMESTONE PREPARATION AND STORAGE). Requirements for waste disposal can be estimated from Figures 17 and 19 (SOLID WASTES).

The approximate areas required for storage and handling of coal, fuel oil, and natural gas are shown in Table 16 for three 700-MWe power plants fired respectively by the three fuels.

Table 16. Approximate Area Requirements for Three 700-MWe Power Plants--One Fired by Coal, One by Fuel Oil, and One by Natural Gas[a]

Components	Area requirements (ha)		
	Coal-fired-plant	Fuel-oil-fired plant	Natural-gas-fired plant
Fuel storage, handling	3.6	5.1	0.3
Power generation	0.8	0.6	0.6
Waste heat dispersal (Cooling towers)	6.5	6.5	6.5
Waste handling	3.1	1.3	0
Total	14.0	13.5	7.4
Area permanently disturbed[b]	101	97	89

[a]Data compiled from references cited in the Report (Table 61).
[b]Includes roads, parking areas, switchyards, landscaping, etc., not included in the rest of the table.

Gaseous emission products from oil, natural gas, and coal combustion are listed in Table 17.

Table 17. Gaseous Emission Products from Oil, Natural Gas, and Coal Combustion[a]

	Products released ($lb/10^6$ Btu)		
Emission product	Fuel oil[b]	Natural gas[c]	Bituminous coal[d]
Particulates	0.06	0.015	2.86
Carbon monoxide	0.02	0.017	0.04
Sulfur dioxide	3.81	0.0006	1.36
Sulfur trioxide	0.05	-	-
Nitrogen oxides	0.73	0.6	0.64
Hydrocarbons	0.01	0.001	0.01
Aldehydes	0.007	-	0.00018

[a]The data represent emission products in the absence of pollution abatement equipment. A hyphen indicates data not provided. Data derived from: U.S. Environmental Protection Agency. 1973. Compilation of Air Pollutant Emission Factors, 2nd ed. Publ. No. AP-42; PB-223 996.
[b]Assumes heat content = 18,000 Btu/lb, 8 lb oil/gal oil, sulfur content = 3.5%.
[c]Assumes 1000 Btu/ft^3.
[d]Assumes 14,000 Btu/lb (30.8×10^6 Btu/MT), 5% ash, sulfur content = 1%.

INFORMATION REQUIREMENTS AND SOURCES

Information Required	Sources
Type of plant being converted	Power plant operator
Land requirements for coal storage in relation to land previously used for oil storage	Power plant operator
Type of coal to be used: Btu/lb, ash, and sulfur content	Power plant operator
Size of generating station	Power plant operator
Quantity of residual oil to be removed	Power plant operator
Methods to contain spills	U.S. Environmental Protection Agency Power plant operator
Enlargement or construction of barge facilities (if applicable)	Power plant operator
Additional land disturbance due to conversion	Power plant operator Site visit

IMPACT ANALYSIS

Terrestrial

To evaluate the impacts of converting a plant to coal, it is necessary to first ascertain the extent of new land required for the storage of coal, limestone, and waste, and for the construction of new handling facilities.

The oil-fired generating station may already contain enough land for these purposes, in which case oil storage facilities will have to be removed to accommodate the new function of the land. This will result in impacts from construction, a much less serious threat to wildlife than preemption of their habitat. At the other extreme is the gas-fired plant, where no fuel storage space has been required in the past. Development of storage and disposal areas at these plants will require expansion into new land. In some sites, this may threaten to clear wildlife habitat. If it is not feasible to convert oil storage areas into a new use, expansion into new land will be required to support operation of coal-fired plants.

Evaluating impacts from these plants after conversion should follow the guidelines outlined in preceding sections of this manual.

Aquatic

Impact analysis will require a determination of the quantity of oil and its components that would be expected to be spilled into a water body during dismantling and conversion, the nature of dispersion of oil in the water, and the quality of water available for dilution. Extent of impact to benthic organisms can be estimated from the area of lake or river bottom covered by heavier oil components in the site vicinity. Direct impacts to algae and fish can be based on the final concentration of oil components in the water (see LIQUID EFFLUENTS, Eqs. 5 and 6), after mixing, compared to toxicity values in the literature.

Impacts from dredging can be evaluated based on percentage of bottom disturbed, methods of spoil disposal, and mitigative procedures proposed to reduce impacts to biota.

MITIGATIVE MEASURES

To reduce the expansion of converted stations into wildlife habitats, there should be an attempt to use lands already disturbed on site. Clearing of such lands is expected to have less of an impact on wildlife populations than clearing new lands.

The most effective method to mitigate conversion effects on aquatic systems is sufficient forethought and proper control technology, e.g., plans for acceptable removal of materials containing residual oil should be discussed with the operator. Proper dredging techniques should be employed to ensure that bottom disruption and downstream turbidity and sedimentation are kept to a minimum. Adequate revegetation and shoreline stabilization, e.g., with rip-rap, can curtail erosion of barge slip areas or other shoreline structures after construction. All construction activities with potential to cause major bottom disruption or sedimentation in water bodies should be performed during periods of no major fish spawning.

ADDITIONAL DATA SOURCES

District Corps of Engineers

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APPENDICES

APPENDIX A. STACK-GAS CLEANING METHODS

FLY ASH CONTROL

The fly ash control systems described here are electrostatic precipitators, wet scrubbers, fabric filters, and mechanical collectors.

Electrostatic Precipitators

Electrostatic precipitators cause the fly ash particles to become electrically charged. The charged particles are then pulled, by electrostatic forces, to collecting electrodes. Four steps are involved:

1. A powerful electric field is maintained between the negative discharge electrode and the positive collecting electrode. The discharge electrode is a wire, and the collecting electrode is a tube or plate.

2. A direct-current, high-voltage corona is established in the interelectrode space. This corona ionizes molecules of electronegative gases such as O_2, CO_2, and SO_2 present in the flue gas. These ions, in turn, charge the fly ash particles by colliding with them and transferring charge.

3. The particles of fly ash, now negatively charged, are pulled by electrostatic forces to the positive (grounded) collecting electrode.

4. The collecting electrode is periodically rapped to dislodge the accumulated fly ash. Upon rapping, the ash falls into a hopper beneath the electrodes.

A parallel plate precipitator utilizes a series of flat parallel collector plates spaced from 15 to 30 cm (6 to 12 inches) apart, with a wire (the discharge electrode) between each pair of plates. The particulate-laden flue gas passes between the plates.

High collection efficiencies, ranging from 99% to 99.9% can be achieved with a low pressure drop through the precipitator and a low power requirement. A 99% efficiency or less is obtained at a generally lower cost than with other types of equipment. Further, electrostatic precipitators are relatively compact, and have low maintenance costs and low downtime. The fly ash escaping from the precipitator (generally 1% or less of the total) is smaller than 2 μm in size.

The precipitator collection efficiency increases with increasing time of particle residency in the electrostatic field and with the strength of the field. Efficiency declines with increasing fly ash resistivity. The resistivity of the fly ash is, in turn, a function of the ash temperature and sulfur content. Low-sulfur coal produces a high resistivity fly ash which reduces collection efficiency. This problem can be overcome by using a "hot" precipitator, placed upstream of the air heater and operated at 315°C (600°F) or more, instead of the conventional "cold" precipitator, placed downstream from the air heater. The higher temperature in the hot precipitator compensates for the low sulfur content so that a high removal efficiency is obtained even with low-sulfur coal. With the growing dependence on low-sulfur coal, hot precipitators are coming into increasing use.

Wet Scrubbers

A wet scrubber removes fly ash particles from the flue gas by transferring the particles to water. The transfer is accomplished by: inertial impaction (primarily effective for > 1 μm particles), interception (primarily effective for 0.1 to 1 μm particles), and diffusion into collector droplets (for < 0.1 μm particles).

Collection efficiency, particle size, and the pressure drop across the scrubber are closely related. For a given efficiency, pressure drop varies inversely with particle size; for a given particle size, efficiency increases with increasing pressure drop.

Venturi and moving-bed scrubbers are the most widely used wet scrubbers in power plant applications.

Venturi scrubbers utilize a venturi throat to obtain a high-velocity flow of stack gas. Velocities are typically in the range of 60-120 m/s (200-400 ft/s). Absorbing liquid is injected (at the throat) into the fly-ash-laden stream of high-velocity stack gas. The gas stream atomizes the liquid into droplets. Internal impaction of the fly ash particles into the droplets is fostered by the high relative velocity between the gas and the droplets. Impaction is considered to be the primary collection mechanism in venturi scrubbers.

Venturi scrubbers have a nominal efficiency of 99%. With an across-scrubber pressure drop of 2500 to 3750 Pa (10 to 15 inches of water) and a liquid-to-gas ratio of 1.3 to 2 L/m^3 (10 to 15 gal/1000 ft^3), they can reduce fly ash content of the flue gas by 0.7 g/m^3 (0.02 g/ft^3).

A moving-bed scrubber consists of a bed of plastic or glass spheres, packed loosely to permit movement and supported underneath by a perforated plate; the spheres and plate are mounted within a cylindrical container. Flue gas passes upward through the sphere bed as the scrubber liquid percolates downward. The spheres provide an extensive surface for gas-liquid contact, and create turbulence in the flue gas which further enhances contact.

In addition to extracting fly ash particles, moving-bed scrubbers are effective in simultaneously removing SO_2 from the flue gas. This effectiveness is due in part to the long residence time of the gas in the scrubber. By contrast, venturi scrubbers provide a short residence time (due to the high velocities) and are correspondingly poor in SO_2 removal.

Particle collection efficiencies are high for moving-bed scrubbers, ranging from 98.7 to 99.9%. These percentages are obtained with pressure drops of 1350 to 2500 Pa (5.5 to 10 inches of water), liquid-to-gas ratios of 4.3 to 10.6 L/m^3 (32 to 80 gal/1000 ft^3), and gas velocities of 2.4 to 3 m/s (8 to 10 ft/s). Increasing the pressure drop increases the collection efficiency.

Fabric Filters

These consist of fabric bags through which the stack gas flows. Fly ash is trapped by the fine threads composing the fabric. As particles accummulate on the filter, its efficiency increases. The bags are periodically cleaned, after which their efficiency returns to the original, lower value.

Fabric filters must be applied in situations where temperature and humidity are not excessive. They are generally not competitive with electrostatic precipitators at efficiencies of 99% or less. However, efficiencies above 99% are economically achievable with fabric filters, and for this reason, their utilization in urban areas may increase.

Mechanical Collectors

Mechanical collectors utilize centrifugal forces to separate fly ash particles from the flue gas. The ash-bearing gas stream is introduced tangentially into the collector. The particles are thrown to the collector's outside wall where they are removed.

Mechanical collectors are most effective for particles of > 10 μm. For < 10-μm size particles, the efficiency drops well below 90%.

NITROGEN OXIDES CONTROL

Combustion-generated nitrogen oxides (NO_x) are produced by two reactions: the combination of nitrogen from the combustion air with oxygen and the oxidation of nitrogen chemically bound in the coal. The formation of nitrogen oxides depends on combustion conditions in the primary flame zone of the boiler.

Four techniques are available to control NO_x emissions from coal-fired boilers: (1) modification of combustion conditions, (2) modification of the coal, (3) extraction of NO_x from the flue gas, and (4) utilization of an alternative, low NO_x combustion process (catalytic combustion, fluidized-bed combustion). Of these, modification of combustion conditions constitutes the best developed and most effective technique for the short and long term. The capital cost of combustion modifications is an order of magnitude lower than that for flue gas cleaning.

To avoid poor combustion, with the consequent production of smoke and unburned fuel, utility boilers always take in more air than is stoichiometrically required. Burning with low-excess air is the most widely used combustion modification strategy. This approach reduces the quantity of oxygen available for combination with atmospheric or coal-bound nitrogen. It also reduces the quantity of atmospheric nitrogen in the furnace. However, if the excess air level becomes too low, smoke and CO are produced.

Staged combustion is a second strategy for the control of NO_x via the modification of combustion. With this approach, the furnace is fired in such a way as to make the primary flame zone rich in fuel. Sufficient air is introduced above the flame zone to complete combustion, while maintaining overall excess air at a low level. The fuel-rich primary flame zone is kept comparatively cool by radiative heat transfer. [Nitrogen oxide formation proceeds rapidly at temperatures above 1650°C (3000°F).] Thus, the main NO_x-forming region of the furnace--the primary flame zone--is maintained in a cool, oxygen-poor state; the coolness and the oxygen scarcity both tend to inhibit NO_x development. The staged combustion technique is constrained by the occurrence of convective section fouling, unburned hydrocarbon emissions, or poor ignition characteristics when the primary zone is too rich in fuel.

The use of staged combustion leads to emission reductions in the 50 to 65% range; the low-excess-air approach is somewhat less effective.

SULFUR OXIDES CONTROL

The following flue-gas desulfurization (FGD) processes are used for controlling sulfur oxide (SO_x) emissions: lime/limestone scrubbing, double alkali scrubbing, magnesia scrubbing, and the Wellman-Lord process.

Lime/Limestone Scrubbing

The lime/limestone scrubbing process extracts SO_2 from the flue gas by reacting it with lime (CaO) or limestone ($CaCO_3$) in a slurry to form a precipitate. The relevant chemical reactions are:

Lime:

$$SO_2 + Ca(OH)_2 \longrightarrow H_2O + CaSO_3 \;;$$

Limestone:

$$SO_2 + CaCO_3 \longrightarrow CO_2 + CaSO_3$$

$$2\ CaSO_3 + O_2 \longrightarrow 2\ CaSO_4 \;.$$

The flue gas and the slurry come into contact in the scrubber, and it is there that the first two reactions take place. From the scrubber, the reacted slurry flows to the reaction tank where fresh lime or limestone is added to make the calcium sulfite and sulfate precipitate out (as hydrates). Part of the slurry leaving the reaction tank is pumped back to the scrubber. The remainder is sent to a solid/liquid separator, which may be a centrifuge, filter, or holding pond. Solids (sludge) from the separator--consisting of hydrated calcium sulfite and sulfate, unreacted lime or limestone, and some fly ash--are removed for disposal. The liquid-output stream of the separator is split, one portion being sent back to the reaction tank and the remaining portion to the scrubber, thus completing the cycle. Makeup water is added to the scrubber-bound portion to compensate for evaporation losses and water lost with the sludge. Large quantities of sludge are produced by the lime/limestone system.

After scrubbing, the flue gas is reheated above its dew point and released up the stack.

With reasonable maintenance, lime/limestone scrubbing systems can function at least 80% of the time. These systems are effective in removing SO_2; removal efficiencies of 80% or more are achieved in normal operation. Lime/limestone scrubbing is the most widely utilized of the available flue-gas desulfurization techniques and it is expected that this predominance will continue well into the 1980's.

Double Alkali Scrubbing

The double alkali scrubbing process uses two solutions--one for absorbing SO_2 from the flue gas and one for regenerating the spent absorbing liquid. Of the many possible combinations, usually a solution of sodium hydroxide or sodium sulfite is used as the absorbing medium and lime or limestone as the regenerating agent. A sodium sulfite-lime/limestone system is described here. As with lime/limestone scrubbing, a solid waste of calcium sulfite and calcium sulfate is generated.

A sodium sulfite (Na_2SO_3) liquor is brought into contact with the flue gas; the flue-gas SO_2 reacts with the Na_2SO_3 as follows:

$$SO_2 + Na_2SO_3 + H_2O \longrightarrow 2\ NaHSO_3\ .$$

The $NaHSO_3$-bearing effluent from the scrubber is regenerated in the reaction tank according to either of the following reactions:

Lime:

$$2\ NaHSO_3 + Ca(OH)_2 \longrightarrow Na_2SO_3 + CaSO_3 + 2\ H_2O\ .$$

Limestone:

$$2\ NaHSO_3 + CaCO_3 \longrightarrow Na_2SO_3 + H_2O + CaSO_3 + CO_2\ .$$

Sodium sulfate (Na_2SO_4) is also formed in the process. This is soluble and is removed by a purge stream.

The solid/liquid mixture from the reaction tank goes to a separator, which discharges the sludge and the scrubbing liquid. Makeup water and alkali are added to the scrubbing liquid which is returned to the scrubber. As in the lime/limestone scrubbing process, the sludge from the separator must be disposed of.

Double alkali absorbers have less potential for scaling and are more efficient than lime/limestone systems. Removal efficiencies for SO_2 of 90-97% have been reported for double alkali units.

Magnesia Scrubbing

The magnesia scrubbing process reacts flue-gas SO_2 with a magnesium sulfite slurry:

$$SO_2 + MgSO_3 + H_2O \longrightarrow Mg(HSO_3)_2\ .$$

Magnesium oxide is used to regenerate magnesium sulfite from the spent absorbing liquor:

$$Mg(HSO_3)_2 + MgO \longrightarrow 2\ MgSO_3 + H_2O\ .$$

The precipitated $MgSO_3$ is concentrated by a separator, dried, and sent to a sulfuric acid plant. At the plant, the magnesium sulfite is heated to regenerate the magnesium oxide.

$$MgSO_3 \longrightarrow MgO + SO_2\ .$$

The SO_2 driven off during heating is converted into 98% sulfuric acid.

Magnesia scrubbing is regenerative, producing no throwaway sludge and requiring no input analogous to the lime or limestone used in the two scrubbing processes described above (except for a minor amount of makeup MgO). Further, the magnesia scrubbing process offers low scaling potential, high SO_2 removal efficiency (90% or more), and a salable end product.

Wellman-Lord Process

The Wellman-Lord process removes flue-gas SO_2 by reacting it with a solution of sodium sulfite, Na_2SO_3:

$$SO_2 + Na_2SO_3 + H_2O \longrightarrow 2\ NaHSO_3\ .$$

The spent absorbing solution is then regenerated by heating in an evaporator/crystallizer:

$$2\ NaHSO_3 \longrightarrow Na_2SO_3 + H_2O + SO_2\ .$$

The gas stream from the evaporator/crystallizer, consisting of H_2O and SO_2, is sent to a condenser to condense out the H_2O, and then to a separator to separate the water and SO_2. The condensed water is mixed with the regenerated sulfite slurry, makeup alkali, and makeup water to provide scrubber-feed solution. The SO_2 can be processed to sulfuric acid, liquid SO_2, or elemental sulfur. Some of the sodium sulfite is oxidized to sulfate, which is unreactive. To prevent sulfate buildup, a sulfate purge stream is required. The makeup water compensates for losses in this purge stream as well as in the scrubber.

The SO_2 removal efficiency of Wellman-Lord system is high. For the 17 units in operation, efficiency is over 90% in normal operations at all installations.

APPENDIX B. NOISE AND ITS EFFECTS ON WILDLIFE

Noise is generally defined as loud, chaotic, and undesirable sound. Sound waves are pressure variations produced by mechanical disturbance in a material medium. The sound pressure range, p, is the force per unit area caused by a sound wave. The sound pressure range over which the human ear is capable of perceiving information extends some 10^{13} Pa (1 Pascal = 0.02 lb/ft^2); therefore, sound pressure levels are expressed on a logarithmic scale known as the decibel scale. A convenient expression of sound pressure levels in decibels (dB) is: $10 \log_{10} (p^2/p_0{}^2)$, where p is the measured sound pressure and p_0 is a reference pressure. Conventionally, the reference pressure is taken as 20 μPa, the lower threshold for detection by the human ear. The perceived intensity of sound is proportional to the square of the sound pressure, and intensity levels (I) are also expressed as decibels: $10 \log (I/I_0)$. With airborne sound, pressure and intensity levels are practically equivalent. The intensity level of a sound wave in a free field (i.e., uninterrupted space for transmission) decreases at a rate of 6 dB per doubling of distance from the source. Barriers to a sound transmission result in reflection or reverberation in sound pressure level.

A common method for measuring sound levels is to utilize detectors with sensitivities approximating the sensitivity of the human ear. One method of designing such detectors is termed A-weighting, and sound levels measured by A-weighted detectors are expressed as dB(A). Measurements from instruments of unweighted sensitivity are expressed as dB.

Coal-fired power plants contain several sources of noise production (Table B.1). Unless proper mitigative procedures are taken, sound pressure levels within 1 meter of the machinery often are within the 90 to 100 dB(A) range. A major contributor to the sound in a power plant is rotating turbomachinery. Forced-draft fans and boiler feed-pumps are the noisiest pieces of equipment in the power plant. The steam turbine-generator contributes a large amount of sound to the plant's background levels. Flow-through valves and piping produce high intensity noise. Electric motors and transformers are other sources of noise. Furnace noise arises from energy release as chemical energy is converted to heat, from fluctuations due to varied

Table B.1. Inherent Noise Characteristics of Mechanical Equipment[a]

Source of noise	Characteristics of sound or vibration
Rotating machinery	A tone of a single frequency and higher harmonics
Cooling towers	Fan noise and water splash
Motors and generators	"Whine"
Gears	"Whine"
Bearings	"Squeal"
Grinders	"Grinding" noise, essentially broadband, often with a relatively strong pure tone of frequency
Internal combustion engines	A "roar" of frequency of firing
Pumps	Intake and exhaust noise
Vibrating machinery	Relatively pure tones
High-speed vibrators	"Vibration," "buzz," or "rattling," essentially broadband
Impact machinery	"Hammering," "rattling," "pounding," "thumping," "banging," etc., essentially broadband
Air or fluid flow	"Rushing," or "flow" sound, relatively broadband
Valves and meters Throttling devices Dampers Flash tanks Orifices Nozzles	"Rushing," "whooshing," "swishing" type of sound--often a strong, almost pure "tone" or "scream" or "screech" and often of very high frequency

[a]Data from: Avril, W. W., and B. A. Popeck. 1977. Power station noise sources and spectra. IEEE Trans. Power Appar. Syst. 97:1010-1020.

rates of burning, and from interactions of the flame and the furnace enclosure. Noise from coal and limestone crushing facilities are also major sources of disturbance. Impulse noise (sound that rises rapidly to its maximum intensity) from coal handling and processing comes primarily from the movement of coal through chutes and screens. Construction noise arises from vehicles, machinery, and impulse noise from hammering, dropping equipment, etc.

There are a number of ways in which noise emissions can be reduced. The noise source can be treated by damping vibrations of the machinery, by preventing the transmission of vibrations to attached materials, or by constructing housing around the source to reduce sound transmission. Other methods involve placing sound-absorbing materials in the path of the sound, using absorbent coatings to reduce sound reverberation within rooms, and coating the source with acoustical insulation in order to absorb sound emissions. Another approach is to construct barriers between the source and the receiver; these barriers redirect sound and reduce its intensity. When designing a power plant, consideration should be given to these mitigative measures for noise control.

Current standards for human exposure to industrial noise have been set by the Occupational Safety and Health Administration (OSHA) at exposure to 90 dB(A) or less for an eight hour workday and a maximum of 115 dB(A) for a quarter of an hour or less (Table B.2). The U.S. Environmental Protection Agency has

Table B.2. Occupational Safety and Health Administration Standards for Occupational Exposure to Noise.

Duration of exposure per day (hours)	Maximum sound level [dB(A)]
8	90
6	92
4	95
3	97
2	100
1-1/2	102
1	105
1/2	110
1/4 or less	115

identified several yearly average equivalent sound levels requisite to protect human health and welfare from excessive noise impact (Table B.3). For exposure to industrial noise, a 24-hour average exposure to no more than 70 dB(A) was considered adequate for protection from hearing loss. The levels identified for protection from interference with outdoor activity was a 24-hour average exposure to 55 dB(A) or less.

Current knowledge is insufficient to determine whether the standards and levels identified for human protection will also protect wildlife from physiological damage or disruption of activity due to exposure to noise. The effects of noise on wildlife have not been extensively studied. Virtually all of the information that has been gathered is based upon experiments with laboratory or domesticated animals.

An animal's response to noise is a function of the frequency spectrum, intensity, duration, and pattern of exposure as well as intrinsic factors such as age, auditory sensitivity, ability to recover, etc. Responses to noise range from interference with behavioral patterns to disruption of the auditory apparatus. For example, it has been shown that continuous exposure for 4 hours to a 2000 Hz tone at 125-130 dB results in histological damage to the sensory cells of the organ of Corti in guinea pigs. Impulse noise of 153 dB has been shown to have an effect equivalent to that of continuous sound at 125-130 dB. Exposure to continuous sound at 100 dB at several frequencies results in modification of biochemical function in the inner ear of guinea pigs.

A common response to intense sound is elevation of the level of lowest intensity of sound that can be heard by the subject (temporary or permanent threshold shift). Chinchillas exhibit temporary threshold shifts in response to intensities of 70 dB. The magnitude of the shift increases with increasing duration of exposure. Exposure of cats to 115 dB has resulted in permanent threshold shifts of up to $\sim$ 40 dB after exposure for 8 hours.

Noise has also been demonstrated to have nonauditory effects upon laboratory animals. Both physiological and behavioral responses to noise may occur. Intermittent exposure to sound pressure levels of about 80 dB or more have been associated with evidence of increased blood pressure, increased adrenocortical activity, increased levels of serum cholesterol, decreased fertility, induction of seizures, and other physiological stresses in laboratory animals. Intermittent sound of over 120 dB induces chickens to abandon brooding of their eggs.

Wild rats and mice have been exposed to continuous sound ranging from 60 to 140 dB in intensity. The only effects

Table B.3. Yearly Average* Equivalent Outdoor Sound Levels Identified as Requisite to Protect the Public Health and Welfare with an Adequate Margin of Safety†

Location	Sound level measure**	Activity interference	Hearing loss consideration††	To protect against both effects (a)
Residential with outside space and farm residences	L_{dn} $L_{eq(24)}$	55	 70	55
Residential with no outside space	L_{dn} $L_{eq(24)}$			
Commercial	$L_{eq(24)}$	(b)	70	70(c)
Inside transportation	$L_{eq(24)}$			
Industrial	$L_{eq(24)(d)}$	(b)	70	70(c)
Hospitals	L_{dn} $L_{eq(24)}$	55	 70	55
Educational	$L_{eq(24)}$ $L_{eq(24)(d)}$	55	 70	55
Recreational areas	$L_{eq(24)}$	(b)	70	70(c)
Farm land and general unpopulated land	$L_{eq(24)}$	(b)	70	70(c)

*Refers to energy rather than arithmetic averages.
†Adapted from: U.S. Environmental Protection Agency. 1974. Information on Levels of Environmental Noise Requisite to Protect Public Health and Welfare with an Adequate Margin of Safety. EPA 550/9-74-004. 1 v. (various pagings).
**L_{dn} = day-night level; $L_{eq(24)}$ = equivalent 24-hour level.
††The exposure period which results in hearing loss at the identified level is a period of 40 years.

Code: (a) Based on lowest level.
(b) Since different types of activities appear to be associated with different levels, identification of a maximum level for activity interference may be difficult except in those circumstances where speech communication is a critical activity.
(c) Based only on hearing loss.
(d) An $L_{eq(8)}$ of 75 dB may be identified in these situations so long as the exposure over the remaining 16 hours per day is low enough to result in a negligible contribution to the 24-hour average, i.e., no greater than an L_{eq} of 60 dB.

observed were decreased nesting near the source of the sound and death at very high intensities. High frequency sounds have been shown to repel bats, rabbits, deer, and some birds. Intermittent noise of over 85 dB has been shown to repel birds, but too frequent noise events result in rapid adaptation.

With the limited amount of knowledge concerning the effects of noise on wildlife, one may infer possible effects from information on (1) the auditory communication of a species, (2) the auditory range of a species, (3) direct effects observed in the laboratory, and (4) the incidental observations of responses of wild animals to noise. Increases in background noise can interfere with auditory communication by masking signals. Japanese quail have been shown to increase the rate of their calls in response to an increase in ambient noise from 36 dB(A) to 63 dB(A). This increases the ratio of signal to background noise, improving the chances that the signal will be received and correctly understood. The use of recorded signals to control unwanted species suggests that high intensities of sound do interfere with auditory signals. Observations have also suggested that wildlife exhibit startle responses to impulse sound, disrupting brooding and other behavioral patterns.

Noise emissions from power stations often approach or exceed the OSHA standards and the USEPA's identified levels of noise requisite for protection of human health and welfare. It is likely that at least some wildlife could suffer deleterious effects if they spend a period of time within a few meters of the source. However, unless the power plant itself is near the site boundary, most wildlife will be 100 m or more from the sources of noise emissions.

Figure B.1 illustrates the effect of distance from a source upon the intensity of the sound received. If a source emits sound which reaches a pressure level of 100 dB(A) at 1 m distance, then at 100 m distance the sound pressure level will be attenuated to about 60 dB(A). This level is still above that which the USEPA considers will interfere with human speech; it may also be sufficient to interfere with wildlife communication. Limited evidence suggests that sound pressure levels for normal auditory communication among wildlife are similar to pressure levels for human speech. At 1 km from the source, however, sound intensity should not be sufficient to markedly interfere with communication. If the level of noise is reduced by noise control methods to 80 dB(A) at the source, even at 100 m from the source, sound intensity is probably no problem. It would appear, then, that neither injury nor interference with communication from noise are likely to occur to wildlife in the vicinity of a power plant, particularly if steps have been taken to control noise emissions.

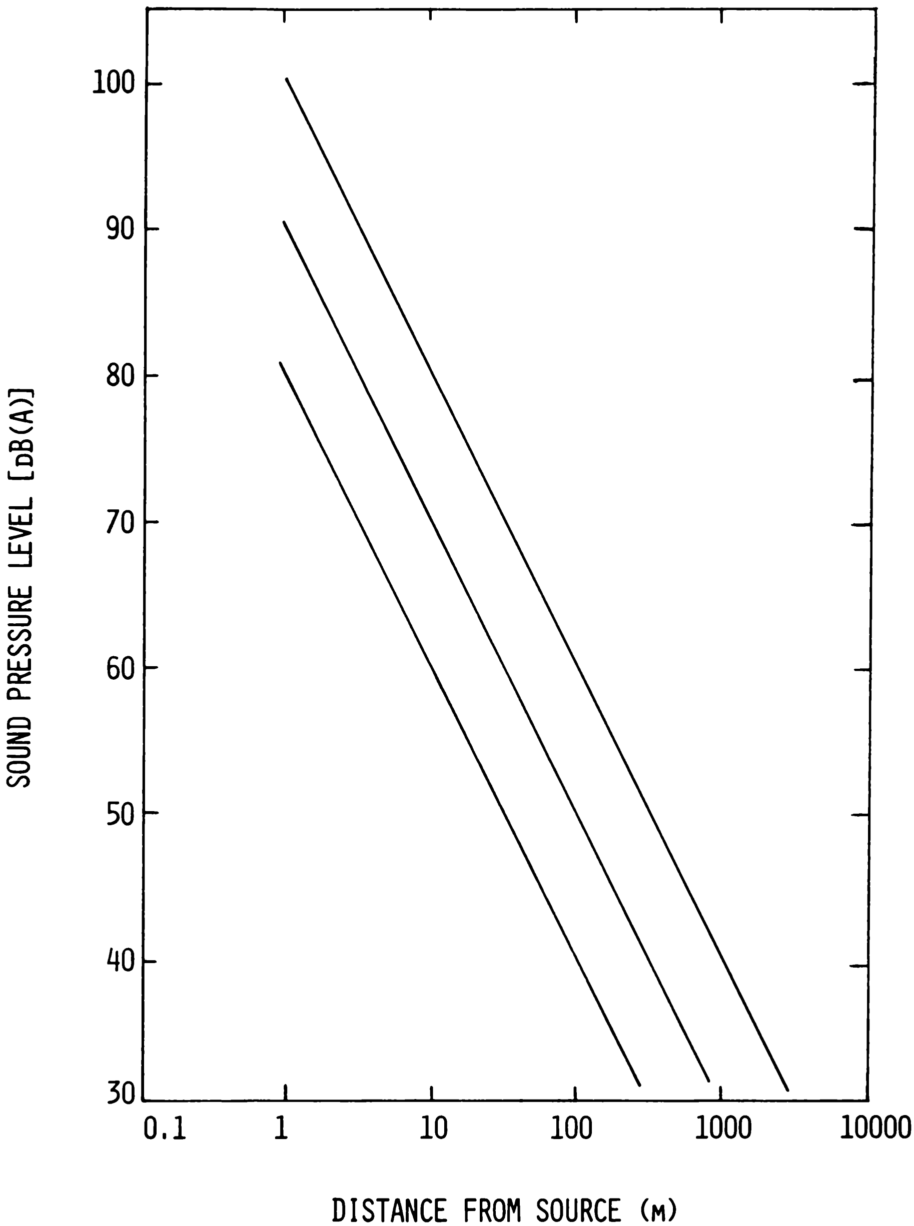

Fig. B.1. Sound Pressure Levels for Three Sources of Noise as a Function of Distance from the Source in a Free Field.

Activities around a plant can result in loud, impulse noises, especially during construction. These often elicit a startle response from animals and may induce wildlife to leave the vicinity of the source. Unfortunately, the extent to which such an effect may occur is not quantifiable on the basis of current information.

Most studies of the effects of noise on animals have investigated the effects of high levels of sound during acute, short-term exposure (several minutes to several weeks). However, wildlife are exposed to noise levels from power plants that are relatively low and continuous for several years. The effects of chronic exposure to sound levels of low intensity have not been evaluated. Thus, wildlife around power plants may suffer subtle physiological or behavioral stresses which may require years before they become overtly manifested.

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APPENDIX C. COAL CLASSIFICATION AND COMPOSITION

CLASSIFICATION OF COAL

Coal is composed of a highly complex and heterogeneous group of substances and possesses a wide range of chemical and physical properties. Coal is formed by the accumulation and subsequent modification of plant matter; its final properties depend on the nature of the original vegetation, the circumstances of deposition, and the subsequent events that occur during metamorphosis into coal.

One of the most commonly accepted methods of coal characterization is the classification by rank, developed by the American Society for Testing and Materials. Classification by rank, which represents the progressive response of coal to pressure and/or heat during the metamorphic process, orders coals into a series ranging from lignite, at the lower end of the scale, through the various ranks of subbituminous and bituminous coals to the anthracites, at the upper end of the scale. This classification (Table C.1) is based upon fixed carbon, volatility content, calorific content, and agglomerating characteristics of coal.

Table C.1. Classification of Coals[a]

Class	Moisture (%)	Fixed carbon limits (%)[b]	Volatile matter limits (%)[b]	Calorific value limits (Btu/lb)[c,d]
Anthracite	< 2	86-98	2-14	14,000-16,000
Bituminous	2-15	50-86	14-50	10,500-14,000
Subbituminous	20-30	40-60	-	8,300-10,500
Lignite	30-50	< 40	-	6,300-8,300

[a]From: Simon, J. A., and M. E. Hopkins. 1973. Geology of coal. In Elements of Practical Coal Mining. Ill. State Geol. Surv. Reprint.
[b]Dry mineral-matter-free basis.
[c]Moist mineral-matter-free basis.
[d]To convert Btu/lb to J/kg, multiply by 2.324×10^3.

Lignite, the parent form of all higher ranks, is often called brown coal. Lignite can contain up to 50% water and has the lowest carbon content of all the ranks of coal and therefore has a relatively low heat content, expressed as Btu output per pound. Consequently, larger quantities of lignite must be burned to equal the energy output of higher ranks of coal. Large lignite deposits are found in western North Dakota, eastern Montana, and northwestern South Dakota; smaller deposits are found in the southcentral states of Texas, Arkansas, Louisiana, Mississippi, and Alabama.

Subbituminous coal has a slightly higher heat value than lignite due to lower moisture content and greater amount of carbon. Subbituminous coal deposits occur in nearly all of the Rocky Mountain states.

Bituminous coal is the most widely distributed and most abundant of all the ranks of coal in the United States. It has a higher heat value than the two previously mentioned lower ranks of coal. Because of its high heat value and abundance, bituminous is the predominant form of coal used by electrical utilities. Bituminous deposits can be found in the eastern, midwestern, Rocky Mountain, and far western states.

Anthracite has the lowest moisture content and the highest fixed carbon content of all ranks of coal. The largest deposits of anthracite being mined in the United States today are in eastern Pennsylvania.

Coal ranking represents a multipurpose classification scheme designating general coal characteristics. The broad rank designations anthracite, bituminous, subbituminous, and lignite will be used in the following discussion, recognizing that subdivision within each of these ranks is possible. To determine a coal's suitability for a given purpose and its usage and waste production rates, more data are required. Characteristics of particular importance in electrical power generation are heat (Btu/lb), sulfur, ash, moisture, and trace-element contents.

IMPORTANT COAL CONSTITUENTS

Heat content (Btu/lb) is important because it dictates the amount of coal consumed annually by a given power plant. Transportation costs per unit heat output may be an important cost factor, and may affect the type of coal used in a particular plant. Sulfur content is important because of the deleterious health and environmental effects of sulfur dioxide, which is created as a combustion byproduct; these deleterious effects have lead to regulatory restrictions on sulfur dioxide emission and/or sulfur content of coals which may be burned. These restrictions often require utilization of low-sulfur coal from distant locations and/or removal of sulfur from coal before combustion or from the flue gases after combustion. The ash content determines the amount of bottom and fly ash produced by combustion of a given quantity of coal. Moisture lowers the effective heat content per unit weight of coal because of its weight and the heat expended in vaporizing the water, thus increasing transportation costs per useful Btu. Trace elements (including radionuclides) emitted in flue gases have received relatively little attention, but are considered in this report because of their potentially harmful environmental effects.

ESTIMATES OF RESERVES FOR THE MAJOR COAL-PRODUCING REGIONS OF THE UNITED STATES

The locations of the major coal-producing regions of the United States are identified in Figure C.1.

MOISTURE, ASH, SULFUR, AND HEAT CONTENT OF REPRESENTATIVE U.S. COALS

Data on moisture, ash, sulfur, and heat content of coals for some major coal-producing states are presented in Table C.2 in order to illustrate typical values. Any given state may contain many mineable seams. In each case, however, data for only one seam was chosen, usually on the basis of its production within that state. The characteristics given for one seam may not be representative of other seams in the same state.

TRACE ELEMENTS AND RADIONUCLIDES IN U.S. COALS

Trace elements are generally defined as those with a relative abundance in the earth's crust of 0.1% (one part per thousand) or less. Many of the trace elements in coal are enriched in coal ash, a combustion byproduct, relative to their crustal abundance, and some are elevated to toxic concentrations. The concentration of some of these elements in the ash of coals from three broad regions of the United States is compared with their crustal abundance in Figure C.2. Manganese is clearly depleted in coal ash relative to its crustal abundance, but the other elements show elevated concentrations in the coal ash from some regions. Figure C.2 also illustrates the regional variability in the concentration of some elements in coals.

Trace-element concentrations may vary widely with location, and even within a single seam. Germanium, for instance, concentrates locally in the top and bottom layers of a coal bed, or next to the parting layer. (The parting layer consists of non-coal materials found in abundance between two coal seams.)

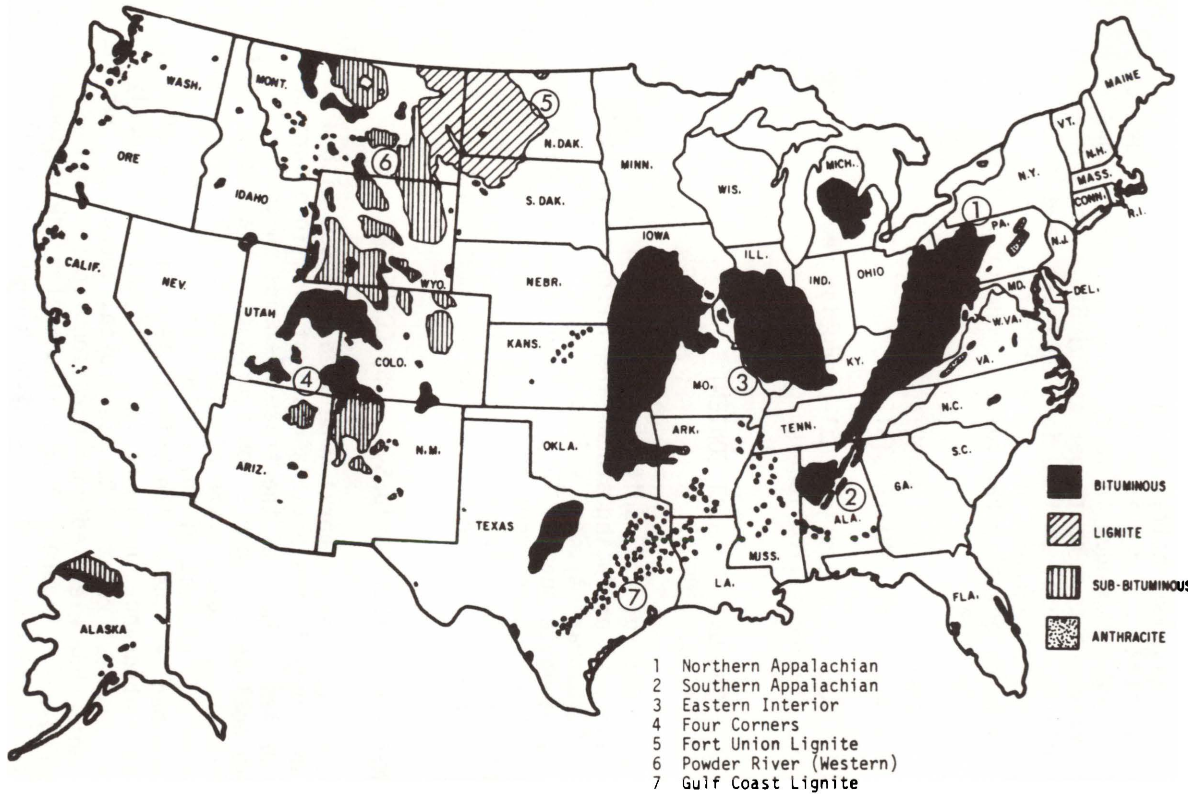

Fig. C.1. Coal-Producing Regions of the United States. Adapted from: Carter, R. P., et al. 1974. Surface Mined Land in the Midwest. (See the Report for complete citation.)

Table C.2. Summary of Moisture, Ash, Sulfur and Heat Content of Coal from Some Major Coal-Producing Seams in the United States[a]

Region/State	Seam	Moisture (%) Range	Moisture (%) Average[c]	Ash (%) Range	Ash (%) Average[c]	Sulfur (%) Range	Sulfur (%) Average[c]	Heat (Btu/lb)[b] Range	Heat (Btu/lb)[b] Average[c]
Northern Appalachian									
West Virginia	Pittsburgh	-	2.9	4 -20	7(M)	0.6 -14	2.2(M)	11,400-14,800	13,800(M)
Pennsylvania	Pittsburgh	1.1-3.9	2.5(MR)	4.2-10.8	7.5(MR)	0.7 -3.3	2.0(MR)	13,040-14,340	13,690(MR)
Southern Appalachian									
Eastern Kentucky	Upper Elkhorn #3	-	3.2	-	3.9	-	0.9	-	14,200
Tennessee	Upper Elkhorn #3 (Jellico)	2.0-7.6	4.8(MR)	1.9-10.5[d]	6.2(MR)	0.7 -3.2[e]	2.0(MR)	12,630-14,290[f]	13,460(MR)
Virginia	Upper Banner	1.8-2.2	2.0(MR)	4.7-5.8	5.3(MR)	0.5 -0.7	0.6(MR)	14,600-14,870	14,735(MR)
Alabama	Mary Lee	1.2-4.0[g]	2.6(MR)	4.9-19.8	12.4(MR)	0.5 -2.6	1.6(MR)	11,570-14,700	13,135(MR)
Eastern Interior									
Illinois	(No. 5) Harrisburg-Springfield	4 -18	11(MR)	8 -12	10(MR)	2 -5	3.5(MR)	10,100-12,700	11,400(MR)
Indiana	(No. 5) Springfield	-	-	5 -30	12	0.7 -7.3	3.3	9,100-14,000	12,800
Western Kentucky	(No. 9)(No. 5 Ill.)	-	5.0	-	10.5	-	3.15	-	12,940
Powder River Region									
Montana	Anderson-Dietz 1 & 2 and Anderson	-	-	4.0-5.3	4.6	0.29-0.5	0.37	7,925-9,652	8,633
Wyoming	Anderson & Canyon & Wyodak-Anderson	21.1-36.9	29.7	3.1-12.2	6.0	0.14-1.2	0.48	7,128-9,600	8,203
Fort Union Lignite									
North Dakota	Undefined	33.5-43.8	37.9	4.4-8.0	6.2	0.2 -1.4	0.6	5,960-7,487	6,783
Gulf Coast Lignite									
Texas	Wilcox Group	-	27.5	-	10.0	-	0.8	-	7,705
Four Corners									
Arizona	Wepo	7.0-17.4	10.35	3.4-6.7	5.2	0.4 -0.9	0.6	10,450-12,060	11,617
New Mexico	Navajo	-	13.2	-	20.4	-	0.72	-	9,200

[a]Adapted from: Dvorak, A. J., et al. 1977. The Environmental Effects of Using Coal for Generating Electricity. NUREG-0252. Prepared by Argonne National Laboratory, Argonne, Ill., for the U.S. Nuclear Regulatory Commission. Compiled from references cited in the Report (Table B.2, Appendix B). Hyphens indicate no data available in the references used for this table.

[b]To convert Btu/lb to J/kg, multiply by 2.324×10^3.

[c]Values are averages unless otherwise noted (MR = midrange; M = median).

[d]Excluding a value of 18.2.

[e]Excluding a value of 4.8.

[f]Excluding a value of 11,690.

[g]Excluding a value of 6.7.

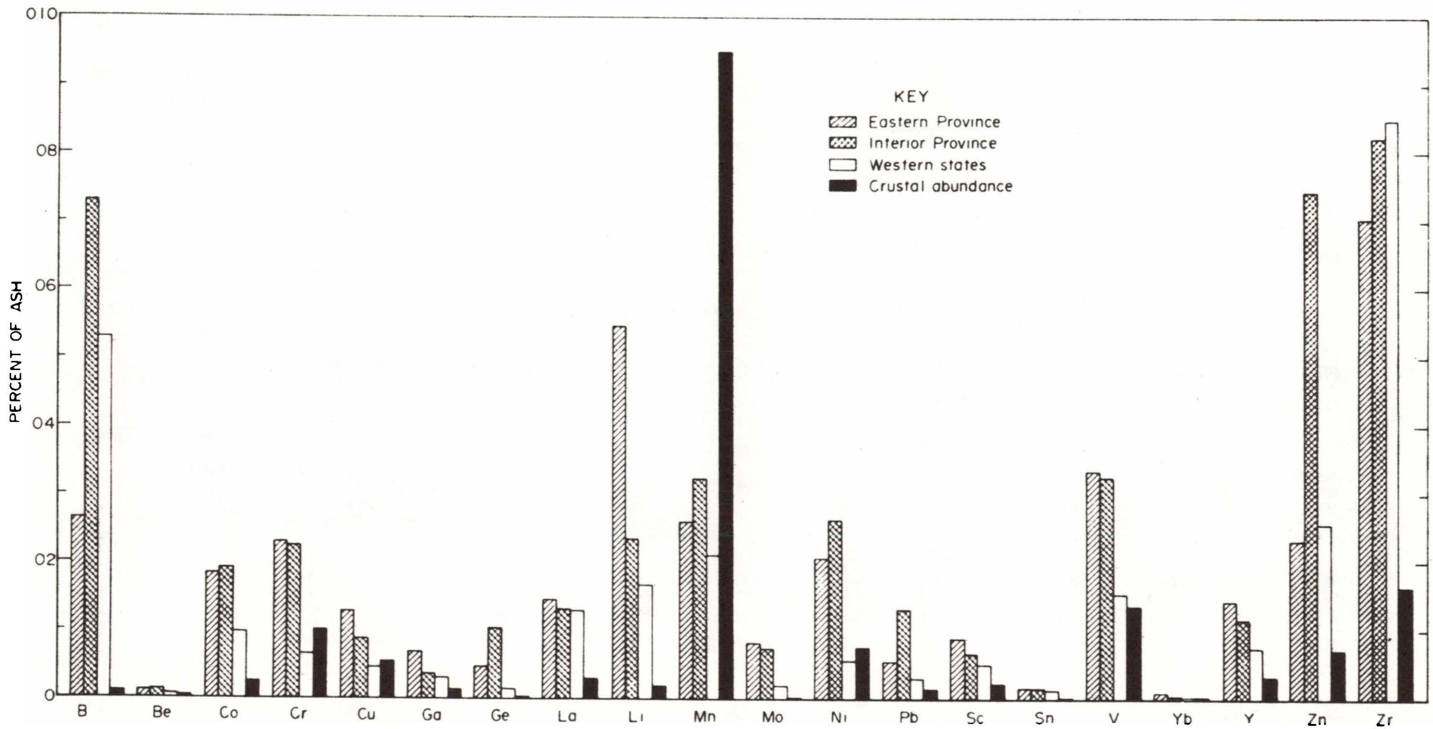

Fig. C.2. Average Trace-Element Content in Ash of Coal from Three Coal-Producing Regions Compared with Abundance in the Earth's Crust. From: Abernethy, R. F., et al. 1969. Spectrochemical analyses of coal ash for trace elements. U.S. Bur. Mines Rep. Invest. 7281.

The concentration of a given element may vary with location by more than two orders of magnitude. High concentrations of a specific trace element may be associated with proximity to ore beds for that element, and such anomalies in the concentration of some elements in coal are used as indicators of possible mineral deposits. The question of high variability was explored by Magee et al., who concluded that when coal is averaged within regions, the extreme variability observed on a local scale is not paralleled by similar variations among other regions. Data were averaged for groups of about three states, and variations of the order of a factor of 2-3 were found among regions for most elements. Sulfur varied by a factor of 8, and of the 18 trace elements examined, only Ge, B, Be, Ga, Zn, Sn, and Mo varied by more than a factor of 4 on this basis.

Uranium and thorium content of coal samples from various regions of the United States are listed in Table C.3. An additional radionuclide found in coal is Potassium-40 (K-40), comprising about 0.012% of the total potassium in natural materials. Coal contains an average of about 400 ppm K and, therefore, about 0.05 ppm K-40.

Table C.3. Range of Uranium and Thorium Concentrations and Geometric Means (expected values) for Coal Samples Taken from Various Regions of the United States[a]

Region	Coal rank	Number of samples	Uranium concentration (ppm)		Thorium concentration (ppm)	
			Range	Geometric mean	Range	Geometric mean
Pennsylvania	Anthracite	53	0.3-25.2	1.2	2.8-14.4	4.7
Appalachia[b]	Bituminous	331	<0.2-10.5	1.0	2.2-47.8	2.8
Interior[c]	Bituminous	143	0.2-43	1.4	<3 -79	1.6
Northern Great Plains[d]	Subbituminous, lignite	93	<0.2-2.9	0.7	<2.0-8.0	2.4
Gulf[e]	Lignite	34	0.5-16.7	2.4	<3.0-28.4	3.0
Rocky Mountain[f]	Bituminous, subbituminous	134	<0.2-23.8	0.8	<3.0-34.8	2.0
Alaska	Subbituminous	18	0.4-5.2	1.0	<3.0-18	3.1

[a]From: Swanson, V. E., and J. H. Medlin, et al. 1976. Collection, Analysis, and Evaluation of Coal Samples in 1975. Open-file Report 76-468 (Draft). U.S. Department of the Interior, Geological Survey.
[b]Pennsylvania, Ohio, Maryland, West Virginia, Virginia, Kentucky, Tennessee, Alabama.
[c]Michigan, Indiana, Iowa, Nebraska, Missouri, Kansas, Oklahoma, Arkansas.
[d]North Dakota, Montana, Wyoming.
[e]Alabama, Mississippi, Arkansas.
[f]Wyoming, Colorado, Utah, Arizona, New Mexico.

Note: The analyses for uranium and thorium were performed on whole coal. The arithmetic average concentrations of thorium and uranium in ppm for all coal samples and various ranks of coal for the whole United States are given in the Report (Table B.4, Appendix B).

APPENDIX D. FEDERAL STANDARDS FOR AIR EMISSIONS

NEW SOURCE PERFORMANCE STANDARDS AND AMBIENT AIR QUALITY STANDARDS

Emission standards from power plants have been set by the U.S. Environmental Protection Agency (USEPA) to protect the public health and welfare. New Source Performance Standards (NSPS) set limits for the amount of pollutants emitted by a facility. Ambient standards set limits on the amount of pollution permitted at ground level. Additionally, areas of the country have been placed into classes based on air quality criteria. These classes are designed to prevent significant deterioration (PSD areas) and to maintain present air quality. Specific rulings, limits, and permits may be required from the USEPA or individual states to construct a new facility or modify an existing facility.

New Source Performance Standards set limits for particulates, oxides of sulfur and nitrogen, as well as visible emissions. The standards are given in Table D.1. Recent rulings by the courts have questioned the validity of the NSPS, but it is assumed that new facilities must be in compliance. Due to the concern over increased emissions from fossil-fired power plants, it is likely that emission limits will be decreased for new sources, making the use of Best Available Control Technology (BACT) necessary (see the following discussion of 1977 Clean Air Act Amendments).

Ambient air quality standards are established to protect the public health (primary standards) and to protect the public welfare (secondary standards). These standards are listed in Table D.2 and are established with a margin of safety. Individual states may establish ambient standards in addition to the federal standards, but state standards must be as restrictive or more so than the federal standards. Ambient concentrations are found by adding calculated concentrations, using applicable meteorological data and realistic plant emissions, to the measured background concentrations. Short-term concentrations can be calculated by adding conservative values (those input values leading to the highest predicted values) to background concentrations.

Table D.1. Federal Emission Standards for New Fossil-Fuel-Fired Steam Generators[a,b]

Pollutant	Emissions ($lb/10^6$ Btu)[c]	Fuel type
Particulates	0.1 (also 20% opacity limit)	All
SO_2	0.8	Liquid fuel
	1.2	Solid fuel
NO_x	0.2	Gaseous fuel
	0.3	Liquid fuel
	0.7	Solid fuel

[a]From: U.S. Environmental Protection Agency. 1971. Standards of performance for new stationary sources. Fed. Regist. 36(247): 24876-24895.
[b]Data are for units of more than 250×10^6 Btu/hr heat input.
[c]Maximum 2-hr average.

Table D.2. Federal Ambient Air Quality Standards[a]

Material	Standards ($\mu g/m^3$) Primary	Secondary
Suspended particulates		
Annual average	75	60
24-hr average[b]	260	150
Sulfur dioxide		
Annual average	80	60
24-hr average[b]	365	260
3-hr average[b]	none	1,300
Nitrogen dioxide		
Annual average	100	100
Carbon monoxide		
8-hr average[b]	10	10
1-hr average[b]	40	40
Photochemical oxidants		
1-hr average[b]	160	160
Hydrocarbons		
3-hr average[b]	160	160

[a]Data from: U.S. Environmental Protection Agency. 1971. National primary and secondary ambient air quality standards. Fed. Regist. 36(84):8186-8190.
[b]Not to be exceeded more than once per year.

Proper measuring and sampling techniques, approved by the USEPA, have been developed for stack monitoring to determine compliance with NSPS and for ambient monitoring to determine compliance with ambient standards. Ambient air quality monitoring has been done at a number of locations, and the data are available from the USEPA, responsible state agencies, and/or facilities requiring air quality permits from those agencies.

In addition to the NSPS and ambient standards, certain areas in the country are designated by the USEPA as Class I, II, or III PSD areas. Class I areas presently encompass national monuments, primitive areas, preserves, recreation areas, and wild and scenic rivers exceeding 10,000 acres. Class II and Class III are less pristine areas. Maximum allowable pollutant increases for each class are given in Table D.3. These additions must also meet NSPS and ambient standards.

Table D.3. Maximum Allowable Increase in Pollutant Concentrations for PSD Areas[a]

Pollutant	Maximum allowable increase ($\mu g/m^3$)		
	Class I	Class II	Class III
Particulates			
Annual geometric mean	5	19	37
24-hr maximum	10	37	75
Sulfur dioxide			
Annual arithmetic mean	2	20	40
24-hr maximum	5	91	182
3-hr maximum	25	512	700

[a]Data from: U.S. Government. 1977. Clean Air Act, 42 U.S.C. 1857 et seq., as amended by PL 90-148, PL 91-604, PL 92-157, PL 93-15, PL 93-319, and PL 95-95; Title I, Part C. Environment Reporter 71:1101-1181.

Due to the changing standards for emissions and air quality concentrations, as well as the variety of different regulatory agencies--either federal, state, or local--having jurisdiction over power plants, the regional USEPA office, the state department of air quality, and all local agencies must be consulted before any licenses are granted and plants constructed.

1977 CLEAN AIR ACT AMENDMENTS

The Clean Air Act Amendments were signed into law on 7 August 1977. Major changes were made in the regulations concerning Air Quality Control Regions (AQCR's) and State Implementation Plans (SIP's) to ensure compliance with the Clean Air Act and emission standards for new or modified stationary sources.

By 6 December 1978, each state is to notify the administrator of the USEPA of those AQCR's within the state which are in violation of the ambient air quality standards or for which insufficient data are available to make a judgment of the air quality. Also, any source which will contribute significant amounts of pollutants to AQCR's across state boundaries must notify all nearby states of the concentrations of pollutants resulting from the emissions of a new or modified source.

States may also redesignate Class I PSD areas to Class II or Class III. However, mandatory Class I areas (international parks, national wilderness areas and national memorial parks exceeding 5,000 acres in size, and national parks exceeding 6,000 acres in size) and certain others (national monuments, national primitive areas, and wild and scenic rivers exceeding 10,000 acres in size) can be designated Class I or Class II areas only.

If an area is not in compliance with the ambient air quality standards, no permits for sources can be issued in the area unless additional emissions from the source will be offset by reduced emissions from existing sources within the area. Lowest achievable emissions from a new or modified source in such a nonattainment area is required. To better quantify existing air quality, the USEPA will establish an air quality monitoring system across the nation.

In the past, New Source Performance Standards have limited the amounts of various pollutants a new source may emit. In addition to these standards, the new Clean Air Act Amendments will require "the achievement of a percentage reduction in the emissions from such category of sources from the emissions which would have resulted from the use of fuels which are not subject to treatment prior to combustion." This requires "best technological system of continuous emission reduction." The use of naturally low-sulfur fuels is not in itself satisfactory. It is probable that sulfur reductions of about 90% and particulate reductions of 99.5% will be mandated. A state governor, the EPA administrator, or the President may prohibit major fuel-burning sources from using any fuels "other than locally or regionally available coal or coal derivatives." The operator of the fuel-burning source may be required to enter into long-term contracts for local coal and also to contract for additional emission abatement devices required to comply with emission standards.

The Clean Air Act amendments will tighten emission standards, disallow the use of inherently low-polluting fuels as a pollution control device, provide no dispersion credit for any stack more than 2.5 times as tall as related facilities, and establish a more complete air quality monitoring system across the nation.

APPENDIX E. SO_2 SENSITIVITY GROUPINGS FOR VEGETATION

Table E.1. SO_2 Sensitivity Groupings for Herbaceous Native Plants/Weeds[a]

Scientific name	Common name
	<u>Sensitive</u>
Agrostis palustris	Bentgrass
Amaranthus palmeri	Careless weed
Amaranthus retroflexus	Pigweed
Ambrosia artemisiifolia	Ragweed
Ambrosia trifida	Ragweed, giant
Aster sp.	Aster
Brassica sp.	Mustard, black
Bromus sp.	Bromegrass
Chenopodium album	Lamb's quarters
Cirsium sp.	Thistle
Convolvulus arvensis	Bindweed
Dactylis glomerata	Orchardgrass
Delphinium sp.	Larkspur
Erigeron canadensis	Fleabane
Fagopyrum sagittatum	Buckwheat
Festuca rubra	Fescue, red
Gaura parvifolia	Velvetweed
Helianthus sp.	Sunflower
Lactuca scariola	Prickly lettuce
Lolium sp.	Ryegrass
Malva parvifolia	Mallow
Parthenocissus quinquefolia	Virginia creeper
Plantago major	Plantain
Poa pratensis	Junegrass
Poa sp.	Bluegrass
Polygonum sp.	Smartweed
Rumex crispus	Curly dock
Rumex sp.	Sorrel
Saponaria officinalis	Bouncing bet
Sisymbrium sp.	Mustard, hedge
Solanum sp.	Nightshade

(continued)

Table E.1. (Continued)

Scientific name	Common name
	Sensitive (cont.)
Solidago sp.	Goldenrod
Stellaria media	Chickweed
Taraxacum officinale	Dandelion
Vicia sp.	Vetch
Xanthium sp.	Cocklebur
	Intermediate
Asclepias sp.	Milkweed
Aster sp.	Aster
Brassica arvensis	Mustard
Capsella bursa-pastoris	Shepherd's purse
Helianthus annuus	Sunflower
Malva parviflora	Cheeseweed
Poa annua	Bluegrass, annual
Poa pratensis	Bluegrass, Kentucky
Portulaca sp.	Purselane
Spartina sp.	Saltgrass
	Resistant
Chenopodium murale	Nettle-leaf goosefoot
Dianthus sp.	Dianthus
Phlox sp.	Phlox

[a]The same genus may appear in more than one SO_2 category since the lists were compiled from the lists of numerous researchers. See the Report for literature citations.

Table E.2. SO_2 Sensitivity Groupings for Woody Trees, Shrubs, and Ornamentals[a]

Common name	Scientific name
	Sensitive
Alder, black	*Alnus glutinosa*
Alder, thinleaf	*Alnus tenuifolia*
Apple	*Malus* sp.
Aspen, large-toothed	*Populus grandidentata*
Aspen, trembling	*Populus tremuloides*
Ash, red (green)	*Fraxinus pennsylvanica*
Ash, white	*Fraxinus americana*
Birch, European	*Betula pendula*
Birch, gray	*Betula populifolia*
Birch, western paper	*Betula papyrifera commutata*
Birch, white (paper)	*Betula papyrifera*
Birch, yellow	*Betula alleghanensis (lutea)*
Blackberry	*Rubus* sp.
Blueberry, lowbush	*Vaccinium angustifolium*
Catalpa	*Catalpa* sp.
Cherry, bitter	*Prunus emarginata*
Cherry, European	*Prunus padus*
Cherry, sour	*Prunus cerasus*
Cherry, sweet	*Prunus avium*
Elm, Chinese	*Ulmus parvifolia*
Fir, subalpine	*Abies lasiocarpa*
Gooseberry	*Ribes grossularia*
Hazel, beaked	*Corylus cornuta (rostrata)*
Hazel, California	*Corylus cornuta californica*
Hazelnut	*Corylus avellana*
Hemlock, mountain	*Tsuga mertensiana*
Horse chestnut	*Aesculus hippocastanum*
Larch, western	*Larix occidentalis*
Maple, Manitoba	*Acer negundo interius*
Maple, Japanese	*Acer palmatum*
Maple, Rocky Mountain	*Acer glabrum*
Maple, sycamore	*Acer pseudoplatanus*
Mock-orange, Lewis	*Philadelphus lewisi*
Mountain-ash, Sitka	*Sorbus sitchensis*
Mulberry, Texas	*Morus microphylla*
Ninebark, Pacific	*Physcocarpus capitatus*
Ocean-spray	*Holodiscus arieafolius*
Peach	*Prunus persica*
Pear	*Pyrus communis*
Pine, eastern white	*Pinus strobus*
Pine, jack	*Pinus banksiana*
Pine, red	*Pinus resinosa*
Pine, Virginia	*Pinus virginiana*
Plum, prune	*Prunus domestia*

(continued)

Table E.2. (Continued)

Common name	Scientific name
	Sensitive (cont.)
Poplar, Lombardy	*Populus nigra* hybrid
Red currant	*Ribes rubrum*
Rockspirea, creambush	*Holodiscus discolor*
Serviceberry, low	*Amelanchier spicata (stolonifera)*
Serviceberry, Saskatoon	*Amelanchier alnifolia*
Serviceberry, Utah	*Amelanchier utahensis*
Sumac, staghorn	*Rhus typhina*
Tulip tree	*Liriodendron tulipifera*
Willow, black	*Salix nigra*
Walnut, English	*Juglans regia*
	Intermediate
Alder, mountain	*Alnus tenuifolia*
Apricot, Chinese	*Prunus armeniaca* var. Chinese
Basswood	*Tilia americana*
Birch, water	*Betula occidentalis (fontinalis)*
Boxelder	*Acer negundo*
Cherry, bitter	*Prunus emarginata*
Chokecherry	*Prunus virginiana*
Cottonwood, black	*Populus trichocarpa*
Cottonwood, eastern	*Populus deltoides*
Cottonwood, narrowleaf	*Populus angustifolia*
Currant, sticky	*Ribes viscosissimum*
Dogwood, red osier	*Cornus stolonifera*
Douglas fir	*Pseudotsuga menziesii*
Elder, blueberry	*Sambucus cerulea*
Elm, American (white)	*Ulmus americana*
Fir, basalm	*Abies balsamea*
Fir, grand	*Abies grandis*
Grape, wild	*Vitis riparia*
Hawthorn, red	*Crataegus columbiana*
Hazel, witch	*Hamamelis virginiana*
Hemlock, western	*Tsuga heterophylla*
Hibiscus	*Hibiscus* sp.
Honeysuckle, tatarian	*Lonicera tatarica*
Hydrangea	*Hydrangea paniculata*
Lilac, common	*Syringa vulgaris*
Mahogany, mountain	*Cercocarpus montanus*
Maple, Douglas	*Acer glabrum douglassi*
Maple, red	*Acer rubrum*
Maple, Rocky Mountain	*Acer glabrum*
Mock-orange	*Philadelphus* sp.
Mock-orange, coronarius	*Philadelphus coronarius*
Mock-orange, virginalis	*Philadelphus virginalis*
Mountain-ash, European	*Sorbus aucuparia*

(continued)

Table E.2. (Continued)

Common name	Scientific name
	Intermediate (cont.)
Mountain-ash, western	*Sorbus scopulina*
Mountain-laurel	*Ceanothus sanguineus*
Oak, white	*Quercus alba*
Pine, Austrian	*Pinus nigra*
Pine, lodgepole	*Pinus contorta*
Pine, ponderosa	*Pinus ponderosa*
Pine, shortleaf	*Pinus echinata*
Pine, western white	*Pinus monticola*
Poplar, balsam	*Populus balsamifera*
Rose	*Rosa* sp.
Sagebrush, big	*Artemsia tridentata*
Snowball bush	*Viburnum* sp.
Snowberry, mountain	*Symphoricarpos oreophilus*
Snowberry, Columbia	*Symphoricarpos rivularis*
Spirea, Van Houts	*Spiraea vanhouttei*
Spirea, shineyleaf	*Spiraea lucida*
Spruce, Engleman	*Picea engelmanni*
Spruce, white	*Picea glauca*
Weigela	*Weigela* sp.
Wisteria	*Wisteria* sp.
	Resistant
Arborvitae (white cedar)	*Thuja occidentalis*
Beech, European	*Fagus sylvatica*
Buck-brush	*Ceanothus velutinus*
Buffalo-berry	*Shepherdia canadensis*
Ceanothus, redstem	*Ceanothus sanguineus*
Cedar, western red	*Thuja plicata*
Citrus	*Citrus* sp.
Cypress, Lawson	*Cupressus lawsoniana*
Dogwood, white	*Cornus florida*
Fir, silver	*Abies amabilis*
Fir, white	*Abies concolor*
Forsythia	*Forsythia viridissima*
Gardenia	*Gardenia* sp.
Ginkgo	*Ginkgo biloba*
Gum, black	*Nyssa sylvatica*
Hawthorn, black	*Crataegus douglasii*
Holly, English	*Ilex aquifolium*
Hornbeam, European	*Carpinus betulus*
Juniper, common	*Juniperus communis*
Juniper, Rocky Mountain	*Juniperus scopulorum*
Juniper, Utah	*Juniperus osteosperma*
Juniper, western	*Juniperus occidentalis*
Kinnikinnick	*Arctostaphylos uva-ursi*

(continued)

Table E.2. (Continued)

Common name	Scientific name
Resistant (cont.)	
Linden, littleleaf	*Tilia cordata*
Locust, black	*Robinia pseudoacacia*
Mahogany, curl-leaf mtn.	*Cercocarpus ledifolius*
Maple, hedge	*Acer campestre*
Maple, mountain	*Acer spicatum*
Maple, Norway	*Acer platanoides*
Maple, silver	*Acer saccharinum*
Maple, sugar	*Acer saccharum*
Oak, English	*Quercus robur*
Oak, Gambel	*Quercus gambelii*
Oak, live	*Quercus virginiana*
Oak, northern red	*Quercus rubra*
Oak, pin	*Quercus palustris*
Oregon grape	*Odostemon aquifolium*
Pine, limber	*Pinus flexilis*
Pine, mugo	*Pinus mugo*
Pine, pinyon	*Pinus edulis*
Planetree, London	*Platanus acerifolia*
Planetree, Oriental (sycamore)	*Platanus orientalis*
Poison-ivy, western	*Toxicodendron radicans rydbergii*
Poplar, Carolina	*Populus canadensis*
Privet	*Ligustrum* sp.
Rhododendron	*Rhododendron* sp.
Sourwood	*Oxydendron arboreum*
Spruce, blue	*Picea pungens*
Squawbush	*Rhus trilobata*
Sumac, smooth	*Rhus glabra*
Sycamore, American (planetree)	*Platanus occidentalis*
Willow	*Salix* sp.
Willow, shrubby	*Salix tristis*
Yew, Pacific	*Taxus brevifolia*

[a]The same genus may appear in more than one SO_2 category since the lists were compiled from the lists of numerous researchers. See the Report for literature citations.

APPENDIX F. FEDERAL EFFLUENT STANDARDS FOR ASH TRANSPORT WATER AND MATERIAL STORAGE RUNOFF

ASH TRANSPORT WATER AND MATERIAL STORAGE RUNOFF

Section 423.11 subparagraph (h) of Title 40, Code of Federal Regulations (40 CFR) states in part that "low volume wastes sources would include but are not limited to waste waters from wet scrubber air pollution control systems." In addition, subparagraph (i) of the same section states, "The term 'ash transport water' shall mean water used in the hydraulic transport of either fly ash or bottom ash." Under guidelines established under Section 423.12 (" ... best practicable control technology currently available"), the quantity of pollutants discharged from low volume sources cannot exceed the quantity determined by multiplying the flow from waste sources times the concentration listed in Table F.1.

Likewise, the quantity of pollutants discharged in ash transport water shall not exceed the quantity determined by multiplying the flow of ash transport water times the concentration listed in Table F.1.

Table F.1. Federal Standards for Low-Volume Waste Effluents[a]

Effluent characteristics	Concentration (mg/L) Maximum for any one day	Average of daily values for 30 consecutive days cannot exceed
Total suspended solids (TSS)	100	30
Oil and grease	20	15

[a]Data from: U.S. Environmental Protection Agency. 1974. Steam electric power generating point source category, effluent guidelines and standards. Fed. Regist. 39(196):36185-36207.

Under Section 423.13 (" ... best available technology economically achievable"), low-volume wastes standards remain the same as those described in Section 423.12 and Table F.1. In Section 423.13, ash transport water is discussed in terms of "fly ash sluicing" and "bottom ash transport water." The standards for fly ash sluicing are the same as discussed under Section 423.12 and Table F.1. The bottom ash transport product is derived using flow of bottom ash transport water and Table F.1. This product is then divided by 12.5.

Section 423.15 ("standards of performance for new sources") again sets standards for low volume wastes equal to those described under Section 423.12 and Table F.1. The product derived for bottom ash transport water as described in Section 423.13 is now divided by 20 rather than 12.5. In Section 423.15, it is further stated that "there shall be no discharge of TSS or oil and grease in fly ash transport water."

Section 423.41 subparagraph (b) of 40 CFR states: "The term 'material storage runoff' shall mean the rainfall runoff from or through any coal, ash or other material storage pile." Under guidelines set forth in 40 CFR Sections 423.42 (" ... best practicable control technology currently available"), 423.43 (" ... best available technology economically achievable"), and 423.44 ("standards of performance for new sources"), effluent standards are set at a maximum of 50 mg/L for total suspended solids (TSS) and a pH range of 6.0 to 9.0.

In addition, subparagraph (b) of these sections states that "any untreated overflow from facilities designed, constructed and operated to treat the volume of material storage runoff and construction runoff which results from a 10 year, 24 hour rainfall event shall not be subject to the limitations ..." described above.

In summary, effluent guidelines for determining ash transport water standards are as follows:

For best practicable control technology:

$$\text{flow} \times \text{concentration*} = \text{standard}$$

For best available technology economically achievable:

- fly ash sluicing

$$\text{flow} \times \text{concentration*} = \text{standard}$$

- bottom ash transport water

$$\frac{\text{flow} \times \text{concentration*}}{12.5} = \text{standard}$$

---

*For appropriate concentration, see Table F.1.

For new source performance standards:

- fly ash sluicing

  no discharge of TSS or oil and grease

- bottom ash transport water

$$\frac{\text{flow} \times \text{concentration*}}{20.0} = \text{standard}$$

Effluent guidelines for determining all low-volume wastes standards, which include scrubber ash, are determined as follows:

$$\text{flow} \times \text{concentration*} = \text{standard}$$

All effluent standards relevant to material storage pile runoff are presented in Table F.2.

Table F.2. Federal Standards for Material Storage-Pile Runoff[a,b]

Effluent characteristic	BPCT	BATEA	NSPS
Total suspended solids (TSS)	50 mg/L	50 mg/L	50 mg/L
pH range	6.0 - 9.0	6.0 - 9.0	6.0 - 9.0

[a]Data from: U.S. Environmental Protection Agency, 1974. (See Table F.1 for complete citation.)
[b]Abbreviations: BPCT, Best practicable control technology; BATEA, Best available technology economically available; NSPS, New Source Performance Standards.

OTHER EFFLUENTS

At present, there are no federal standards regulating downward movement of effluents from ash or sludge disposal ponds through the substrata (seepage). However, the USEPA may have authority to investigate possible groundwater contamination under the Resource Conservation and Recovery Act of 1976 and/or the Safe Drinking Water Act. The agency is currently engaged in a study to determine the impacts of toxic pollutants in the effluents from waste-disposal ponds. Regulations controlling the discharge of these toxic pollutants are expected within a year of completion of the study.

*For appropriate concentration, see Table F.1.

If the discharge from an ash or sludge disposal pond flows into a stream, lake, or aquifer that is used as a drinking water source (for at least 20-25 people), the U.S. Public Health Service Drinking Water Standards apply, and may limit the quality of the seepage or discharge water allowed.

In addition to the federal standards and regulations, various states may have regulatory authority over seepage and/or surface-water runoff through such means as state environmental impact statements and National Pollutant Discharge Elimination System permits. Possible state agencies which may be involved in regulating groundwater and/or surface-water runoff include departments of natural resources, conservation departments, pollution control boards, and state environmental protection agencies. Public law PL 92-500 stipulates that the state regulation takes precedence over the federal regulation when the former is more stringent.

APPENDIX G. QUALITATIVE ASSESSMENT OF THE POTENTIAL FOR ADVERSE EFFECTS TO THE TERRESTRIAL ENVIRONMENT FROM WASTE-DISPOSAL SITE SEEPAGE

Currently, all soils in the United States are being evaluated for their limitations for waste disposal. These ratings can be found in published Soil Survey Reports for various counties; included in the reports are reasons for the limitations. Unfortunately, most counties in a large number of states do not have completed Soil Survey Reports published; other reports are of older vintage when such ratings were not routinely made. Inquiries to the district Soil Conservation Service regarding published and unpublished data on the soils of a specific site should be an initial step in any assessment of land disposal impacts. Soil Survey Reports also contain a wealth of information on the vegetation, wildlife, and land use of a given county, as well as data on the geology, soils, climate, topography, and depths to the seasonally high water table.

In the absence of soil survey information, Table G.1 can provide some measure of the potential for impact from seepage, given some general information about a particular site and assuming that the impoundment area is unlined. (Lining of an impoundment area implies, here, the correct placement of clay or a synthetic material on the bottom and sides of the impoundment.) It must be emphasized that the table does not include all factors involved in the evaluation of seepage effects; rather, it lists the major factors related to specific site characteristics that could be readily evaluated. It is essential to realize that the factors must be considered concurrently, rather than as separate entities. An explanation of these factors follows, and a hypothetical example is presented to illustrate the use of the table.

NATURE OF WASTE

When the ash and sludge are deposited dry, or with no standing water, there will be very little or no seepage of waste liquors, but leaching by rainfall may occur. The chances for the leachate reaching the groundwater are high in a region where rainfall is high. If the groundwater aquifer is below a relatively impervious layer such as granite or shale, contamination of the aquifer is unlikely. Such an impervious layer

Table G.1. Potential for Adverse Effects to Groundwater and the Terrestrial Food Chain from Seepage from Unlined Ash and Sludge Waste-Disposal Sites

	Relative probability of	
Factor	Groundwater contamination	Food chain contamination via soil
Nature of waste		
Dry	Low to moderate	Low to moderate
Slurry	High	High
Acid	High	High
Alkaline	Low to moderate	Low to moderate
Nature of substrata[a]		
Granite	Extremely low	Not applicable
Shale	Low	Not applicable
Sandstone	Moderate	Not applicable
Sand	High	Not applicable
Soil	High	High
Nature of soils		
Clays	Low	High
Loams	High	High
Sands, sandy loams	Very high	High to low
Rainfall zone[b]		
< 25 cm (< 10 inches)	Low	Low to high
25-76 cm (10-30 inches)	Low to high	High
> 76 cm (> 30 inches)	High	High, except for sandy areas

[a]Defined as the layer or layers of natural material beneath the waste, or between the waste impoundment and the groundwater aquifer.
[b]Annual average precipitation.

will not, however, protect the food chain, except where the soils are sandy; in this latter case, the contaminants will tend to be washed downward, away from the root zone of most plants.

If the waste is deposited as a slurry, chances of contamination of both groundwater and the food chain are high, unless the impoundment area is lined or impervious layers are present.

Because trace metals are relatively insoluble in alkaline media, chances of movement of the trace elements to groundwater are low when the waste is alkaline, particularly in regions of low rainfall. However, these relatively insoluble forms may become slowly soluble (and more readily available to vegetation) over the long term--due to physical, chemical and biological processes in the soil. Very little, if anything, is known about this aspect of waste material in soils.

NATURE OF SUBSTRATA

Where the disposal area is not excavated to bedrock, the underlying strata is the natural soil. In cases where the impoundment is excavated to bedrock, the material forming the sides of the impoundment is usually surface soil and subsoil. In either case, unless the impoundment basin is completely lined (e.g., with clay or with a synthetic liner) lateral seepage through the soil can occur, particularly if the waste is deposited as a slurry.

Contamination of groundwater is related to the permeability of the impoundment material; in general, the permeability of such material increases in the order granite < shale < sandstone < soil < sand. In regions where the rainfall is low (i.e., less than 25 cm/year), seepage to groundwater will be unlikely in areas underlain by all but the most permeable material unless the water table is high (e.g., less than 5 meters below the surface). In areas of high water table, installation of a liner, particularly if the impoundment is underlain by sandstone, soil, or sand would be essential to preclude contamination of the groundwater even if the waste were deposited in a dry state.

An impermeable substrata, on the other hand, would essentially have no effect on the chances for food chain contamination by waste impoundment leaching; such contamination will be dependent on the nature of the surrounding soils and the amount of rainfall.

NATURE OF SOILS

At most waste-disposal sites, it can be assumed that the waste will be in physical contact with the surrounding soils, unless the impoundment is lined. One property of soils that is a major factor in transport of seepage is soil texture, i.e., the proportions of sand, silt, and clay. "Sand" refers to particle sizes between 2 mm and 0.05 mm diameter, "silt" between 0.05 mm and 0.002 mm diameter, and "clay" less than 0.002 mm diameter (USDA Classification). The size range of "sand" is further classified as follows: very coarse sand, 2.0-1.0 mm; coarse sand, 1.0-0.5 mm; medium sand, 0.5-0.25 mm; fine sand, 0.25-0.10 mm; very fine sand, 0.10-0.05 mm. The textural names used in soil science to designate the proportions of the sand, silt, and clay size classes are given in Table G.2.

Table G.2. Percentages of Sand, Silt, and Clay in the Textural Classes[a]

Textural name (Soil class)	Range in percent		
	Sand	Silt	Clay
Sand[b]	85-100	0-15	0-10
Loamy sand[b]	70-90	0-30	0-15
Sandy loam[b]	43-80	0-50	0-20
Loam	23-52	28-50	7-27
Silt loam	0-50	50-88	0-27
Silt	0-20	8-10	0-12
Sandy clay loam	45-80	0-28	20-35
Clay loam	20-45	15-53	27-40
Silty clay loam	0-20	40-73	27-40
Sandy clay	45-65	0-20	35-55
Silty clay	0-20	40-60	40-60
Clay	0-45	0-40	40-100

[a]From: U.S. Department of Agriculture, Forest Service. 1961. Handbook of Soils.
[b]These textural names can be modified by the following designations: coarse = greater than 25% coarse sand; fine = 50% or more fine sand, less than 25% coarse sand; very fine = 50% or more very fine sand.

Although a high clay content in a soil tends to decrease concentrations of cations in seepage to groundwater, such retention in the soil allows a greater concentration source for eventual uptake by vegetation. Even where the waste is deposited dry, leaching by rainwater can introduce potentially toxic elements to the soils from the waste if the impoundment area is not lined. If the soils are sandy, there is a tendency for rainfall to leach away the cations from the root zone, but this increases the chances for groundwater contamination.

There are regions of the country where high concentrations of certain elements such as selenium and molybdenum occur locally (see the Report, Appendix E). In these regions, addition to the soil of these elements from waste seepage over the long term may aggravate the potential for adverse effects to wildlife.

RAINFALL ZONE

The amount of rainfall entering a waste-disposal site and environs markedly affects the potential for adverse effects from the waste at sites where the waste-disposal impoundments are not lined. If the average annual rainfall is low, seepage from the waste-disposal site will tend to remain in the upper layers of the soil, thus increasing the chances for uptake by vegetation; however, seepage to groundwater will be unlikely, depending on the depth at which the water table occurs. In zones of high rainfall, ionic constituents of waste will tend to be leached rapidly to groundwater, particularly where the substrata is sandy. High rainfall will also tend to move dissolved material laterally into the soil; in sandy soils, these dissolved materials would tend to be leached from plant root zones, whereas in soils with higher proportions of clay, a larger fraction of the dissolved constituents would be retained in the soil and may eventually be available for plant uptake.

OTHER FACTORS

The four factors discussed above are important in the transport of waste-pond constituents into soils and groundwater. The ultimate appearance of adverse effects to vegetation and wildlife will be dependent also on the nature of the vegetation. For example, introduction of selenium and/or molybdenum into certain species of vegetation may cause no adverse effects to the vegetation; herbivores, however, may become toxified. Calcium is not normally considered a toxic element, but if present in the soil at high levels, particularly at alkaline pH, it can cause a phosphate deficiency in vegetation by tying up the phosphate as insoluble calcium phosphate. Sulfates and chlorides are plant nutrients, but if present in high concentrations in areas of low rainfall, they can cause salinization of the soil. Salinized soil is a poor medium for the growth of most vegetation.

The presence of a unique community (e.g., a bog or marsh) on or in the close environs of ash/sludge ponds dictates that careful evaluation of seepage flow be made. Such site-specific factors should be included in the assessment of seepage effects.

ILLUSTRATIVE EXAMPLE

To illustrate the use of Table G.1, consider a hypothetical site with the following characteristics:

1. The site is located in a region where the annual average rainfall is less than 25 cm (10 inches).

2. Directly beneath the waste ponds is a sandy loam soil overlying a sandstone formation that includes a groundwater aquifer.

3. Ash and sludge are slurried to the ponds, which are not lined. The waste slurries are alkaline.

Reference to Table G.1 indicates that the chances of groundwater contamination will be high, due primarily to the slurry nature of the waste, the sandy loam soil, and the sandstone substrata. Rainfall plays little part in this instance. The chances for food chain contamination will also be high, due primarily to the slurry nature of the waste which would tend to seep laterally into the sandy soil, as well as vertically downward. The low rainfall of the area would be insufficient to wash the contaminants below the root zone of most plants, particularly because areas of low rainfall generally also have high evaporation rates, which would tend to move solutes upward with soil water. It is very likely that contamination of the vegetation will not occur immediately; the alkaline nature of the waste indicates that most of the potentially toxic elements will be insoluble. Over the long term, however, these elements may slowly become available and accumulate in perennial vegetation.

If the waste is deposited dry, however, the potential for groundwater contamination is low despite the sandy nature of the substrata, because the rainfall is very likely insufficient to leach contaminants down to the aquifer. Contamination of the food chain will also tend to be low due to insufficient water (low rainfall) to move contaminants into the surrounding soil, and the relative insolubility of the contaminants (alkaline waste).

At this site, therefore, seepage contamination of groundwater or vegetation (unless some other site-specific factor indicates otherwise) is of minor concern if the waste is to be deposited in the dry state. Indeed, a recommendation can be made to the effect that the waste should be deposited dry. However, in that case, attention must be focused on protecting air quality by suitable dust-control measures until reclamation can be accomplished.

This example indicates the importance of proper reclamation of the disposal site after operation, i.e., an adequate depth of earth cover prior to revegetation to ensure that plant roots do not penetrate to the waste material if toxic effects are expected. An additional aspect of the earth cover is the attenuation effect on radon emanation and gamma radiation from the radioactive elements in the waste.

APPENDIX H. GUIDE TO THE CHOICE OF LINERS FOR ASH AND FGD SLUDGE DISPOSAL PONDS

The type of liner to be used should be determined by the amount of seepage which can be tolerated and by the expected tolerance to the chemical and physical stresses that the liner will be subjected to. There are six major categories of liners:

1. Compacted earth liners are formed by compacting the surface of the soil which forms the impoundment embankments. These liners may have relatively high hydraulic conductivities.

2. Clay liners are a special type of compacted earth liner. Clay is usually borrowed from a nearby pit or purchased commercially. Sodium-rich clays, bentonite in particular, are preferred. Hydraulic conductivities for pure clay liners may be in the vicinity of 9.7×10^{-8} cm/sec.

3. Chemical sealants and soil additives fill soil interstices or cause chemical reactions which reduce permeability. They may by applied by spraying, mixing with the soil, or as additives to the waste stream. Presently, chemical sealants are not always effective.

4. Fly ash may be compacted to achieve a hydraulic conductivity of between 5×10^{-5} and 5×10^{-4} cm/sec. Although this is somewhat higher than what is usually desired in a liner, addition of a chemical sealant might produce a suitable material.

5. Rigid liners include Portland cement concrete, gunite, asphalt concrete, and soil cement. These have a very low hydraulic conductivity but are not impermeable. Their biggest drawback is a susceptibility to fracture.

6. Flexible synthetic liners include plastics, rubbers, and combinations of the two. Some of these are very nearly impermeable. Many, however, deteriorate with exposure to the sun, chemicals, or temperature extremes. Puncture, ripping, and joint sealing may be problems. Most are conditionally guaranteed for 20 years.

The suitability of these liners under various subsoil and embankment conditions is indicated in Table H.1. Several types of synthetic liners are rated in Table H.2.

Table H.1. Liner Suitability for Various Subsoils and Embankments

Subsoil or embankment material	Liners: Most suitable	Suitable	Least suitable
Silty, clayey soils; loess	1,2,6	3,4,5	
Expansive soils	2,6	1,3,4	5
High-sodium clays	1,2,6	3,4	5
Alluvium	1,2,6	3,4,5	
Colluvium	1,2,6	3,4,5	
Micaceous soils	2,6	3,4	1,5
Clean sands	6	2,4,5	1,3
Clean gravels	6	2,4,5	1,3
Fractured, porous, or soluble rocks	5,6	2,4	1,3

Code for liners: 1 - compacted earth; 2 - clay; 3 - chemical sealants and additives; 4 - compacted fly ash; 5 - rigid liners; 6 - flexible synthetic liners

Table H.2. Qualitative Assessment of the Characteristics of Synthetic Liners

Characteristics	Liners[a]: PVC	PE	CPE	Hypalon	Butyl	Neoprene	3110
Tensile strength	A[b]	B	B	A	B	B	B
Elastic strain	B	C	B	C	A	B	B
Puncture resistance	A	C	B	B	B	B	B
Abrasion resistance	A	C	B	B	B	B	B
Flexibility	B	C	A	B	B	B	B
Adhesive system	B	C	B	B	C	C	A
Resistance to sun	C	C	A	A	A	C	A
Resistance to chemicals	A	A	A	A	A	B	A
Resistance to temperature	C	C	C	A	A	0	B

[a]Abbreviations for liners: PVC = polyvinyl chloride; PE = polyethylene; CPE = chlorinated polyethylene; 3110 = elasticized polyolefin.

[b]Rating of liners: A = very good; B = good; C = poor; 0 = unknown.

GLOSSARY

The terms selected for the Glossary are mainly terms that would not ordinarily be familiar to biologists. The definitions provided are those applicable to the subject matter of the Manual.

ACID RAIN - Rain that contains acidic substances such as sulfuric, hydrochloric, and nitric acids, in addition to the normal carbonic acid component. Acidity of the rain can be as low as pH 3. "Normal" rain is typically pH 6-8.

AMBIENT AIR QUALITY - The background concentrations of pollutants present in an area.

AQUIFER - A permeable unit of rock or sediment from which groundwater can be extracted. Confined aquifers are bounded on top and bottom by impermeable materials. Unconfined aquifers are bounded on top by a water table.

ASH (COAL) - The solid material remaining after coal is burned. Contains most of the mineral and inorganic material originally present in the coal.

AVAILABLE ELEMENTS (SOIL) - Chemical elements in a soil that are in a form capable of assimilation by plants. May comprise only a portion of the total amount of the element present in that soil.

BAG HOUSE - A series of filters to remove particles from the flue gases.

BENEFICIATION (COAL) - A mechanical process for cleaning coal to remove noncombustible material.

BERM - A bench of soil or rock built on an earthen structure. It may serve various purposes such as a dike, as an encasement for a drainage system, as weight for structural stabilization of an embankment, or as erosion control.

BOTTOM ASH - Dry ash from coal combustion that does not melt but is too heavy to be entrained in the flue gas. Also called cinders.

BUFFERING CAPACITY - A measure of the tendency of a soil or water to resist large changes in pH.

BULK DENSITY (SOIL) - The weight per unit volume of soil. Agricultural soils have bulk densities usually between 1.2 and 1.7 g/cm^3. A compacted clay may have a bulk density of 2 g/cm^3.

CAPACITY (POWER PLANT) - Rated capacity is the design output (MWe) or size of a power plant. Operating capacity is the actual output (MWe) of a power plant, averaged over a year. Typically, it is around 70% of the rated capacity. Capacity factor = $\frac{\text{Operating capacity}}{\text{Rated capacity}} \times 100$

Note: These are not precise definitions, but are correct for purposes of this Manual.

CATION EXCHANGE CAPACITY (SOIL) - The relative adsorptive power of a soil for cations. Expressed as the number of milliequivalents of cations per 100 grams of dry soil.

CLARIFLOCCULATOR - A device for handling dilute suspensions to produce a relatively clear supernatant liquid (overflow), and an agglomeration of settleable or filterable solids that are withdrawn at the bottom of the device (underflow). It consists of a tank, a means for introducing the feed suspension, a drive-actuated rake mechanism for moving settled solids to a discharge point, a means for removing the thickened solids, and a means for removing the clarified liquor. Chemicals may be added to the feed to enhance the physical separation.

CLAY LINER (WASTE DISPOSAL) - A liner consisting of a compacted layer of a clay with a low hydraulic conductivity.

CLOSED-CYCLE COOLING SYSTEM - Condenser cooling water is passed through the condensers; cooled in cooling towers, cooling ponds, or cooling sprays; and returned to the condensers. Withdrawal of water (makeup) from a natural water source is required to replace evaporative and other losses. Some portion of the water is discharged to natural surface waters (blowdown) to prevent accumulation of excessive amounts of salts in the cooling water.

CONSUMPTIVE USE (WATER) - That portion of water taken into a power plant that is not directly returned to the surface water body. The water is lost through evaporation and seepage.

DEWATERING (CONSTRUCTION) - Removal of water from an excavation, usually by pumping.

DEWATERING (SLURRY) - The process of removing water from a slurry. Processes include natural evaporation, centrifugation, decantation, and filtration.

DISPERSION (ATMOSPHERIC) - The mixing and dilution of a pollutant in the atmosphere.

DISPERSION MODEL (ATMOSPHERIC) - An analytical method used to predict the downwind concentration of a pollutant emitted into the atmosphere.

EFFICIENCY (POWER PLANT) - The electrical energy output achieved by a power plant per unit of coal energy put into the plant.

ELECTROSTATIC PRECIPITATOR - A device used to remove particles from flue gases, by charging the particles electrically and collecting them on appropriate electrodes.

FABRIC FILTER - A material to remove particles from an air stream, similar to a vacuum cleaner bag.

FGD (FLUE-GAS DESULFURIZATION) - Any process used to remove sulfur (largely sulfur oxides) from flue gases.

FILL AREA (CONSTRUCTION) - Natural or man-made excavations used for the disposal of unwanted solid material.

FIXATIVE (FOR FGD SLUDGE) - A chemical additive that is mixed with FGD sludge to give it more desirable properties for disposal. Commonly, a fixative is used to lessen the thixotropic characteristics of the sludge.

FLOODPLAIN - The portion of a river or stream valley that is periodically inundated during episodes of excessive runoff. The proposed solid waste disposal regulations (40 CFR, Part 257) use the term "floodplain" to refer to the 100-year floodplain. The 100-year floodplain is the area which is likely to be inundated once in one hundred years.

FLOW, AVERAGE ANNUAL - The average volume of water to pass a given cross-section of a stream during a given year. This is usually expressed in units such as cubic feet per second (cfs).

FLOW, 7-DAY/10-YR LOW FLOW - The lowest volume of flow statistically expected to pass through a given cross-section of a stream during a 7-day timespan in any 10-year period.

FLUIDIZED BED COMBUSTION (COAL) - Burning coal along with ground limestone ($CaCO_3$) or dolomite ($MgCO_3$). This is one method to reduce emissions of sulfur dioxide from coal-fired power plants. The calcium (or magnesium) combines with sulfur dioxide during the burning process to form solid calcium sulfate (or magnesium sulfate).

FLUSHING TIME (IMPOUNDMENT) - The period of time required to completely replace the volume of water in an impoundment through natural processes.

FLY ASH - The portion of the coal ash carried up the flue.

FUGITIVE DUST - Particles of dust removed from a surface by the wind.

FUMIGATION CONDITIONS - Atmospheric conditions during which relatively undiluted pollutants are brought to ground level by turbulent motions, thereby increasing surface concentrations of the pollutant.

GOB - Solid fragments in waste material from coal washing that do not remain suspended in the cleaning water.

GROUNDWATER - The water contained within the pore spaces of rock or soil.

HARDNESS (WATER) - A characteristic of water represented by the total concentration of calcium and magnesium ions, expressed as calcium carbonate.

HEAT CONTENT (COAL) - The heat per pound (usually expressed as Btu/lb) that is released from coal during combustion.

HIGH-SULFUR COAL - In general, coal that contains over 1% sulfur. In some instances, however, it is defined as coal containing over 3% sulfur.

HYDRAULIC CONDUCTIVITY - The rate at which water can flow through a permeable material.

HYDRAULIC GRADIENT - The change in hydraulic head over a distance. Nearly horizontal flow has a very small gradient.

HYDRAULIC HEAD - The energy which allows water to flow. It consists of a pressure and a height component. Water flows from areas of higher to lower head.

IMPERMEABLE LINER (WASTE DISPOSAL) - Material placed on the bottom and sides of a waste impoundment to contain the waste material. No liner is completely impermeable, but many of the synthetic materials are relatively impermeable compared to natural earth liners.

INFILTRATION RATE (SOIL) - The rate at which water enters the surface layer of soil.

LAY-DOWN AREA (CONSTRUCTION) - An area used for temporary storage of construction material.

LEACHATE - Water and dissolved constituents draining out of a given column of saturated porous material such as soil.

LEACHING - The process of moving dissolved constituents (usually by water) downward through a column of porous material such as soil.

MARCASITE - White iron pyrites, FeS_2.

MESH SIZE - Refers to size of sieve openings. A list of the U.S. standard mesh screen numbers and sizes of openings includes the following:

Mesh No.	Diameter (mm)
4	4.76
6	3.36
10	2.00
20	0.84
40	0.42
60	0.25
100	0.149
200	0.074

MINE-MOUTH - Operations such as coal washing and power generation carried out adjacent to the coal mine.

MODELS - Simplified representations of complex phenomena. Models may be graphic, mathematical, or verbal.

ONCE-THROUGH COOLING SYSTEM - Condenser cooling water is withdrawn from a surface water source, passed through the condensers, and returned to the surface water source.

ORGANIC MATTER (SOIL) - The amount of plant and animal residues in a soil. Soils typically contain around 1 to 6% organic matter.

PARTICULATES - Particles of material suspended in the atmosphere.

PERMEABILITY (SOIL) - The quality of a soil that enables it to transmit water or air. It is not equivalent to infiltration rate (see INFILTRATION RATE).

PERMEABILITY CLASSES (SOIL) -

Very slow	< 0.05 inches/hour
Slow	0.05-0.20
Moderately slow	0.20-0.80
Moderate	0.80-2.50
Moderately rapid	2.50-5.00
Rapid	5.00-10.00
Very rapid	> 10.00

PIPING - A progressive failure of a dike or embankment which occurs when a seepage velocity is great enough to cause internal erosion.

PLUME (ATMOSPHERIC) - A continuous, definable volume of pollutant in the atmosphere. Can be visible or invisible.

PLUME (WATER) - A stream of water that enters an existing body of water and is still distinguishable because of differences such as velocity, chemistry, or temperature between the influent water and that of the receiving water. A plume dissipates with dilution and dispersion.

PLUME MODEL (ATMOSPHERIC) - An analytical method for the prediction of plume behavior in the atmosphere.

POINT SOURCE (AIR) - A single emitter of pollution.

POINT SOURCE (WATER) - A single source of pollutant discharge to surface waters.

PSD - Prevent significant deterioration. Pollutant concentration levels in various PSD class designations may increase only by set amounts. Designed to maintain pristine air quality regions.

PYRITE - Iron sulfide, FeS_2, yellow in color.

RADIATION DOSE - Generally refers to the quantity of energy absorbed in matter from ionizing radiation. When the term is applied to humans, dose is given as dose equivalent, the unit of which is the REM. In computing the rem, the quantity and type of radiation is taken into account to obtain a measure of the biological effect on humans of the radiation. When the term is applied to animals, dose is given in terms of the more basic absorbed dose. The unit of absorbed dose is the RAD, defined as equal to 100 ergs per gram.

RADIATION DOSE RATE - The radiation dose delivered per unit time.

RECLAMATION - Usually implies the restoration of disturbed land to primary production.

REFUSE (COAL) - Waste material from the coal cleaning process.

RUNOFF (RAINFALL) - All rainfall (and snowmelt) that does not soak into the ground, evaporate immediately, or is used by vegetation becomes runoff. This flows down slopes and forms streams.

SCALES OF MOTION (METEOROLOGICAL) - A description of the size of meteorological phenomena.

Scale	Typical dimensions (km)
Planetary	1,000-10,000
Synoptic	100-1,000
Meso	10-100
Micro	< 10

SCRUBBER SLUDGE (FGD) - Semisolid waste material, usually $CaSO_3$ and $CaSO_4$, resulting from the removal of sulfur oxides from flue gases using lime, limestone, or double alkali techniques.

SEEPAGE - Any water or liquid effluent which flows through a porous media. This term is often used to refer to the liquid lost through the bottom of a waste pond.

SLAG - That portion of the coal ash that melts to a viscous fluid at boiler operating temperatures, and cools to a glassy, angular material.

SLURRY - Any mixture of water and finely divided solids. Can refer to mixtures of coal and water (coal slurry), ash and water (ash slurry), desulfurization sludge and water (scrubber slurry), or coal refuse and water (refuse slurry).

STACK (POWER PLANT) - A chimney associated with a power plant for the purpose of discharging gases into the atmosphere.

STEAM-ELECTRIC POWER PLANT - A power plant that generates electric power through steam-driven turbines. In commercial power plants, the fuel used to produce steam from water can be coal, oil, natural gas, or enriched uranium.

SUPERHEATER (POWER PLANT) - A system of tubes located at the top of the boiler in which saturated steam is superheated by combustion gases.

SYNTHETIC LINER - Refers to any of a growing number of liners manufactured from plastics, rubbers or asphalts.

TEXTURE (SOIL) - The proportion of sand, silt, and clay in a soil. Soil texture is expressed in terms such as "sandy loam," "clay," "silty clay loam," etc.

THROW-AWAY SYSTEM (FLUE-GAS DESULFURIZATION) - A system in which the waste product from flue gas desulfurization is not recycled or reclaimed, but instead disposed of as waste.

TRACE ELEMENTS - Chemical elements that normally are present in minute (trace) quantities. Includes metals such as chromium, zinc, cadmium, copper, and non-metals such as selenium, boron, and arsenic.

UNDERFLOW (CLARIFIER) - The stream of coarse particles that are separated by a clarifier or cyclone (see also CLARIFLOCCULATOR).

UNSATURATED FLOW - Flow of a liquid through a porous medium in which some of the pore space is occupied by air. Unsaturated flow is usually slower than saturated flow under the same conditions.

VACUUM DISC FILTER - A continuous rotary vacuum filter made up of filter disks mounted at regular intervals around a hollow center shaft covered with a cloth filter. The device is used for dewatering sludge or solids by application of a vacuum inside the disks. A layer of caked solids (filter cake) is formed on the outer filter surface, and is subsequently removed.

WATER-HOLDING CAPACITY (SOIL) - The total amount of water capable of being held in a soil by capillary forces. Usually expressed as percent by weight of dry soil.

WATERSHED - An area, usually a valley or collection of valleys, surrounded by surface water divides. All precipitation falling into a watershed supplies runoff to the same stream.

WATER TABLE - The surface which separates the groundwater in an unconfined aquifer (an aquifer not bounded on top by an impermeable layer) from the unsaturated zone above it (see AQUIFER).

TABLE OF METRIC/ENGLISH EQUIVALENTS

Multiply	By	To obtain
Centimeters (cm)	0.3937	Inches
Cubic centimeters (cm^3)	0.0610	Cubic inches
Cubic meters (m^3)	2.6417×10^2	Gallons
Cubic meters (m^3)	35.3146	Cubic feet
Cubic meters (m^3)	1.308	Cubic yards
Cubic meters/second (cm^3/s)	15.8503×10^3	Gallons/minute
Degrees Celsius (°C) + 17.78	1.8	Degrees Fahrenheit
Grams (g)	0.0353	Ounces
Hectares (ha)	2.47	Acres
Joules (J)	9.485×10^{-4}	British thermal units
Joules (J)	2.778×10^{-7}	Kilowatt-hours
Joules/kilogram (J/kg)	4.303×10^{-4}	British thermal units/pound
Kilograms (kg)	2.2046	Pounds
Kilograms (kg)	0.0011	Tons, short
Kilometers (km)	0.6214	Miles
Liters (L)	0.2642	Gallons
Liters/second (L/s)	15.851	Gallons/minute
Meters (m)	3.2808	Feet
Pascals (Pa)	0.145×10^{-3}	Pounds/square inch
Square kilometers (km^2)	0.3861	Square miles
Square meters (m^2)	10.764	Square feet
Square meters (m^2)	1.1960	Square yards
Tons, metric (MT)	1.1023	Tons, short

NOTE: μg/g = ppm; mg/L $\cong$ ppm (in water).

TABLE OF ENGLISH/METRIC EQUIVALENTS

Multiply	By	To obtain
Acres	0.4047	Hectares
British thermal units [(Btu) thermochemical]	1.0544×10^3	Joules
British thermal units/pound (Btu/lb)	2.324×10^3	Joules/kilogram
Cubic feet (ft^3)	0.0283	Cubic meters
Cubic inches ($in.^3$)	16.387	Cubic centimeters
Cubic yards (yd^3)	0.7646	Cubic meters
Degrees Fahrenheit (°F) - 32	5/9	Degrees Celsius
Feet (ft)	0.3048	Meters
Gallons (gal)	3.7854	Liters
Gallons (gal)	0.0038	Cubic meters
Gallons/minute (gal/min)	0.0631	Liters/second
Gallons/minute (gal/min)	6.309×10^{-5}	Cubic meters/second
Inches (in.)	2.540	Centimeters
Kilowatt-hours (kW•h)	3.60×10^6	Joules
Miles (mi)	1.6093	Kilometers
Ounces (oz)	28.350	Grams
Pounds (lb)	0.4536	Kilograms
Pounds/square inch (psi)	6.8947×10^3	Pascals
Square feet (ft^2)	0.0929	Square meters
Square miles (mi^2)	2.590	Square kilometers
Square yards (yd^2)	0.8361	Square meters
Tons, short (t)	9.0718×10^2	Kilograms
Tons, short (t)	0.9072	Tons, metric

As the Nation's principal conservation agency, the Department of the Interior has responsibility for most of our nationally owned public lands and natural resources. This includes fostering the wisest use of our land and water resources, protecting our fish and wildlife, preserving the environment and cultural value of our national parks and historical places, and providing for the enjoyment of life through outdoor recreation. The Department assesses our energy and mineral resources and works to assure that their development is in the best interests of all our people. The Department also has a major responsibility for American Indian reservation communities and for people who live in island territories under U.S. administration.