Environmental Impacts of Power Generation

Introduction

Most environmental impacts can be classified into those that primarily affect our air, water, or land. For example, emissions of nitrogen oxides (NO_x) from power plant stacks may affect smog levels; discharges of heated water into our rivers and the Chesapeake Bay affect fish populations. Other parts of our environment are affected by power plants as well: noise from power plants can intrude on the environment, and the construction of power plants and transmission lines can affect valuable historical and archaeological resources.

Some activities at power plants can affect the air, water, and land resources simultaneously. Acid rain, for example, arises partially from air pollutants that are released from power plant stacks, transformed in the atmosphere and then fall to the ground affecting lakes, rivers, and forests. Radiological releases from nuclear power plants enter the air, water, and river sediments. Each of these topics is discussed in the following section.

Air Impacts

The combustion of fossil fuels to generate electricity at power plants in Maryland results in the release of air pollutants that can potentially degrade the air quality both locally and regionally. Since the 1970s, the U.S. Environmental Protection Agency (U.S. EPA) has taken action through provisions of the Clean Air Act and its subsequent Amendments to monitor and control the effects of air pollutants from power plants and other sources.

Air monitoring performed by the state indicates that existing controls are effective in keeping most pollutant levels in the ambient air below air quality standards. Currently, ambient levels of sulfur dioxide (SO_2), nitrogen dioxide, and particulate matter are well within the limits set by the U.S. EPA. There are some localized exceedances of the carbon monoxide standard in high traffic areas of metropolitan Washington, D.C., but these primarily result from motor vehicle emissions. At present, the two key air quality issues concerning Maryland power plant emissions are: 1) ozone pollution, and 2) acid rain.

Air Quality Index

The U.S. EPA has defined **National Ambient Air Quality Standards (NAAQS)**, or upper limit air concentration levels of various pollutants, that it judges to be necessary to protect the public. Maryland has devised a simple system of reporting the current state of air quality with respect to these standards called the **Air Quality Index** or **Pollutant Standards Index.** The index is reported on a scale from 0 to 500, with 100 corresponding to the NAAQS for ozone, carbon monoxide, nitrogen dioxide, sulfur dioxide, or particulate matter.

This index is often reported on local news broadcasts with the weather forecast. Measurements of pollutant concentrations are assessed at 9 a.m., 1 p.m., and 4 p.m. daily. If the index is between 0 and 50, the air quality is considered good. Values between 51-100 refer to moderate air quality, 101-200 refer to unhealthful levels, and values of 200 or greater refer to very unhealthful or critical air quality. Rarely in Maryland do values ever exceed the critical value of 100 for extended periods of time. When this situation occurs, meteorological conditions are watched closely to see if conditions are expected to improve. If not, an **air stagnation advisory** may be declared, and actions will be taken to help prevent the air quality condition from worsening. Incineration may be halted, fuel-burning facilities may be asked to switch to less-polluting fuels, and other sources of air pollution may be urged to take measures to reduce their emissions.

Ozone: Good Guy or Bad Guy?

The topic of ozone is frequently in the press . . . usually with reference to either the **"ozone layer"** or the **"urban ozone problem."** These are two completely different issues. In the first case, we are worried about the destruction of ozone; in the second case, we are worried about its formation. What is ozone? And why are we so concerned about it? It is the difference in location and origin that leads to confusion regarding ozone. The same chemical with the same properties is regarded as a "good guy" or a "bad guy" depending on where it is found and how it is formed.

Ozone is a colorless gas composed entirely of oxygen. It is most recognizable by its odor — the electrical smell noticeable immediately after the passage of a strong thunderstorm is ozone. Ozone occurs naturally in the stratosphere (about 18 to 30 miles above the ground) and in trace amounts at the Earth's surface. The naturally occurring ozone found in the stratosphere is essential for life on earth because it absorbs most of the dangerous ultraviolet radiation coming into the atmosphere. A major reduction in this stratospheric ozone layer could produce a substantial increase in the number of human skin cancers and major changes in the Earth's flora and fauna.

Ozone also results from human activities but, unlike most air pollutants, there are very few manmade sources of ozone. Instead, ozone is formed indirectly from other air pollutants emitted by humans. When these **"ozone precursors"** (such as nitrogen oxides from power plants and cars, and hydrocarbons from cars and petroleum-based chemicals) are cooked by sunlight under stagnant weather conditions, large quantities of ozone can be formed near the ground.

The manmade ozone found near the ground is considered an air pollutant because, among other effects, it reduces lung function in humans and causes damage to forests, crops; rubber, and fabrics. It is the presence of this ground-level ozone of human origin that gives rise to the urban ozone problem.

NO_x Emissions and Urban Ozone

Of the major pollutants for which the U.S. EPA has set **National Ambient Air Quality Standards** (NAAQS), the most pervasive problem continues to be ozone, an important component of urban smog. One of the goals of the Clean Air Act is to bring areas that are not attaining the NAAQS (that is, **nonattainment areas**) into attainment with the standard. In the past, ozone reduction strategies focused on controlling volatile organic compound (VOC) emissions; however, recent studies indicate the need to control both VOCs and NO_x emissions to attain the ozone NAAQS. Power plants are major sources of NO_x but only minor sources of VOCs. The 1990 Amendments to the Clean Air Act require major NO_x sources to reduce their emissions.

Ozone Levels in Maryland

Maryland's ozone air pollution is a significant concern; the ozone problems in the Baltimore and Washington, D.C. areas rank sixth and tenth worst in the nation, respectively. Under the U.S. EPA's classification system for indicating the severity of ozone pollution, the Baltimore area is designated a **severe nonattainment area**, and the Washington, D.C. area is designated a **serious nonattainment area** (Figure 2-1). Ozone measurements for 1991 showed that the NAAQS was exceeded on 17 days somewhere in Maryland.

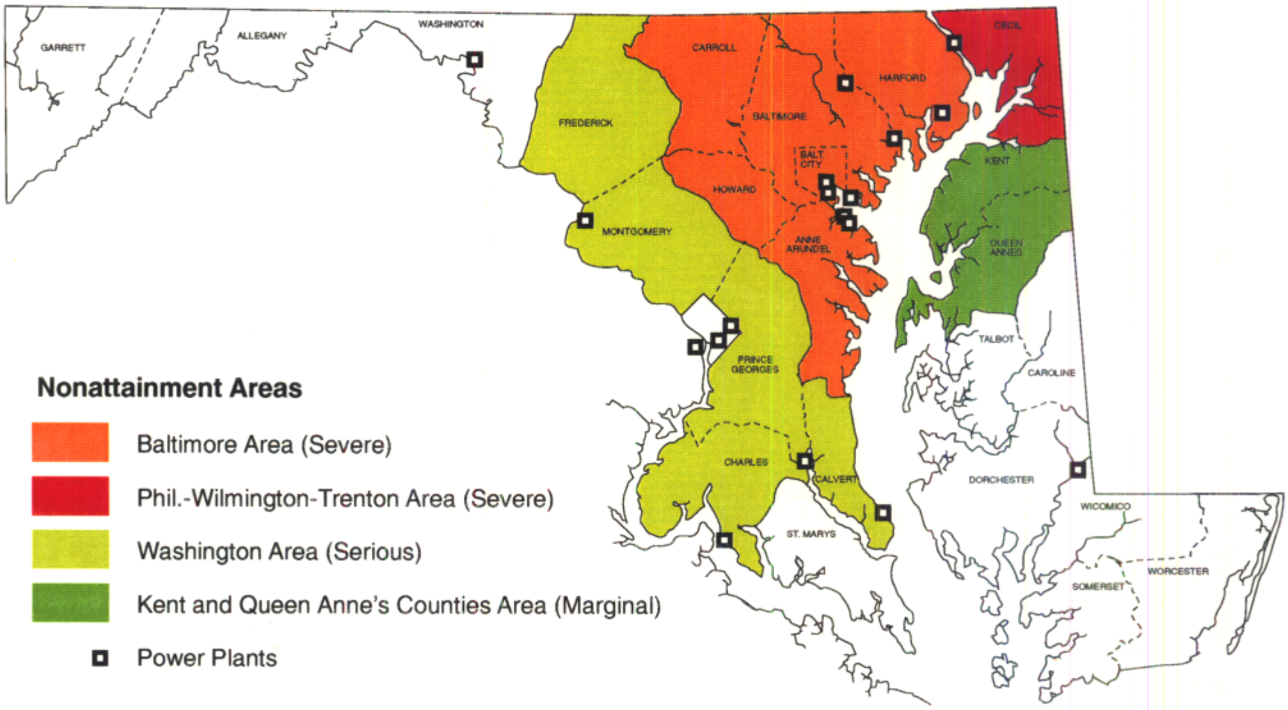
Almost all Marylanders have a stake in the success of any ozone air pollution abatement program. Nearly 90 percent of the people in Maryland live in areas where current ozone levels may be unhealthful, according to the U.S. EPA.

Power Plant Emission Contributions

Volatile organic compounds emitted by power plants are formed from the incomplete combustion of fossil fuels. As shown in Figure 2-2, mobile sources, such as cars, are the prime emitters of VOCs, accounting for about 96 percent of the total VOC emissions. Power plants are responsible for less than one percent of the total VOC emissions.

On the other hand, power plants are significant emitters of NO_x. NO_x emissions from power plants are formed by high-temperature chemical processes during the combustion of fuels. These NO_x emissions consist primarily of nitrogen

Figure 2-1
Ozone Nonattainment Areas in Maryland



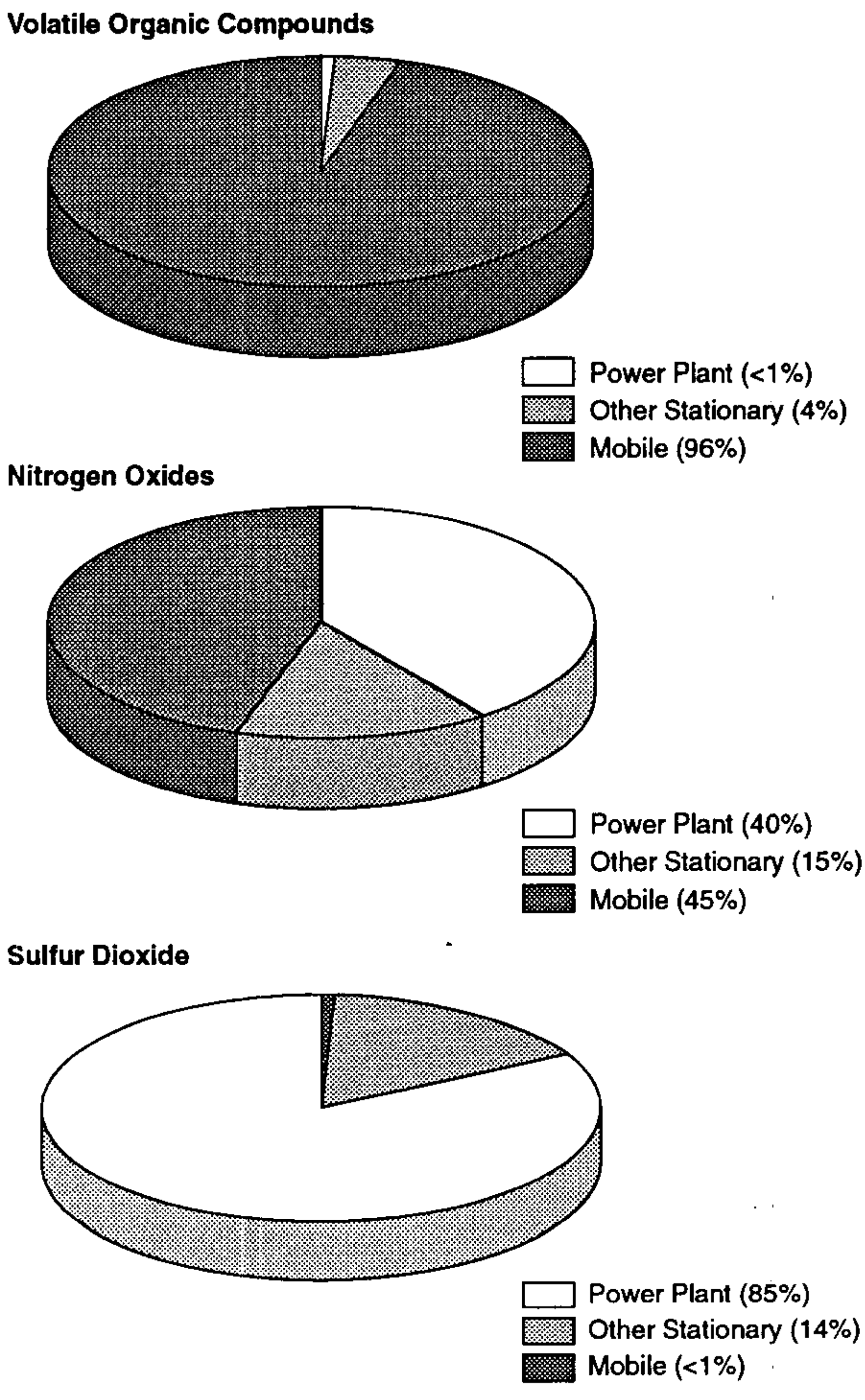
dioxide (NO_2) and nitric oxide (NO); the NO converts to NO_2 in the atmosphere. Power plant emissions account for 40 percent of the total NO_X emissions in Maryland, by far the largest stationary source contributor; mobile sources account for 45 percent of the total NO_X emissions (Figure 2-2).

Regulatory Approaches to Reducing NO_X Emissions

Title I of the 1990 Clean Air Act Amendments addresses the ozone problem. The U.S. EPA is required to designate the boundaries and classifications of ozone nonattainment areas (see Figure 2-1). These designations are important in that they determine the severity of the control program for these areas. Title I requires all states, including Maryland, to submit new plans to the U.S. EPA for meeting the ozone NAAQS. Most importantly for power plants, for the first time, these state plans must include NO_X emissions control and reduction, as well as VOC emissions control, as part of the solution to the ozone problem. The state plans must outline requirements for existing NO_X and VOC sources to use **Reasonably Available Control Technology (RACT)** and for new sources to use even stricter controls. Also, the state plans must include provisions requiring new sources to **offset** any additional NO_X and VOC emissions with reductions at other sources so that overall emission levels do not increase.

In addition, the states must demonstrate to the U.S. EPA that acceptable ozone levels will be attained by the deadlines mandated in the Clean Air Act Amendments. These demonstrations are made through the use of computer modeling that predicts smog levels. The U.S. EPA has developed such a computer model

Figure 2-2
Sources of VOCs, NO_x and SO_2 in Maryland



for the entire northeast region of the United States, including Maryland. Recently completed studies for this region suggest that both NO_x and VOC emissions reductions are needed throughout the region to attain the ozone standard.

Concurrently, studies using a more detailed model are being conducted by states, including Maryland. The goal of the state studies is to identify specific areas where NO_x and VOC reductions will help achieve the ozone standard. The Maryland Department of the Environment is currently conducting the modeling analysis of the Baltimore-Washington, D.C. area with assistance from the University of Maryland. These results will be critical for designing appropriate control plans for the various source categories, including power plants, and for determining areas where NO_x emissions control would help in attaining the ozone NAAQS. PPRP is closely following the progress of these studies.

Power Plant NO_x Control Options

NO_x is generated during the combustion of fossil fuels in two ways: 1) **thermal NO_x** formation and 2) **fuel NO_x** formation. Thermal NO_x results from the high-temperature reaction of nitrogen and oxygen in air used for combustion. As the combustion temperature increases, the amount of thermal NO_x formation increases. Fuel NO_x results from the release during combustion of nitrogen bound in the fuel. Increasing amounts of fuel-bound nitrogen will result in higher NO_x emissions.

Utility boilers and combustion turbines in Maryland emit approximately 128,000 tons per year of NO_x into the atmosphere. Nearly 80 to 85 percent of the utility NO_x emissions come from utility boilers, the units that provide the bulk of the generating capacity in Maryland. On the other hand, combustion turbines burn relatively clean fuels and operate for short periods compared to boilers; therefore, the greatest stationary source NO_x reductions will be realized by controlling utility boilers.

There are two types of boiler modifications — **combustion** and **post-combustion** modifications — available for controlling NO_x emissions from utility boilers. These types of modifications can reduce NO_x emissions by 20 to 90 percent. Combustion modifications reduce NO_x emissions by altering the relative amounts of fuel and air supplied to the **combustion zone** and/or the flame temperature. Post-combustion technologies reduce NO_x after it has already formed in the combustion zone, by injecting ammonia into the exhaust gas and converting the NO_x into atmospheric nitrogen and water.

At Maryland power plants, combustion modifications will most likely be used to control NO_x emissions. PEPCO and BG&E are planning to install combustion modification equipment known as **low-NO_x burners** at selected facilities to meet NO_x control requirements of the Clean Air Act Amendments.

NO_x RACT

In response to Title I of the 1990 Clean Air Act Amendments, Maryland is developing **Reasonably Available Control Technology (RACT)** rules for the control of NO_x emissions from existing major utility boiler and combustion turbine sources. RACT is defined as the lowest emission limit that a particular source is capable of meeting by using control technologies that are reasonably available, considering technological and economic feasibility. Maryland, and other affected states, were required to submit NO_x RACT regulations to the U.S. EPA by November 1992. RACT controls are to be implemented by major sources by May 1995.

In October 1992, the U.S. EPA published guidance to assist states in developing RACT for NO_x. Additionally, various regional organizations, such as the Ozone Transport Commission, the Northeast States for Coordinated Air Use Management, and the State and Territorial Air Pollution Program Administrators/Association of Local Air Pollution Control Officials, have developed RACT technology guidance and RACT emission limits for NO_x. Locally, state agencies, including the Maryland Department of the Environment and PPRP, and utilities have been working jointly to develop the RACT regulation. Successful determination and implementation of NO_x RACT is a positive step towards achieving ozone attainment.

Tradeoffs of Control Options

Selecting one control strategy over another often involves an environmental tradeoff. In some instances, one pollutant can increase as a result of reducing another. For example, using a common technology called water injection to control NO_x emissions from combustion turbines results in an increase of both carbon monoxide and unburned hydrocarbon emissions. Similarly, a post-combustion modification called selective catalytic reduction results in ammonia emissions. Moreover, periodic replacement of the catalyst results in generation of a hazardous waste. Some control technologies transfer contaminants from one environmental medium to another (such as from the air to a solid waste). In the case of low-NO_x burners in boilers, unburned fuel (in the form of carbon) present in the ash is not uncommon and can affect reuse of ash. Post-combustion technologies using ammonia injection for NO_x control have also been found to contaminate ash, possibly hampering its reuse. All aspects of the tradeoff will be considered by the regulators and affected utilities to select the best economic and technically feasible control strategy.

Power Plants and Acid Rain

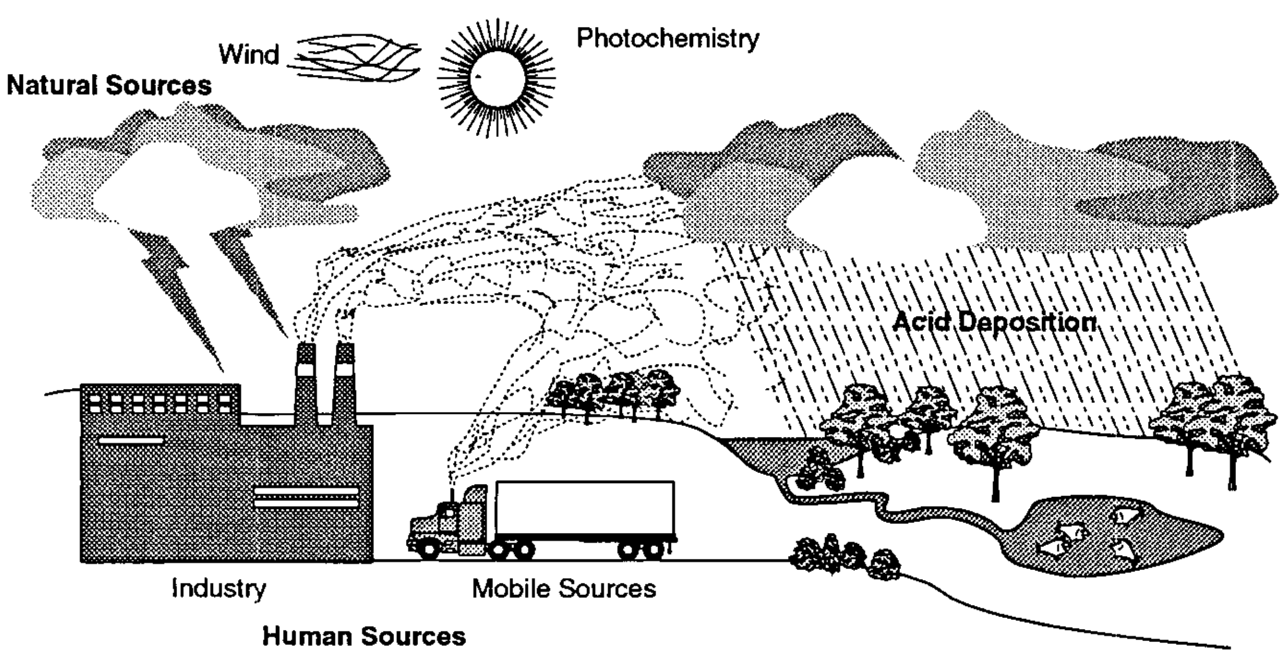
Power plant emissions also contribute to another regional air quality problem — the formation of **acid rain**. Acid rain is produced by the reaction of **precursor** compounds, SO_2 and NO_x, with water in the atmosphere to form sulfuric and nitric acids. The majority of SO_2 emissions and a significant but smaller percentage of NO_x emissions arise from the burning of fossil fuels in power plants.

From 1960 until 1970, nationwide SO_2 emissions increased by approximately 40 percent. Emissions of NO_x steadily increased by nearly 50 percent between 1960 and 1980. Emissions of both precursors have generally declined during the past decade for several reasons: 1) the advent of clean air legislation, 2) greater pollution control efficiencies, and 3) slower growth in fuel use since the oil embargoes of 1973-74 and 1979.

Power Plant Emission Contributions

In Maryland, power plants are responsible for roughly 85 percent of the SO_2 and approximately 40 percent of the NO_x emissions (see Figure 2-2). Motor vehicles contribute substantially to the total NO_x emissions, but contribute a negligible amount of SO_2.

The Acid Deposition Process



SO_2 and NO_x, two compounds emitted by power plants, have been found to be precursors to the formation of acid deposition. The precursors react with other pollutants and with water vapor and sunlight in the atmosphere to form sulfuric and nitric acids. The acids can dissolve in water droplets that make up rain, snow, and fog, creating "wet deposition"; they can also bind to gases, aerosols, and particulate material and reach ground level as "dry deposition."

Regulatory Approaches to Reducing Acid Rain

Title IV of the Clean Air Act Amendments of 1990, or the **acid rain program,** sets forth an innovative program to control acid rain precursor emissions. The program is directed primarily toward coal- and oil-burning utility plants, due to the magnitude of their SO_2 and NO_x emissions.

The acid rain program mandates significant SO_2 reductions from power plants to meet a national emissions cap of 8.9 million tons of SO_2 per year from electric utilities, a reduction of 10 million tons per year compared to 1980. The reductions to meet these limitations will be achieved in two phases. In Phase I, which begins in 1995, the 110 largest utility plants located in 21 Eastern and Midwestern states, including six units at three power plants in Maryland, must meet an intermediate SO_2 emissions limitation requirement. In Phase II, beginning in the year 2000, the annual emission limits imposed on these large plants will be tightened, and limitations will be set for smaller, cleaner plants. All existing utility units in Maryland and across the United States with generating capacity greater than 25 MW and all new utility units will be subject to these requirements.

Allowance Trading

Because of the uncertainties surrounding SO_2 allowance trading — that is, how the revenues and costs will be treated — few trades of allowances have occurred. To date, three trades have taken place: the sale by Wisconsin Power and Light of 15,000 to 25,000 tons, with no time limit, to Duquesne Light; the sale of 10,000 tons by Wisconsin Power to the Tennessee Valley Authority, also with no time limit; and the sale by Alcoa Generating Corporation of 5,000 emission allowances annually over a five-year period beginning in 1995 to Ohio Edison Company.

The acid rain program of the Clean Air Act Amendments also calls for an approximate two-million-ton reduction in NO_x emissions below 1980 levels. Utility coal-fired boilers will be required to meet new emissions standards based on the installation of low-NO_x burner technologies. These standards will also be implemented in two phases. For Phase I, the U.S. EPA will establish NO_x emissions limits for two types of utility boilers. For Phase II, NO_x emissions limits will be set for all other types of utility boilers. Ozone attainment strategies (under Title I) may also require NO_x reductions.

The centerpiece of the acid rain program for SO_2 control is an innovative pollution trading system based on the use of marketable **emissions allowances**. An allowance is effectively a permit to emit one ton of SO_2. Existing electric utility units will be granted allowances annually based on their historic fuel use and the emission limitations specified in the acid rain program. The units must not emit SO_2 in quantities that exceed the number of allowances they hold.

The market-based allowance approach is designed to allow utilities to meet their emission control requirements in the most cost-effective manner possible. As part of its compliance strategy, a utility may install SO_2 emission controls, switch to fuels that contain less sulfur (either lower-sulfur coals or oil or natural gas), or purchase allowances from another utility. Utilities may purchase allowances from distant utilities, even ones that are out of state. The rationale behind such long-distance trading is that acid rain is a regional problem, caused by emissions over a large area, not by sources concentrated in a particular location. Consequently, the specific location in which the emission reductions actually occur is unimportant, assuming the total regional reductions are achieved.

Power Plant SO_2 Control Options

There are a number of ways to reduce SO_2 emissions from power plants. **Scrubbers**, using wet or dry technology, are commercially proven pollution control systems that can remove SO_2 very efficiently. The most common type of scrubber in use or

Assessment of Acid Rain Control Strategies

PPRP is analyzing acid rain emission reduction strategies for Maryland. A distinguishing feature of this effort is the development of site-specific estimates of the amount of acid rain that an ecosystem can tolerate without continuing to acidify. These estimates are known as **critical loads** and were developed for 73 locations throughout Maryland that had previously been determined to be acid-sensitive. The overall goal is to determine whether reducing pollutant emissions (and hence, acid rain levels) can allow these sites to remain below their critical loads. The analyses use several different computer models, including a mathematical model to simulate regional acid rain, models to estimate the critical loads, and models to help determine which pollution sources should reduce their emissions so that we obtain cost-effective abatement strategies. The potential impact of the allowance trading provisions of the 1990 Clean Air Act Amendments with respect to meeting critical loads in Maryland was assessed. Certain pollution control strategies, such as those prescribed by the 1990 Clean Air Act Amendments, were found to result in acid rain levels that meet the critical load criteria at most of Maryland's sensitive sites. The remaining sites, where the critical loads are not satisfied even with emissions reductions, might be good candidates for different types of acidic protection, notably, direct liming of the affected streams.

planned for use at power plants is a **wet limestone scrubber.** This type of scrubber introduces a limestone solution into the exhaust gas, where it absorbs or "scrubs" SO_2 from the exhaust. Limestone scrubbers can achieve SO_2 removal rates of 95 percent or more. Scrubbers offer a high degree of flexibility, allowing use of a range of coals with differing sulfur contents. However, potential drawbacks of scrubbers include the loss of generating efficiency of the power plant and the production of large amounts of waste, which may present a costly solid waste disposal problem. Of the many SO_2 reduction options available, scrubbers are relatively efficient at reducing SO_2 emission rates, but with relatively high costs.

Switching to a fuel that contains less sulfur is another SO_2 control option. Most often this involves changing from a higher to a lower sulfur content coal. Utility boilers are designed to burn coal of a specific quality, so utilities must evaluate potential lower-sulfur coals carefully before switching fuels. For example, modifications to the coal and ash handling and processing operations, boiler configuration, and particulate emission controls must be assessed when switching to lower-sulfur fuels. In general, fuel switching options involve lower capital investment and can be implemented in a short timeframe, compared to scrubbing. A potential risk with this approach, however, is the uncertainty in the future cost and availability of low-sulfur fuels.

Because the acid rain program is designed to achieve regional SO_2 emission reductions at the lowest overall cost, utilities that have the largest SO_2 reduction requirements may consider the more capital-intensive strategies, such as scrubbing. On a "dollars spent per ton of SO_2 removed" basis, scrubbing a plant that burns a high-sulfur coal is more cost-effective than scrubbing one that burns a lower-sulfur coal.

SO_2 Control Plans for the Maryland Utilities

Two electric utilities have generating units in Maryland that are subject to acid rain controls in Phase I: PEPCO's Chalk Point Units 1 and 2 and Morgantown Units 1 and 2; and BG&E's C.P. Crane Units 1 and 2. Under Phase II, virtually all generating units in Maryland will be affected. Maryland utilities have outlined Phase I acid rain control strategies, but due to uncertainties in fuel prices and allowance prices, compliance strategies for Phase II are not yet finalized. Utilities must file their Phase II compliance plans with the state by early 1997.

Both PEPCO's and BG&E's plans for Phase I include substantial reductions at the Conemaugh plant located in Pennsylvania, a plant in which both utilities (in addition to others) share ownership. The owners of the Conemaugh units have elected to install high-efficiency SO2 scrubbers on two generating units; this measure will reduce emissions beyond the level required in Phase I, thereby generating excess allowances. PEPCO's Phase I plan entails using its share of these excess allowances and switching to lower-sulfur coal at Chalk Point and Morgantown (see Figure 2-3). BG&E will benefit from the installation of the Conemaugh scrubbers also. Excess allowances generated will help to offset the reduction requirements for the C.P. Crane units. Additionally, BG&E plans to use lower-sulfur coal at C.P. Crane (see Figure 2-3).

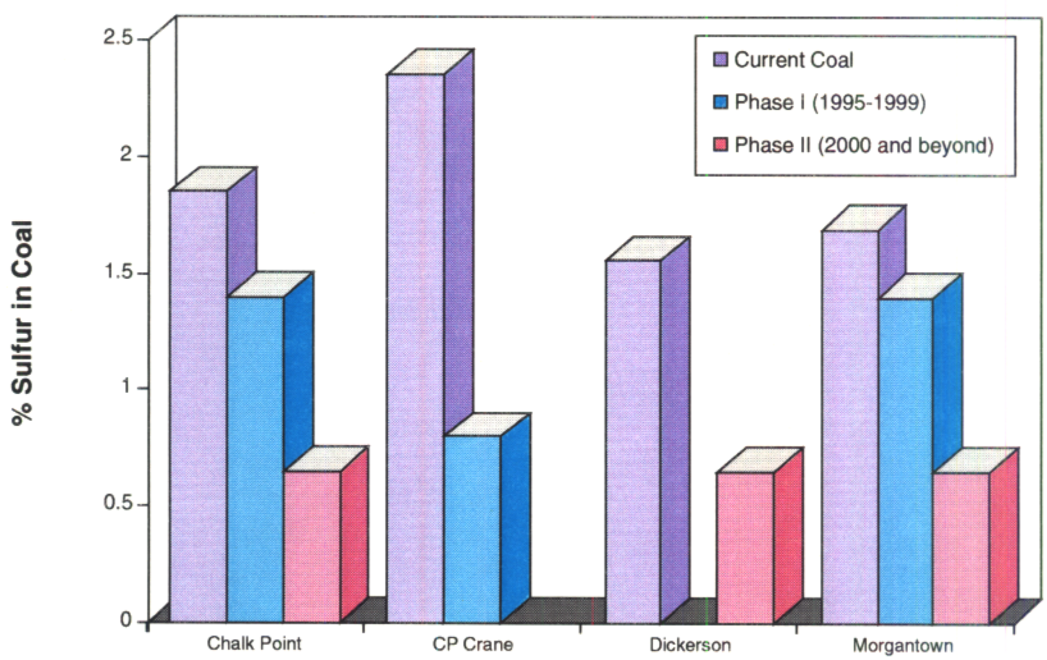
To meet Phase II requirements, PEPCO tentatively plans to switch to even lower-sulfur coal at Chalk Point and Morgantown, and to switch to lower-sulfur coal at Dickerson Units 1, 2, and 3 (see Figure 2-3). PEPCO also plans to co-fire Chalk Point Unit 2 with gas and to use the open allowance market to buy allowances as needed. For Phase II, BG&E currently plans to continue burning low-sulfur coal at Crane, switch to lower-sulfur coal at H.A. Wagner Units 2 and 3, and purchase allowances as needed.

Generally, Maryland utilities have emphasized flexibility in their acid rain compliance plans. To date, no utility has proposed scrubbing any existing generating units at Maryland power plants to achieve SO_2 reductions. The cost of lower-sulfur coal, which will likely increase due to increased demand, and the market price of allowances will have a large impact on the future compliance actions taken by Maryland utilities. PPRP has had continuing contact with the utilities on the status of their compliance plans, and recently participated in hearings before the PSC on PEPCO's fuel switching proposal. The goal of PPRP's involvement is to ensure that the evaluation of various compliance alternatives takes into account environmental considerations as well as economic factors.

Impacts of Acid Deposition

The formation of acid rain, or **acid deposition**, has been evaluated in a number of projects nationally over many years. Years of research have enabled scientists to

Figure 2-3
Average Sulfur Content



characterize the types and amounts of emissions of acid deposition precursors. However, researchers found it more difficult to discern how acid deposition actually affects terrestrial and aquatic resources. As a result, Congress created the National Acid Precipitation Assessment Program (**NAPAP**) in 1980 to conduct scientific and economic analyses of the causes and effects of acid deposition.

In addition to federal research efforts, PPRP has conducted a substantial amount of research on the generation and effects of acid deposition in Maryland. This research program is ongoing, and the state has sponsored a variety of acid deposition studies in recent years. These projects have been designed to evaluate the effects of acid deposition on resources unique to Maryland or to address topics important to understanding acid deposition in Maryland not being studied elsewhere. Recent research has focused on a number of areas including:

- *acidification processes,*
- *mitigation studies, and*
- *"critical loads."*

Acidification Processes

Studies have shown that the deposition of acidified materials can affect terrestrial and aquatic resources. The magnitude and type of impact of the acid deposition, however, depends on a variety of complex factors, including the amount of materials deposited, the relative ability of the water body or soils to buffer the effects of the acidity, the sensitivity of the organism to pH changes, and the types and amount of vegetation. PPRP has examined a number of these processes in recent years because studies have shown that some aquatic resources in Maryland could be particularly sensitive to acid deposition.

Recent research has generated water quality data to further analyze probable sources of acidity in Maryland's Coastal Plain streams. In another study, the state surveyed 79 stream reaches in western Maryland, an area of the state with a high proportion of sensitive streams and fish to correlate the presence and abundance of fish in these streams with chemical and physical characteristics of the water bodies. Other studies have been conducted to investigate the impact of **episodic acidification**, a short-term peak in acidity due to an acid rain event or from runoff of acidic materials from the ground into a stream or lake. PPRP is studying the relative importance of episodic versus chronic acidification at several sites in Maryland.

Mitigation Studies

Once it is determined that streams, fish, or other wildlife habitats are sensitive to acid deposition and that impacts have occurred, questions are raised about how the impacts can be mitigated. Maryland has conducted a number of research projects to investigate the effectiveness of various mitigation strategies.

Federal Acid Deposition Research

The National Acid Precipitation Assessment Program (**NAPAP**) was created by Congress in 1980 to conduct scientific and economic analyses of the causes and effects of acid deposition. NAPAP concluded its 10-year, $500 million research and assessment activities in 1990. The results of NAPAP's 10-year research efforts into the causes and effects of acid deposition were presented in an **Integrated Assessment Report** and in the more than 25 separate **State of the Science/Technology (SOS/T) Reports**. PPRP reported on the NAPAP results in its sixth annual report on acid deposition prepared for the Governor and legislature.

In a series of studies, PPRP has been investigating the ability of **stream liming** to mitigate acidification of Coastal Plain and western Maryland streams. Some of this research was prompted by the observation that early life stages of some migratory fish species (such as blueback herring) that spawn in Coastal Plain streams are particularly sensitive to acidified streams. In stream liming projects, limestone materials, which are basic (as opposed to acidic materials), are added to streams in an attempt to neutralize acidity. Maryland has been testing stream liming projects in two Coastal Plain streams since the mid-1980s. In these projects, researchers operated **dosers** in study streams, which automatically release liming materials at preset intervals into the streams.

In addition to stream liming, PPRP has been evaluating a different type of mitigation technique for acidified streams known as **watershed liming**. With this technique, limestone materials are placed over the land area of a watershed and natural precipitation processes wash the limestone into the stream over time, instead of a doser applying the materials directly to the stream. The research is designed to determine whether watershed liming is an appropriate and feasible strategy to mitigate acidification of western Maryland streams. After extensive review of potential study watersheds, PPRP selected Alexander Run in Garrett County as the subject for a long-term watershed liming project. After the initial liming of the watershed, PPRP has been monitoring stream chemistry, stream discharge, soils, vegetation, and aquatic life to evaluate the effects of the liming.

Critical Loads

Maryland has also sponsored studies to determine the **critical loads** of streams. The critical load for a particular location is defined as the level of acidic deposition below which adverse impacts to sensitive biological resources would not be expected. Maryland's research in this area, which began in the late 1980s, is being conducted to determine the critical loads of sulfur and nitrogen that can be accommodated by sensitive Maryland streams without causing further acidification. The work will also be used to evaluate the ability of various precursor emissions control strategies at power plants to achieve these critical load targets. Much of this research involves computer modeling that calculates the levels of deposition necessary to acidify streams to varying degrees. Using information on impacts of levels of acidification on different types of fish, the modeling results can be used to develop strategies to protect sensitive fish species. The study has also considered projected reductions in SO_2 and NO_x from power plants that will be instituted under the Clean Air Act Amendments of 1990, to assess how reductions in precursor emission rates will affect acid-sensitive habitats.