SULFUR

Sulfur Emissions and Midwest Power Plants

Clean Air Task Force
77 Summer Street Boston, MA 02110

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Hazy and Clear Days — Boundary Waters Canoe Area Wilderness, MN

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Sulfur emissions from power plants form some of the most harmful common air pollutants. Power plants release more sulfur in to the atmosphere than any other emissions sources.

Sulfur emissions form some of the most harmful and environmentally damaging pollutants in our air. Each year, uncontrolled power plants release twice as much sulfur into the air as cars, factories and trucks combined. Most of this power plant sulfur (94% nationally, 99% in the Midwest states) comes from burning coal to produce our electricity. Sulfur air pollutants from power plants include *sulfur dioxide (SO_2),* a deadly gas that is toxic to communities near power plants*, sulfate particulate matter*, unhealthy fine particles that pollute our communities and places hundreds of miles away, and *sulfuric acid* that damages our environment. These air pollutants are responsible for asthma attacks, heart attacks, lost workdays, school absences and thousands of premature deaths each year. The same sulfur pollutants also cause hazy parklands and city skylines, and acid rain-damaged ecosystems. Due to a loophole in the Clean Air Act, millions of tons of sulfur air pollution are being unnecessarily released into the atmosphere each year by "grandfathered" power plants. This is occurring despite the fact that "scrubbers" have been in use for two decades capable of neutralizing and removing most (90-95%) of the sulfur emissions from America's largest and dirtiest smokestacks.[1] It's time to clean up these old and dirty plants.

Sulfur dioxide emissions from the six Midwest states discussed in this report total about 5.4 millions tons per year, representing 28% of all U.S. SO_2 emissions. Electric generating units (EGUs) in this six-state region emit nearly four million tons of sulfur per year, representing about 30 percent of the U.S. SO_2 emissions from power plants. In the Midwest, coal combustion accounts for nearly 99 percent of the sulfur emissions from electric utilities.

Sulfur is an impurity in coal and oil. Coal mined in the Midwest states of Illinois, Indiana and Ohio have the highest sulfur content of any region of the country. Coal from these states supplies much of the US coal needs.[2] Over 80 percent of the nation's coal is used to fuel the electric utility industry.[3] Extraction and combustion of fossil fuels, largely coal, has resulted in the doubling of the amount of sulfur released into the environment during the industrial era.

This fact sheet focuses on the impacts of emissions of SO_2 in the six state area of Indiana, Illinois, Ohio, Michigan, Minnesota and Wisconsin and demonstrates the need for SO_2 pollution reductions from power plants in the Midwest. The Clean Air Task Force publication *Cradle to Grave*, outlines the full range of impacts of pollutants that are released during coal mining, cleaning, processing and disposal of the post-combustion wastes.

Table 1:

Sulfur Dioxide Emissions in Six Midwest States in 1998[4] ***(in tons per year)***

SO_2 Emissions	All Sources	Power Plants	Power Plant %	Coal Plants	Coal Plant %
Illinois	1,152,732	810,557	70.3	804,675	99.3
Indiana	1,159,258	972,703	83.9	967,470	99.5
Michigan	628,005	431,339	68.7	424,453	98.4
Minnesota	162,278	89,961	55.4	87,177	96.9
Ohio	1,921,199	1,442,903	75.1	1,414,985	98.1
Wisconsin	378,108	229,170	60.6	229,170	100.0
Total	5,401,580	3,976,633	73.6	3,927,930	98.8

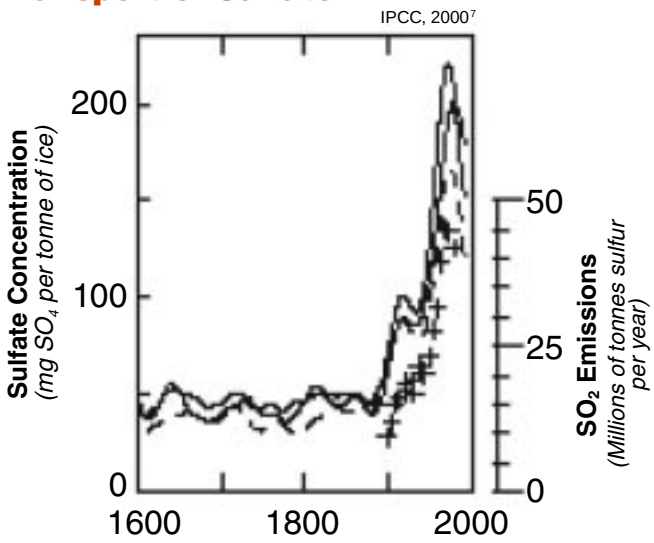
Sulfur dioxide gas converts to harmful sulfate particulate matter ("sulfates") in the atmosphere.

Upon release, sulfur dioxide gas emissions rapidly form sulfate, a common form of fine particulate matter. If mixed with water in the atmosphere, these sulfate compounds may form sulfuric acid. Sulfate particulate matter drifts downwind, with some being deposited near the source while the balance travels hundreds of miles from the smokestack. For example, EPA analyses[5] suggest that about two thirds of sulfate may be deposited by the time it has traveled 500 and 1200 kilometers downwind (about 300-750 miles) in the Midwest and Northeast regions. Figure 1 shows that sulfate concentrations in ice cores in Greenland have increased in parallel with sulfur emissions. The source of this sulfur is thousands of miles away. A recent modeling and health analysis of nine Illinois power plants found the highest concentrations of sulfate occur within 50 miles of a given plant.[6] The combination of long- and short-range transport means that there are threats both to nearby communities as well as to downwind cities and forests.

Figure 1:

Sulfate in Greenland Ice Cores Demonstrate Long-Distance Transport of Sulfate

IPCC, 2000[7]



Sulfur dioxide and sulfates are associated with respiratory and cardiac disease and premature death.

Sulfur dioxide, sulfate particulate matter and fine particulate matter – all pollutants resulting in part from power plant emissions – are lethal to breathe. The hospitalizations and deaths caused by the great 1952 London Fog, and events in Donora, Pennsylvania were the first indicators of a relationship between sulfur dioxide, sulfate and health.[8] However, scores of recent studies of sulfate and human health show that much lower levels of this acid pollutant can have serious effects. Sulfur dioxide is also a local health concern too; close to its source, sulfur dioxide is a harmful gas. Both sulfur dioxide gas and sulfate particulate matter have been associated with premature death, respiratory and cardiovascular disease.

Sulfur dioxide gas is toxic to nearby communities.

Sulfur dioxide is a dangerous gas that can directly affect communities in close proximity to power plant smokestacks. Numerous studies link sulfur dioxide with bronchial reactions, reduced lung function and premature death.[9] Sulfur dioxide gas can also destabilize normal heart rhythms.[10] Controlled laboratory and epidemiology studies have demonstrated that children and people with constrictive pulmonary disease such as asthma are at increased risk from exposure to SO_2.[11] When this population is exposed to SO_2, individuals are commonly stricken with shortness of breath, coughing, wheezing and reductions in lung function. Moreover, sulfur dioxide gas is toxic following only minutes of exposure. Exercising asthmatics can experience lung constriction within 5-10 minutes of exposure.[12] SO_2 is deadly too; some studies suggest that very small SO_2 exposures are associated with premature death.[13]

Children's exposure to SO_2 is greater because children spend twice as much time outdoors as adults. In addition, low birth weight and other serious health effects are associated with levels significantly lower than the National Ambient Air Quality Standard (NAAQS) for SO_2.[14] In 1998, approximately 2.6 million people in the Midwest lived in counties designated entirely, or in part, nonattainment for SO_2 under the National Ambient Air Quality Standards (NAAQS). Sulfur dioxide gas is also considered to be most toxic in the presence of ozone and particulate matter, a common air pollutant mixture in the Midwest states.[15]

Sulfate particulate matter poses a serious health problem in much of the Midwest.

Sulfate particulate matter ("sulfate") is a serious problem in the Midwest. Numerous health studies have examined the health effects of sulfate and found strong associations with lung and heart ailments as well as with premature death. Once inhaled, sulfates can reduce lung function and exacerbate constrictive pulmonary disease (asthma). Studies also show that those who are particularly vulnerable are the millions of people who are young, old and/or already suffering from lung and heart ailments. Other studies of fine particulate matter and health suggest that $PM_{2.5}$ may also destabilize heart rhythms. And unlike ozone, which does not penetrate indoor environments readily, sulfates can be an indoor health hazard when they enter our homes and workplaces through windows and ventilation systems.

The groundbreaking 1995 American Cancer Society (ACS) study[16] examined the health impacts of sulfate. The study tracked over one half million Americans in 151 metropolitan areas and showed that people in the most polluted cities in the U.S. (including some in the Midwest) had an overall 15 percent higher risk of premature death due to sulfate. In addition ACS results suggest a possible link between sulfate and increased risk of death due to lung cancer. In another important medical study of six U.S. cities, including two in the Midwest, residents of the city with the highest sulfate levels (Steubenville OH) had a 27% higher chance of premature death than the residents of the cleanest city (Portage, WI).[17] During the 1997 review of the air quality standards that culminated in the setting of standards for $PM_{2.5}$, results of the ACS and Six Cities studies were challenged by industry. This challenge prompted a comprehensive, multi-year reanalysis by an independent third party (funded by EPA and industry), the Health Effects Institute, which confirmed the validity of the results in 2000.[18]

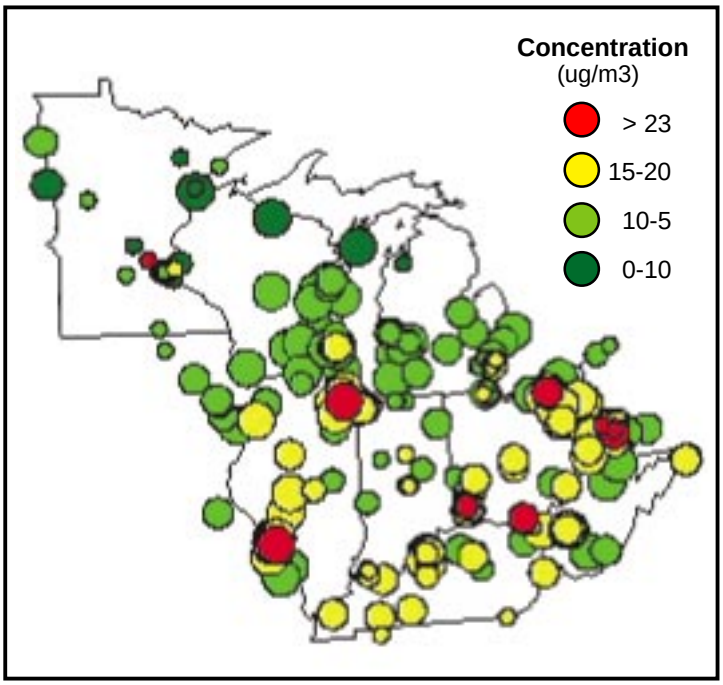
Unfortunately, states are not required to measure sulfates at most monitoring sites. But because sulfate dominates fine particulate matter outside of inner urban

Figure 2:

1998 Annual Average $PM_{2.5}$ in the Midwest States (EPA[19])

Many residents of the Midwest live in areas where particulate matter levels exceed the national standard.

(For reference the national standard is 15 ug/m^3)



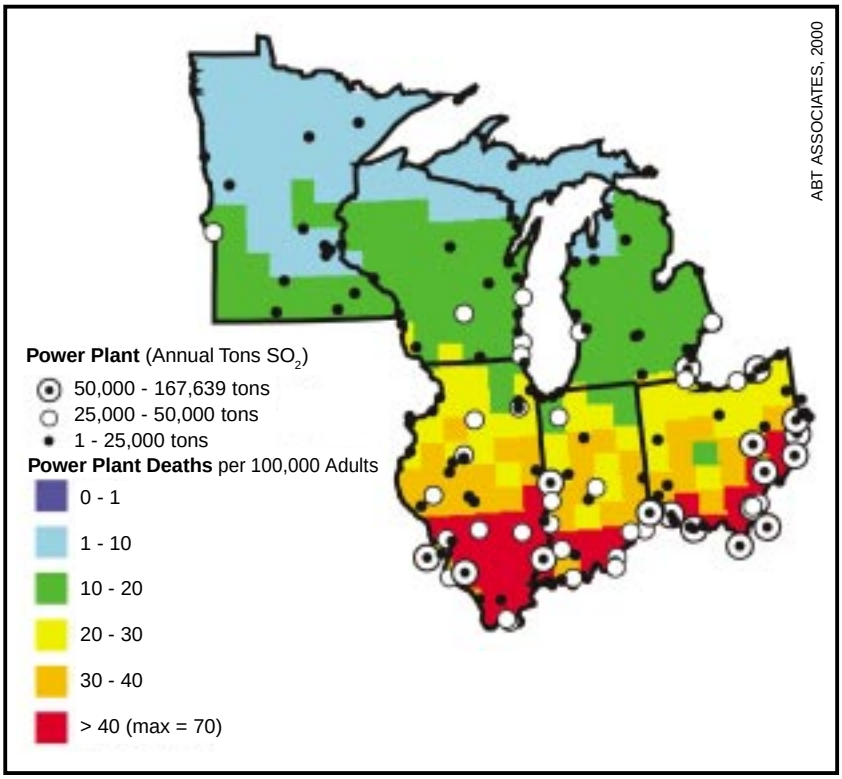
Midwest cities that may have significant diesel contribution, levels of fine particulate matter are the best indicator of unhealthy sulfur-laden air. In 1998 – the most recent year for which data is available – monitors throughout the region registered violations of the annual average air quality standard for fine particles. The high number of $PM_{2.5}$ exceedences makes it clear that people living in the Midwest may be particularly at-risk to the impacts from sulfates and related fine particles.

Deep reductions in sulfur emissions would save thousands of lives in the Midwest.

In a recent study about 30,000 premature deaths in the U.S. each year were attributable to power plant emissions of particulate matter. In addition, premature deaths attributable to diesel sources estimated in the study were equivalent to about 80% of the power plant deaths. *Particulate-Related Health Benefits of Reducing Power Plant Emissions,*[20] a report prepared by Abt Associates for the Clean Air Task Force, estimates that about 6200 deaths per year are attributable to sulfate-dominated particulate matter in the six Midwest states. The same analysis suggests that about 3700 of these lives would be saved if sulfur dioxide emissions were reduced by about 63% beyond phase II of the Acid Rain Program. In addition, the report estimates that hundreds of emergency room visits for asthma as well as hundreds of thousands of lost work days can be attributed to fine particulate matter. Importantly, deeper cuts would result in greater benefits. Current research suggests that there is no lower threshold below which health effects disappear: fine particles and sulfates may adversely impact human health at any concentration.

Figure 3:

$PM_{2.5}$ – Related Deaths per 100,000 Population in the 6-State Region



Again, populations most at risk for fine particles are the young, the old and persons who already suffer from lung and heart ailments. According to a recent Harvard School of Public Health study of only nine power plants in Illinois' Chicago area[21] (representing one fifth of the power gener-

Table 2:

Estimated Health Impacts from Fine Particulate Matter

ESTIMATE – Year 2007 / current emissions				Asthma Attacks	Deaths per 100,000	Chronic Bronchitis	Asthma ER Visits	Work Loss Days	Minor Restricted Activity Days
State	Pop 2007	Deaths	Hosp						
Illinois	12,434,632	1,695	1,113	33,126	24.6	1,021	385	282,705	1,454,490
Indiana	6,253,063	1,024	681	20,469	29.8	626	239	172,816	885,690
Michigan	9,813,453	870	578	18,527	16.3	564	215	158,856	817,280
Minnesota	5,070,807	246	182	5,821	9.0	175	60	49,836	258,057
Ohio	11,577,089	1,915	1,252	37,067	29.7	1,145	443	313,289	1,602,140
Wisconsin	5,570,223	447	318	9,348	14.6	283	100	79,303	408,749

ABT ASSOCIATES, 2000

Table 3:

Estimated Reductions in Deaths and Illness from a 63% Reduction in Particulate Matter

63% SO_2 Reduction in Year 2007				Asthma Attacks	Deaths per 100,000	Chronic Bronchitis	Asthma ER Visits	Work Loss Days	Minor Restricted Activity Days
State	Pop 2007	Deaths	Hosp						
Illlinois	12,434,632	981	634	18,953	14.2	582	212	164,212	847,537
Indiana	6,253,063	581	384	11,500	17.0	352	134	99,318	511,681
Michigan	9,813,453	521	342	11,008	9.8	336	124	95,628	493,829
Minnesota	5,070,807	151	110	3,533	5.5	105	32	30,624	158,793
Ohio	11,577,089	1,196	770	22,781	18.5	710	267	195,860	1,006,740
Wisconsin	5,570,223	267	188	5,548	8.8	175	57	47,573	245,984

ABT ASSOCIATES, 2000

ated in the state), there are about 400 excess deaths per year as a result of the fine particulate matter related to emissions from these plants. Of these, about 140 deaths are specifically attributable to sulfate and nitrate particles with the remaining deaths attributable to acid gases and directly emitted particulate matter. Moreover, the study found that per capita health risks were greater close to the power plants and decreased with distance from plants and that the risks were greatest in inner city Chicago. Finally, the study estimated that a 75% cut in sulfur emissions would result in saving 300 lives per year in the Chicago area.

Sulfate particulate matter equals hazy parks and city skylines.

The spectacular scenic vistas in Midwest parks, wilderness areas and city skylines are blighted by sulfate haze. Sulfate particulate matter scatters light, degrading a sharp, colorful scene and leaving it shrouded in a milky white haze. Sulfates are not the only contributors to haze. Other particles including organics, carbon (soot), nitrates and soil contribute to a much lesser extent to haze formation in the Midwest as well. However, in humid conditions, sulfate particles grow larger in size compared to other particles and therefore scatter light (or form haze) at a disproportionate rate. Therefore, sulfates are the single most important air pollutant to control to also reduce haze.

In the 1977 Clean Air Act Amendments, Congress recognized the problem of haze in our parks and established a goal of "remedying any existing and prevention of any future visibility impairment" in federal parks and wilderness areas. Over two decades later, EPA's 1999 Regional Haze Rule established a program to meet this goal. Protected areas in the region include Voyageurs National Park, the Boundary Waters Canoe Area Wilderness and Isle Royale National Park in Minnesota and Rainbow Lake Wilderness and Seney Wilderness in Michigan.

How bad is the visibility in our parks? In the eastern U.S., where natural visual ranges are in the order of 100 miles and summer visibilities are now as low as 11-20 miles, sulfates are generally responsible for half to three quarters of the haze.[22] At Boundary Waters Canoe Area, average visibility is less than one third of the natural visual range, with an annual average visibility of about 35 miles. Sulfate is responsible for 54 percent of the visibility impairment.[23] Accordingly, air in public lands of the Midwest may also be unhealthy to breathe.

Figure 4:

Haze Conditions from Navy Pier, Chicago, Illinois in 2001

Photos: Illinois EPA

Left: Chicago, August 26, 2000 – $PM_{2.5}$ = 35 µg/m³

Right: Chicago, August 16, 2000 – $PM_{2.5}$ <10.0 ug/m³

Visibility is an economic resource important in areas that depend on tourism. People escape the dirty cities to seek clean, clear air in midwestern parks and wilderness areas but all too often the spectacular and peaceful scenes are shrouded in an unhealthy haze. A 2000 report by Abt Associates[24] calculated lost visitor enjoyment in Midwest parks, wilderness areas and cities. The benefits of eliminating haze were estimated at $97 million for Minnesota and $20.6 million for Michigan. Visibility is an important resource in cities too. According to the same report, the cost of residential visibility impairment in the 6 Midwest states is:

- **Michigan:** $167 million
- **Minnesota:** $47 million
- **Ohio:** $183 million
- **Wisconsin:** $29 million
- **Illinois:** $3 million
- **Indiana:** $190 million

Ecosystems are damaged by sulfur.

Sulfur dioxide gas affects nearby vegetation by causing leaf injury, decreasing plant growth and yield and reducing the number and variety of plant species. Because of its ability to be transported many hundreds of miles downwind, sulfate particulate matter is the prime cause of acidified rain and cloudwater in sensitive eastern ecosystems. In areas downwind from large sources of sulfur dioxide emissions, concentrations of sulfates and sulfuric acids in rain and cloudwater makes precipitation much more acidic – 10 to 100 times more than natural rain that falls in unpolluted areas.[25] Rain falling in the Great Plain States where there is little sulfur is considerably less acidic (pH above 5.5) than rain that falls in Ohio, which is typically below pH 4.5.[26] When sulfate and sulfuric acid[27] fall to the earth's surface, acidic deposition has occurred. During rain, snow and fog events, deposition occurs as wet deposition. Deposition under dry conditions is termed dry deposition.

How a site handles acid deposition depends on level of deposition, soils and underlying geology. Ohio, Indiana and Illinois continue have some of the highest deposition of sulfates in the country.[28] Most of the soils is these three states are well buffered – that is they have ample supplies of bases (namely calcium and magnesium) to neutralize high acid inputs. The low elevation, when compared to higher elevation sites to the east, also provides protection.

However, not all sites in the region are well buffered. This is the case for the sandstone-based soils of southern Illinois, Indiana and Ohio where research was conducted for the National Acid Precipitation Program (NAPAP). A study that examined sites in the oak-hickory forest from Arkansas through southern Ohio found that the soils with the highest deposition of acid (Ohio and Indiana) had lower pH, less calcium and reduced populations and species diversity of earthworms and other invertebrates. In addition, growth declines of oaks were attributed to to the acidity of the site.[29]

And for those sites with soils that are able to withstand acid inputs, impacts are still a concern. Modeling work conducted in the early 90s showed that the buffering capacity of Ohio soils downwind of Akron and Cleveland were depleted much faster than soils in parts of the states that received less acid deposition. These results suggest that eventually the soils and the plants in areas receiving high acid deposition could be hurt by acid rain.[30]

Another analysis conducted for NAPAP examined sugar maple forests across northern states – from northeastern Minnesota to western southern Michigan and found that sulfate is leaching nutrients from forest soils.[31] In addition, there are naturally acidic lakes in Minnesota and Wisconsin with very little natural buffering capacity, where even small changes in acidic deposition can harm the aquatic life. Documented damaged from acid rain is also occurring close to the borders of Midwest states. In western Pennsylvania, sugar maple health is deteriorating,[32] and acid-sensitive fish have disappeared from streams where they formerly occurred in large numbers.[33]

Figure 5:

Hazy and Clear Days – Voyageurs National Park, MN

Over half of the haze in Voyageurs National Park is caused by sulfate particles.

Sulfates eat away at buildings.

Calcium and other soil nutrients that effectively absorb and resist the effects of sulfate in acid rain in Midwest soils are the key constituents in limestone and marble buildings. Acid in the air can react with the calcite in marble and limestone and cause surfaces and details to dissolve.

Recently, parts of the Lincoln Memorial in Washington D.C. were restored to counteract the effects of acid rain. These kinds of effects would be typical in many Midwest cities where marble and limestone statues, buildings and monuments are exposed to acidic-sulfur laden air.

Methods to remove sulfur from power plant emissions are well -known and have been in use for two decades or more.

Sulfur "scrubbers" typically remove and reduce as much as 90-95 percent of sulfur dioxide gas emissions from coal-fired power plant smokestacks and are described in a recent EPA report.[34] Scrubber technologies (flue gas desulfurization—or FGD) are well known, and have been in use for about 3 decades. Scrubbers operate by adding a lime (calcium) slurry to the flue gas that combines with the sulfur dioxide gas and results in a solid waste byproduct composed of marketable elemental sulfur or gypsum (calcium sulfate) that in some cases can be used to produce wallboard. Newer methods are being developed such as an ammonia scrubber that produces ammonium sulfate. There are no technological or market barriers that would limit use of sulfur scrubbers and a 90-95% level of reduction can be assumed to be achievable for most coal plants by applying existing FGD methods.

Solutions

Call on state and federal lawmakers to:

- **Clean Up Power Plants.** Electric power generation is responsible for two thirds of the sulfur dioxide emissions in the United States. For over thirty years the oldest, dirtiest coal-burning power plants have circumvented the most protective air emissions standards required of modern plants. As a result, these "grandfathered" power plants (1962-1977 vintage) are allowed to emit as much as 10 times more sulfur dioxide than modern power plants. To significantly reduce sulfur from our air, polluting power plants must be made to comply with modern emissions control standards or better, specifically, a 75% reduction in sulfur dioxide emissions. Proven sulfur-scrubbing technologies, together with cleaner-burning fuels, mean that there are no technological barriers to cleaning up the oldest and dirtiest plants. We must demand that power plants modernize to protect our health and environment.

Call on EPA to:

- **Tighten the NAAQS for SO_2.** Sulfur dioxide exposures well below current federal standards are associated with disease and death. We must call for a five-minute standard that would be more protective since these short-term exposures are associated with serious health impacts and the current short-term 24-hour standard is insufficient to protect against spikes in the deadly gas.
- **Tighten the NAAQS for $PM_{2.5}$.** EPA is reviewing the nation's air quality standards for $PM_{2.5}$ in 2001and must make a recommendation by 2002. The current 24-hour standard is set at a level that is too high to protect human health (65 $\mu g/m^3$). In fact, it was set so high by EPA that few areas will be in nonattainment despite the fact that about 30,000 people die per year from exposure to this harmful pollutant from power plants alone. We must call for a more protective standard.
- **Finalize the BART (Best Available Retrofit Technology) Rule.** As a part of the Regional Haze Rule, EPA has developed guidelines requiring states to identify and clean up grandfathered power plants that cause or contribute to visibility impairment in national parks and wilderness areas. The parks and wilderness areas in the Midwest are affected by power plant emissions in the Midwest, in addition to parks downwind to the east. It is likely that all coal plants in the Midwest will be reviewed by states under BART, which sets a presumptive level of control at 90-95% for sulfur dioxide. These guidelines must be finalized to ensure this improvement of air quality in our treasured natural areas.
- **Call on the Department of Justice and EPA to Aggressively Enforce Lawsuits against Power Plants that Illegally Upgraded their Facilities.** Numerous Midwest power plants have illegally upgraded the capacities of their coal plants and evaded the permitting process required to prevent deterioration of air quality in their regions. Electric utilities have hired top U.S. attorneys and lobbyists to persuade the government to drop these enforcement actions. Call for renewed vigor in bringing these sources to justice and to clean them up.

You can:

- **Use less energy.** Energy production is the primary cause of sulfur in our air. The United States uses more energy per capita than any other country. Using less energy combined with using energy more efficiently will reduce the amount of sulfur in our air.
- **Demand the use of fuels with lower sulfur content**. Natural gas contains virtually no sulfur. Increased reliance on renewable resources to replace older energy production would result in no sulfur emissions.

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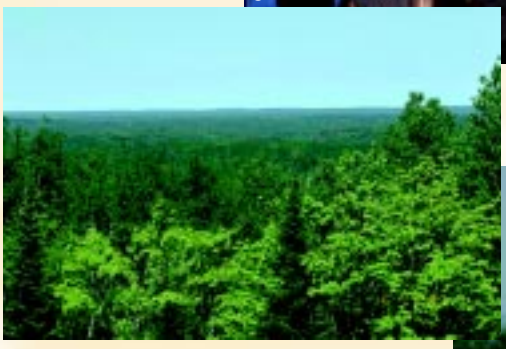

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