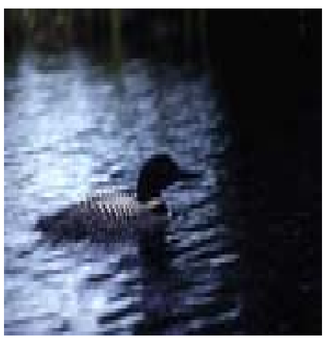
The information presented here reflects EPA's modeling of the Clear Skies Act of 2002. The Agency is in the process of updating this information to reflect modifications included in the Clear Skies Act of 2003. The revised information will be posted on the Agency's Clear Skies Web site (www.epa.gov/clearskies) as soon as possible.

Overview of the Human Health and Environmental Effects of Power Generation: Focus on Sulfur Dioxide (SO_2), Nitrogen Oxides (NO_X) and Mercury (Hg)



June 2002

Contents

The Clear Skies Initiative is intended to reduce the health and environmental impacts of power generation. This document briefly summarizes the health and environmental effects of power generation, specifically those associated with sulfur dioxide (SO_2), nitrogen oxides (NO_X), and mercury (Hg). This document does not address the specific impacts of the Clear Skies Initiative.

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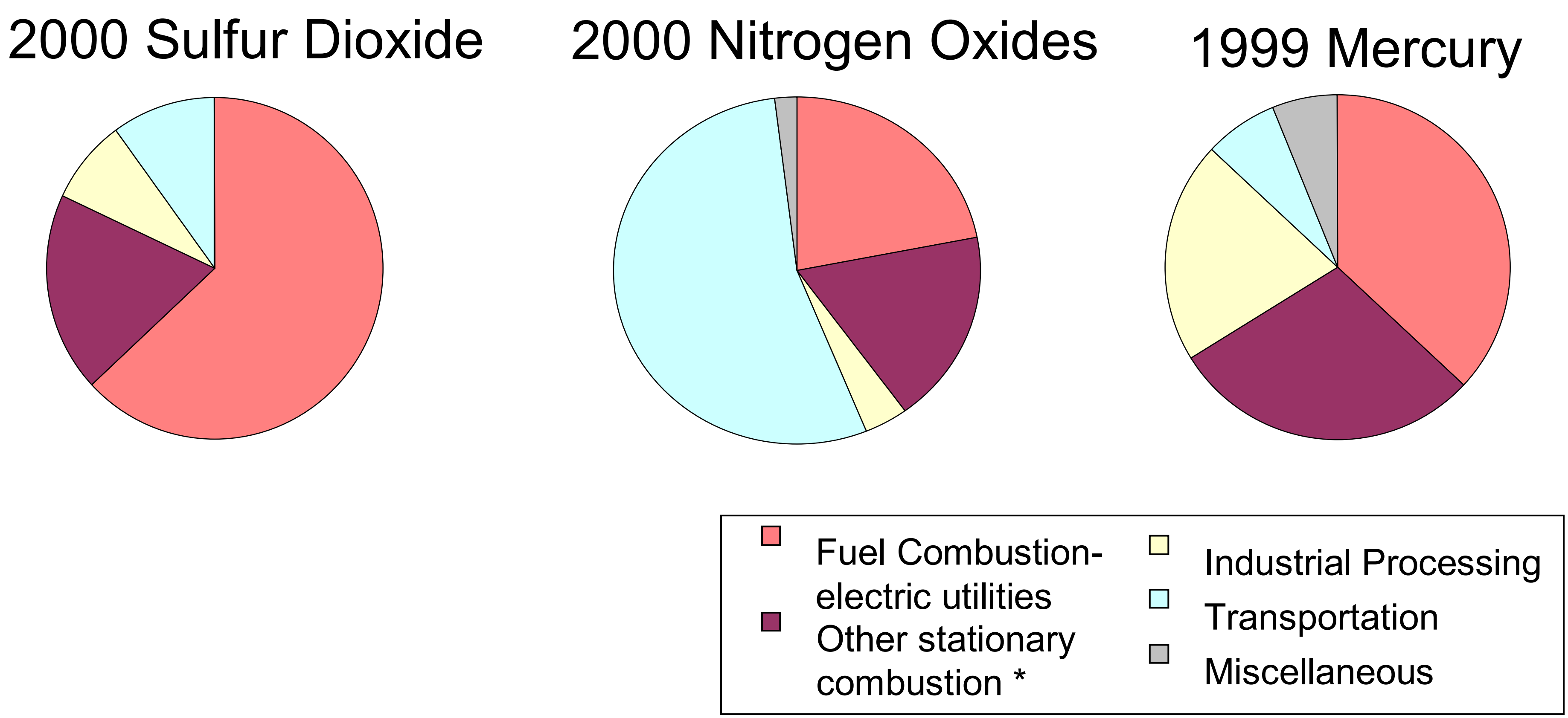
Electric Power Generation: Major Source of Emissions

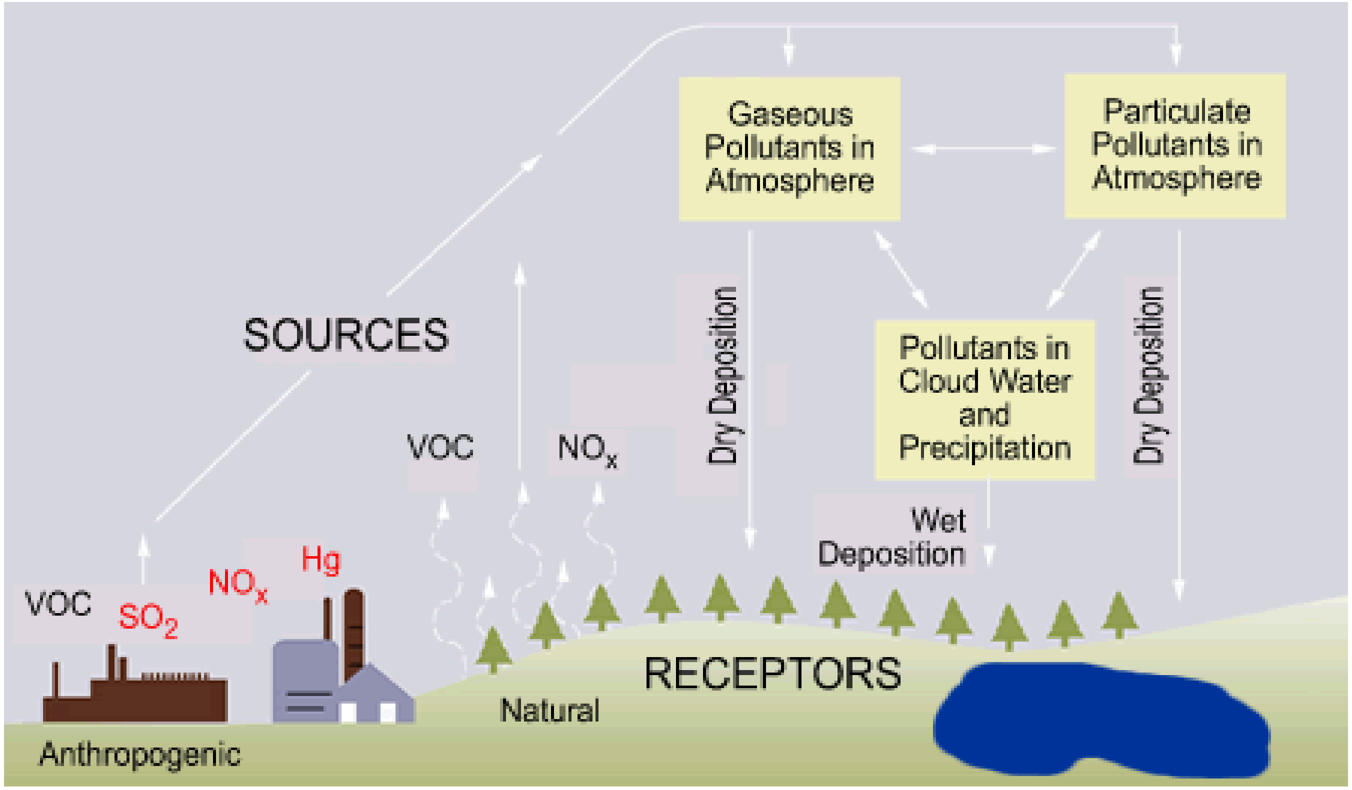


* Other stationary combustion includes residential and commercial sources.

- Power generation continues to be an important source of these major pollutants.
- Power generation contributes 63% of SO_2, 22% of NO_X, and 37% of man-made mercury to the environment.

Overview of SO_2, NO_X, and Mercury Emissions, Transport, and Transformation

- When emitted into the atmosphere, sulfur dioxide, nitrogen oxides, and mercury undergo chemical reactions to form compounds that can travel long distances.
- These chemical compounds take the form of tiny solid particles or liquid droplets and can remain in the air for days or even years.
- These and other pollutants can return to the earth through the processes of wet and dry atmospheric deposition.



- Wet deposition removes gases and particles in the atmosphere and deposits them to the Earth's surface by means of rain, sleet, snow, and fog.
- With dry deposition, particles and gases reach land and water surfaces without precipitation.
- Depending on the chemical form in which it is emitted, mercury is a pollutant of concern at local, regional, and global scales. Mercury emissions in the ionic form are prone to deposit closest to a source.

What are the Health and Environmental Effects of SO_2, NO_X, and Mercury?

Effects of Nitrogen Oxides (NO_x)

- Contributes to death and serious respiratory illness (e.g., asthma, chronic bronchitis) due to fine particles and ozone.
- Acidifies surface water, reducing biodiversity and killing fish.
- Damages forests through direct impacts on leaves and needles, and by soil acidification and depletion of soil nutrients.
- Damages forest ecosystems, trees, ornamental plants, and crops through ozone formation.
- Contributes to coastal eutrophication, killing fish and shellfish.
- Contributes to decreased visibility (regional haze).
- Speeds weathering of monuments, buildings, and other stone and metal structures.

Effects of Sulfur Dioxide (SO_2)

- Contributes to death and serious respiratory illness (e.g., asthma, chronic bronchitis) due to fine particles.
- Acidifies surface water, reducing biodiversity and killing fish.
- Damages forests through direct impacts on leaves and needles, and by soil acidification and depletion of soil nutrients.
- Contributes to decreased visibility (regional haze).
- Speeds weathering of monuments, buildings, and other stone and metal structures.

Effects of Mercury (Hg)

- Humans are effected primarily by eating contaminated fish.
- Human neurological effects can include:
  - impaired motor and cognitive skills, particularly in young children;
  - cardiac, respiratory, and immune system impairments are strongly suspected.
- Loons, mink, otter, and other fish-eating animals also exhibit adverse effects.

How Do Fine Particles ($PM_{2.5}$) Affect Human Health?

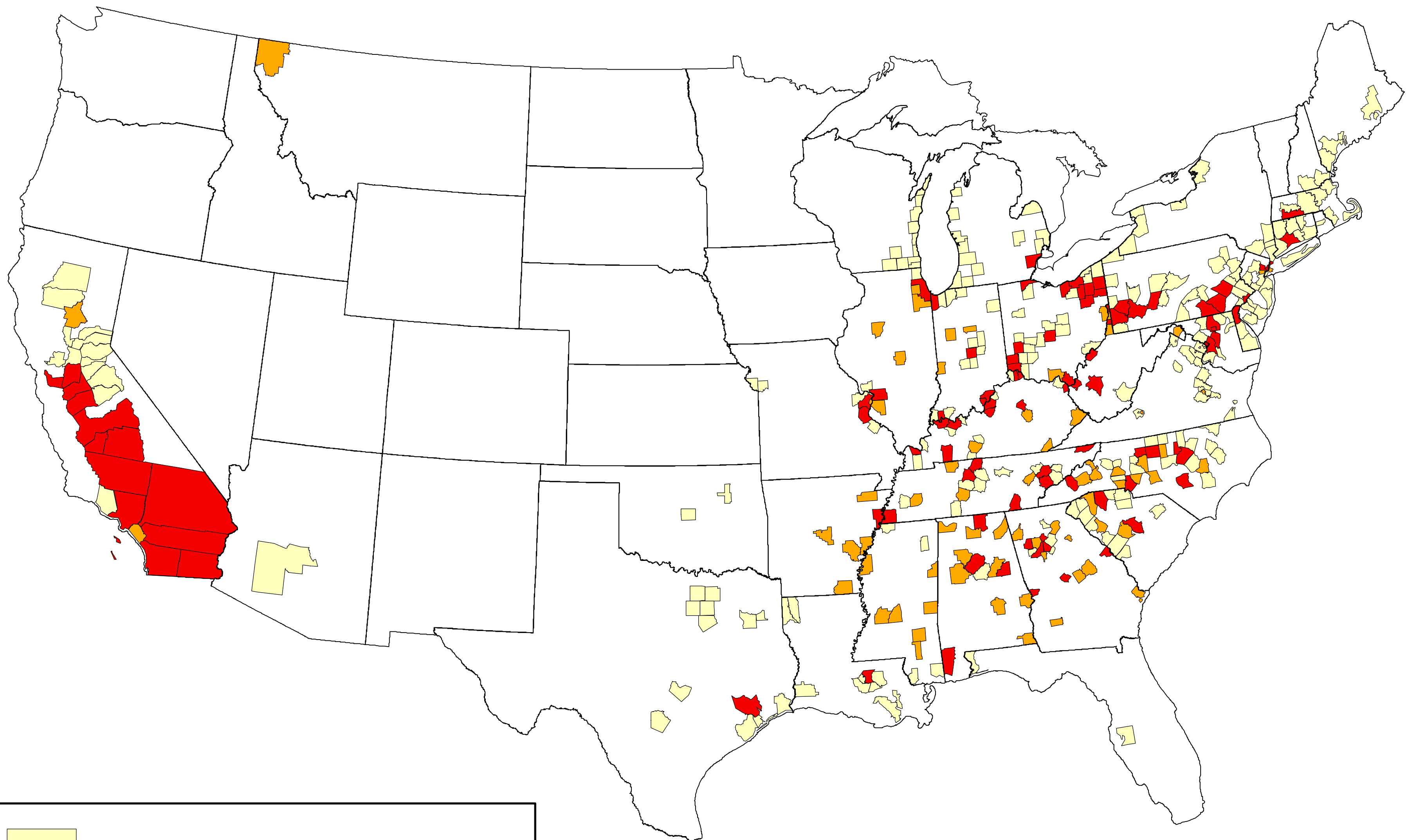
- Particulate matter is the term used for a mixture of solid particles and liquid droplets found in the air; fine particles are smaller than 2.5 microns (millionths of a centimeter) in diameter ($PM_{2.5}$).
- Power plants emit particles directly into the air, but their major contribution to particulate matter air pollution is emissions of SO_2 and NO_x, which are converted into sulfate and nitrate particles in the atmosphere and can be transported for hundreds of miles.
- Health effects include:
  - Increased premature deaths, primarily in the elderly and those with heart or lung disease;
  - Aggravation of respiratory and cardiovascular illness, leading to hospitalizations and emergency room visits in children and individuals with heart or lung disease;
  - Decreased lung function and symptomatic effects such as those associated with acute bronchitis, particularly in children and asthmatics;
  - New cases of chronic bronchitis;
  - Increased work loss days, school absences, and emergency room visits;
  - Changes to lung structure and natural defense mechanisms.
- Under the 1990 Clean Air Act Amendments, local air quality must meet certain standards (National Ambient Air Quality Standards) in order to protect against the human health impacts of fine particle pollution. Based on preliminary data, 173 counties across the country (82 million people), including 157 counties in the eastern U.S. (59 million people), are not attaining these standards.

How Does Ozone (Smog) Affect Human Health and Vegetation?

- Nitrogen oxides and volatile organic compounds react in the atmosphere in the presence of sunlight to form ground-level ozone (smog).
- Ozone is a major component of smog in our cities and other areas of the country. Though naturally-occurring ozone in the stratosphere provides a protective layer high above the earth, the ozone that we breathe at ground level causes respiratory illness and other health and environmental problems.
- Health and environmental effects from high levels of ozone include:
  - Moderate to large (well over 20%) decreases in lung function resulting in difficulty in breathing, shortness of breath, and other symptoms;
  - Respiratory symptoms such as those associated with bronchitis (e.g., aggravated coughing and chest pain);
  - Increased respiratory problems (e.g. aggravation of asthma, susceptibility to respiratory infection) resulting in more hospital admissions and emergency room visits;
  - Repeated exposures could result in chronic inflammation and irreversible structural changes in the lungs that can lead to premature aging of the lungs and other respiratory illness.
  - Damage to forest ecosystems, trees and ornamental plants, and crops

- Under the 1990 Clean Air Act Amendments, local air quality must meet certain standards (National Ambient Air Quality Standards) in order to protect against the human health impacts of ozone (smog) pollution. Currently, 333 counties across the country (122 million people), including 305 counties in the eastern U.S. (94 million people), are not attaining the standards.

Current* 8 hour Ozone and PM2.5 Nonattainment



Ozone only [234 Counties]

PM2.5 only [74 Counties]

Both nonattainment [99 Counties]

*1997-1999 Ozone
1999/2000 PM2.5 - preliminary depiction based on two years of data. Three years of complete data are required for attainment demonstrations.

Visibility is Decreased by Fine Particles in the Air

- SO_2 and NO_X emissions form sulfate and nitrate particles in the atmosphere which can be transported many miles downwind from emissions sources.
- Fine particles (including sulfates and nitrates) in the air scatter light and create hazy conditions, decreasing visibility. Decreased visibility is known as “regional haze.” Humidity intensifies the visibility degradation caused by fine particles, particularly in the East.
- Effects of visibility impairment include:
  - Spoiled scenic vistas across broad regions of the country, in National Parks and wilderness areas;
  - Reduced visual range by as much as 80% to 10 miles or less on the haziest days in some National Parks;
  - Impaired urban vistas nationwide.
- In the western U.S.:
  - The primary goal is to maintain clean conditions, although some National Parks and Wilderness areas currently experience decreased visibility;
  - Sulfates account for 25-50% of haze in the West;
  - Nitrates contribute between 5% and 45% of visibility problems, with the biggest impacts in California National Parks and many urban areas.
  - Visibility impairment for the worst days has remained unchanged over the decade of the 1990s.
- In the eastern U.S.:
  - Substantial visibility impairment exists due to regionally high levels of fine particles;
  - Sulfates cause up to 60-80% of haze in eastern parks and urban areas;
  - Nitrates contribute less, but are more significant in winter;
  - Visibility has improved in some areas during the 1990s, but remains significantly impaired.

Comparison of Good and Poor Visibility

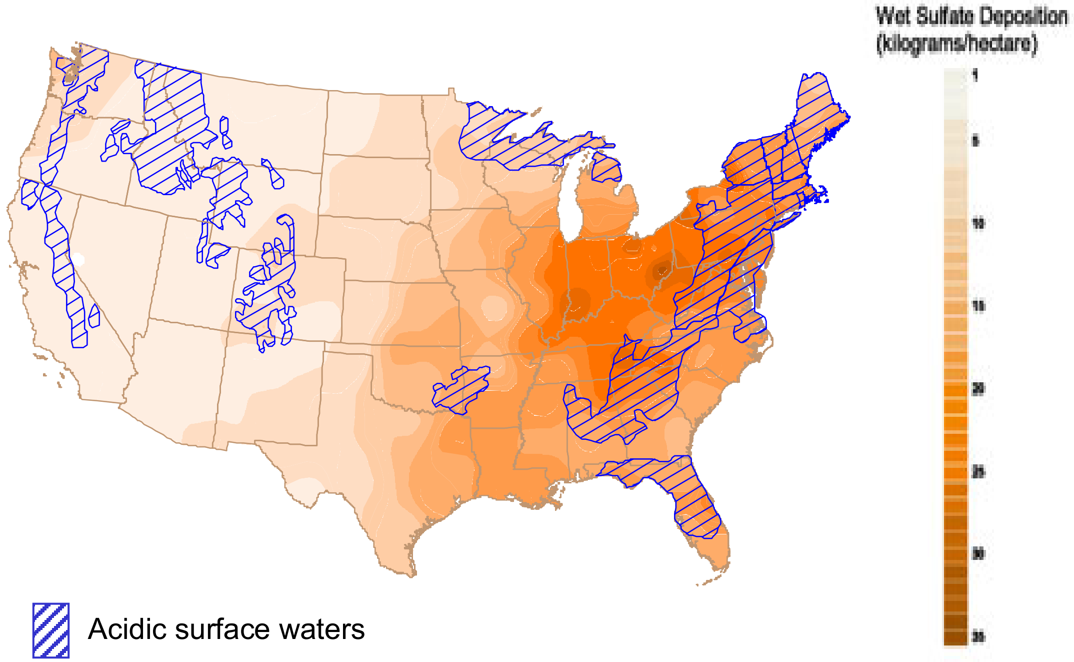
Modeled visibility conditions on the National Mall in Washington, DC. Left image: Poor visibility, 5 mile visual range, 39 deciview*, 65 ug/m^3. Right image: clear day, 90 mile visual range, 12 deciviews, less than 2.5 ug/m^3.

*A deciview is a measure of visibility which captures the relationship between air pollution and human perception of visibility. When air is free of the particles that cause visibility degradation, the Deciview Haze Index is zero. The higher the deciview level, the poorer the visibility; a one or two deciview change translates to a just noticeable change in visibility for most individuals.

How Does Acid Rain Damage Lakes, Streams, Forests, and Buildings?

- Acid deposition occurs when emissions of SO_2 and NO_X react in the atmosphere to create acidic gases and particles which reach the Earth in wet and dry forms.
- Highest sulfur and nitrate deposition occurs in areas of the Midwest and northeastern United States which are downwind of the highest SO_2 and NO_X emission areas.
- Impacts occur in both the eastern U.S. and mountainous areas of the West.
- Effects of acid deposition include:
  - Acidification of lakes and streams, making them unable to support fish and other aquatic life;
  - Damage to forests through acidification of soil, depletion of soil nutrients, and direct injury to sensitive tree leaves and needles;
  - Harm to buildings, statues and monuments.

Wet Sulfate Deposition (1997-1999) and Acid-Sensitive Surface Waters



Source: CASTNet/NADP; National Surface Water Survey

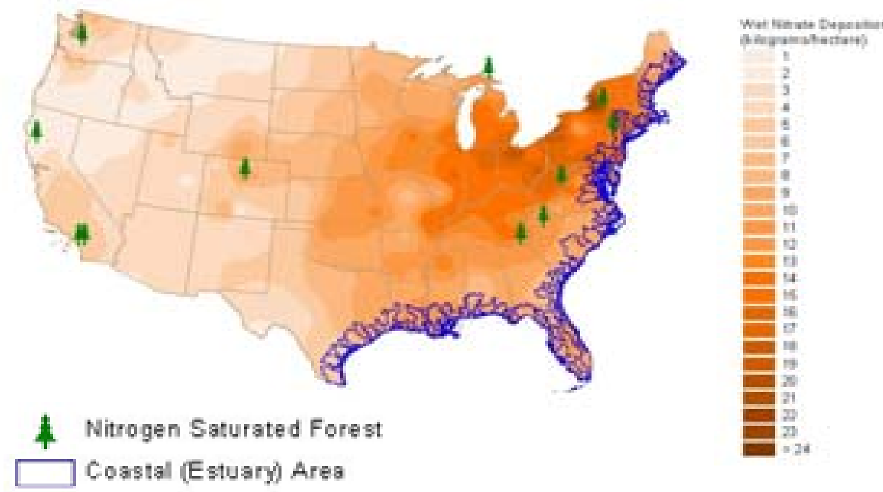
- High levels of sulfur and nitrogen deposition still enter acid-sensitive lakes and streams leading to high levels of acidity.
- Southeastern streams will continue to grow **more** acidic without significant further reductions in sulfate and nitrogen deposition.
- Many scientists believe that significant further reductions in SO_2 and NO_X emissions are necessary to fully protect acid-sensitive ecosystems.

How Does Nitrogen Deposition Harm Forests and Coastal Ecosystems?

- NO_X emissions from power plants contribute significant amounts of nitrogen to coastal waters and affected forests.
- For example, 10-40% of the nitrogen reaching East and Gulf coast estuaries is transported and deposited via the atmosphere.
- Excess nitrogen in coastal waters causes "eutrophication" and results in:
  - Algal blooms, some of which are toxic (e.g. red and brown tides);
  - Depletion of dissolved oxygen (hypoxia), stressing or killing marine life;
  - Loss of important habitat, such as seagrass beds and coral reefs;
  - Changes in marine biodiversity and species distribution;
  - Economic and social impacts due to loss of fisheries and tourism.
- Two thirds of U.S. estuaries (about 84) experience symptoms of moderate to high eutrophication.

- High nitrogen deposition levels can lead to loss of soil nutrients and declines in sensitive forest ecosystems.
- Nitrogen saturation occurs when too much nitrogen enters sensitive forest soils and begins to leach out, stripping soil nutrients.
- Signs of nitrogen saturation have been observed in various sensitive forests in the Eastern and Western U.S. (e.g., Great Smoky Mountains, Adirondack/ Catskill Mountains, Colorado Front Range, southern California).

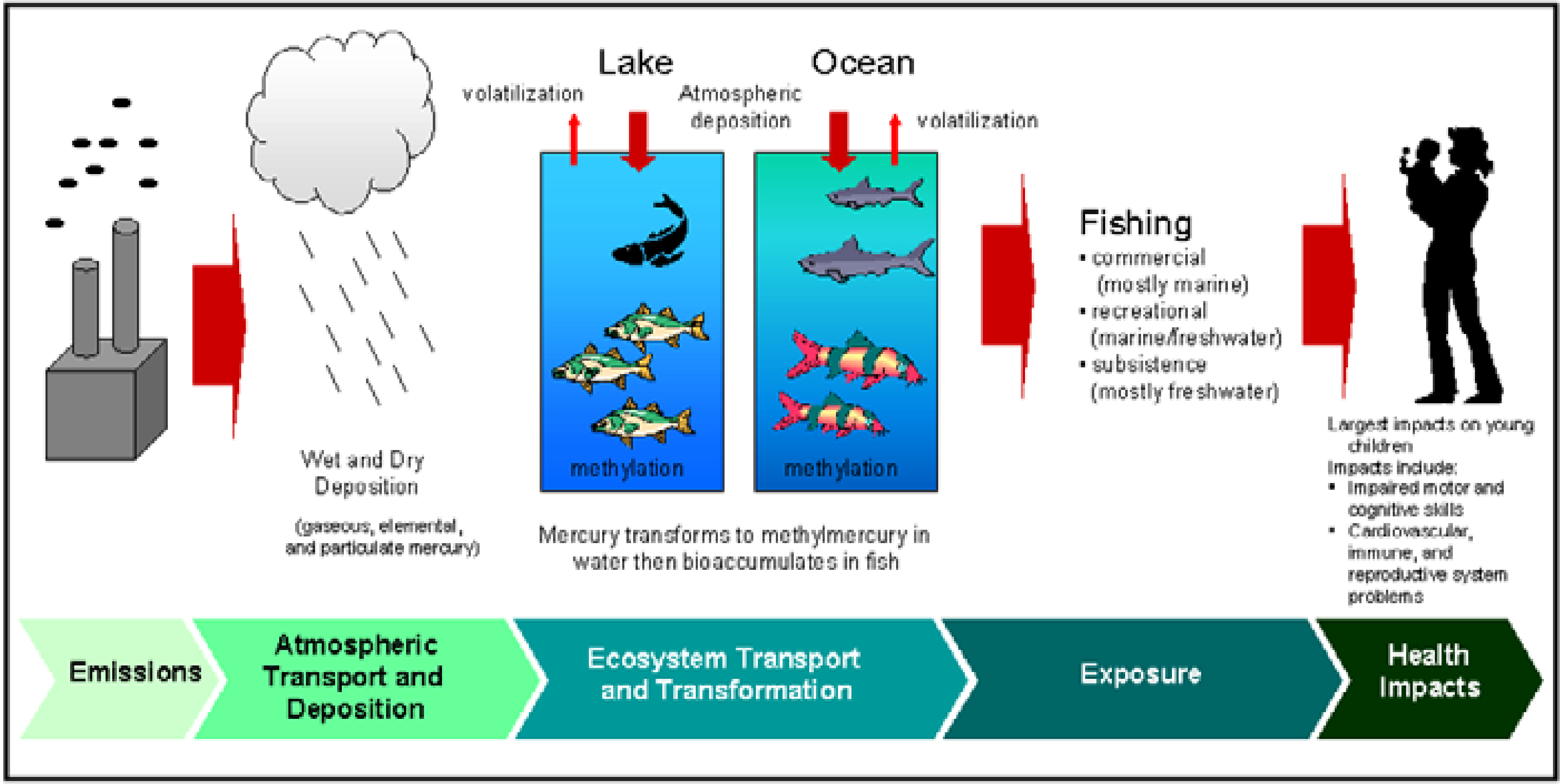
Wet Nitrate Deposition to Sensitive Resources



Deposition data measured by CASTNet and NADP, 1997-1999

Nitrogen deposition contributes to nutrient over-enrichment (eutrophication) along eastern and Gulf coasts and to excess nitrogen in sensitive forests.

Mercury Emissions from Power Plants Contaminate Fish

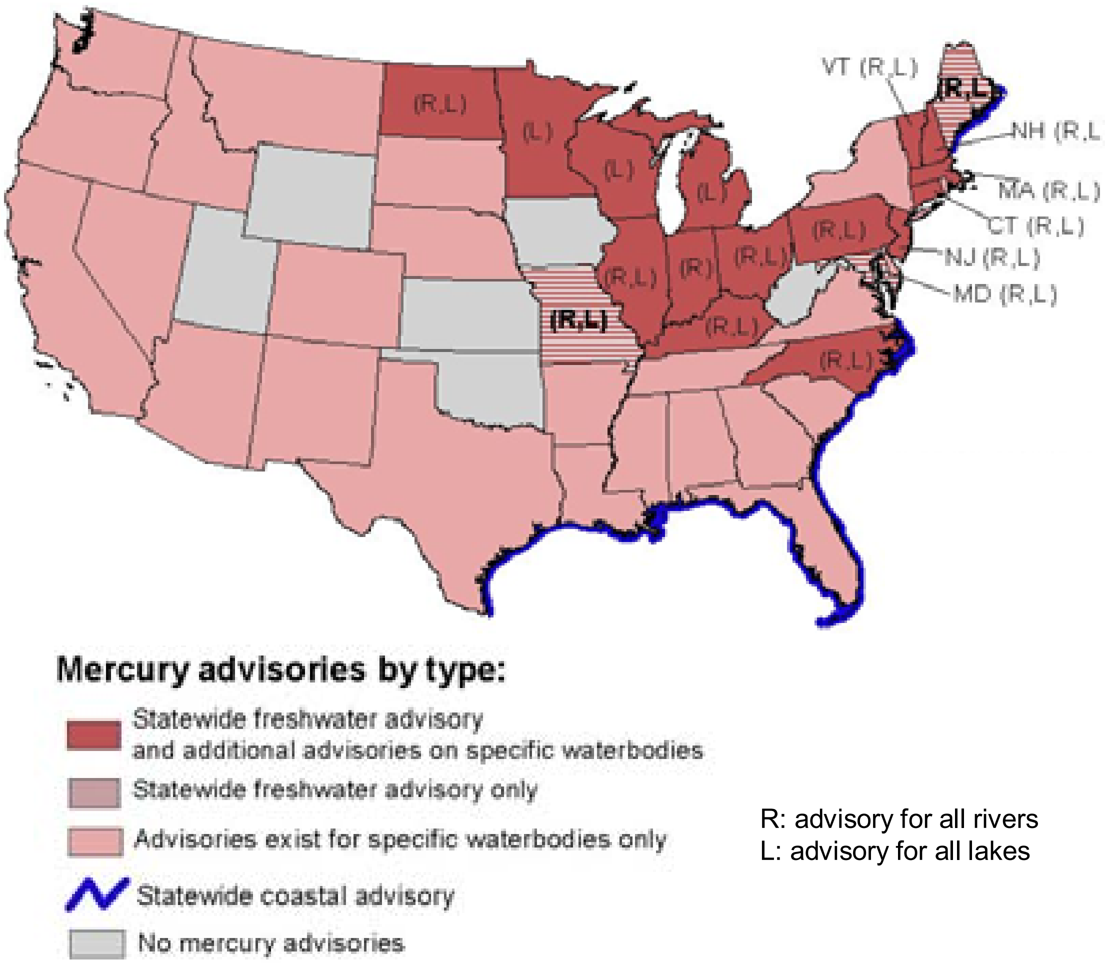


- The primary way in which people are exposed to mercury is through eating contaminated fish.
- A portion of the mercury emitted from power plants accumulates in fish.
    - Mercury that is deposited from the atmosphere accounts for more than 50% of the mercury input to many waterbodies, including the Chesapeake Bay and Lake Michigan.

Mercury Exposure and Health Effects

- Typical US consumers eating moderate amounts of a variety of fish from restaurants and grocery stores are not likely to be exposed to dangerous levels of mercury.
- The most highly exposed populations are those who eat substantial amounts of fish, including recreational anglers, some recent immigrants, and subsistence fishers.
- Ten percent of U.S. women have blood mercury levels that put their fetuses at risk of adverse impacts.
- Almost 400,000 children are born in the U.S. each year at risk of adverse neurological impacts due to mercury.
- 42 states have fish advisories for mercury contamination.

Mercury currently impairs 5.6 million acres of lakes, estuaries and wetlands and 43,500 miles of streams, rivers and coasts

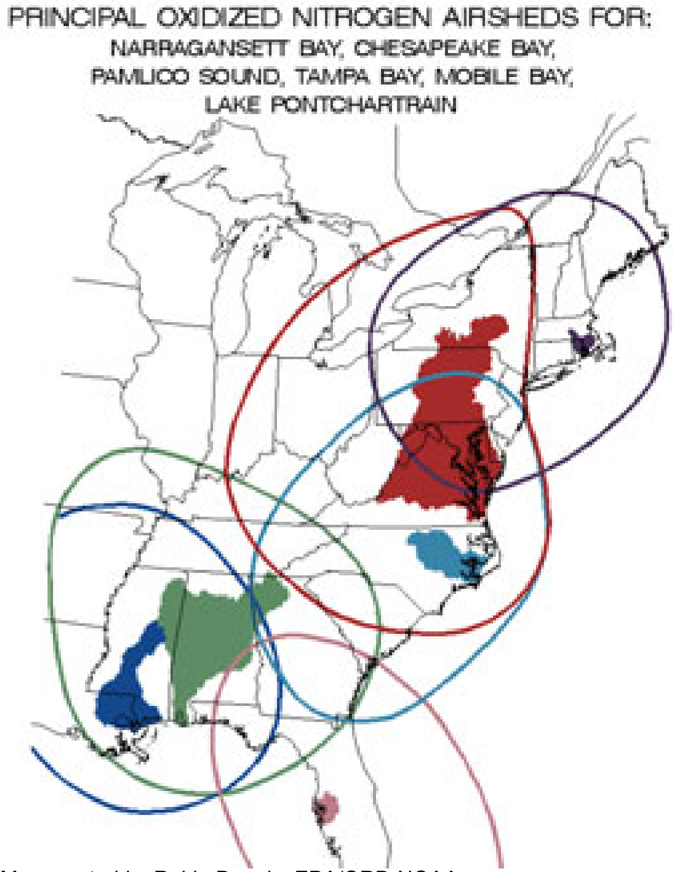


R: advisory for all rivers
L: advisory for all lakes

he health impacts of mercury can include:

Brain damage	Lack of motor skills
Impaired cognitive skills	Difficulty speaking and hearing
Cardiovascular problems	Impairment of immune and reproductive systems

Multiple Pollutant Approach to Addressing Multiple Impacts and Long-Range Transport



Map created by Robin Dennis, EPA/ORD-NOAA

- Emissions in an airshed are responsible for the majority (but not all) of the deposition that occurs in the receptor region (in this case an estuary)
- As these airsheds demonstrate, NOx emissions are often transported long distances before being deposited in estuaries
- Therefore, regional reductions in emissions are the most effective way to reduce nitrogen deposition to all estuaries

- Air pollution can be carried hundreds of miles from its source and can cause multiple human health and environmental problems on regional or national scales.
- A single pollutant, such as SO_2 or NO_X, can often create multiple human health and environmental effects. For example, NO_X emissions contribute to the formation of particulate matter and ozone, reduce visibility, cause acidification of lakes and streams, degrade forest ecosystems by directly damaging trees and causing soil nutrient loss, and contribute to eutrophication of coastal waters.
- Sulfur Dioxide, Nitrogen Oxides, and Mercury pollution can cause human health and environmental impacts in a different environmental medium (water) than the medium into which the pollutant was originally emitted (air).
- Because air pollutants travel long distances, often crossing local and state boundaries, states and communities cannot independently resolve all of their air pollution problems.
- By reducing emissions from power generation in an integrated manner, improvements in relation to multiple health and environmental concerns occur over large geographic areas.