EPA United States Environmental Protection Agency
Office of Water

Oceans and Coastal Protection Division

Air Pollution and Water Quality

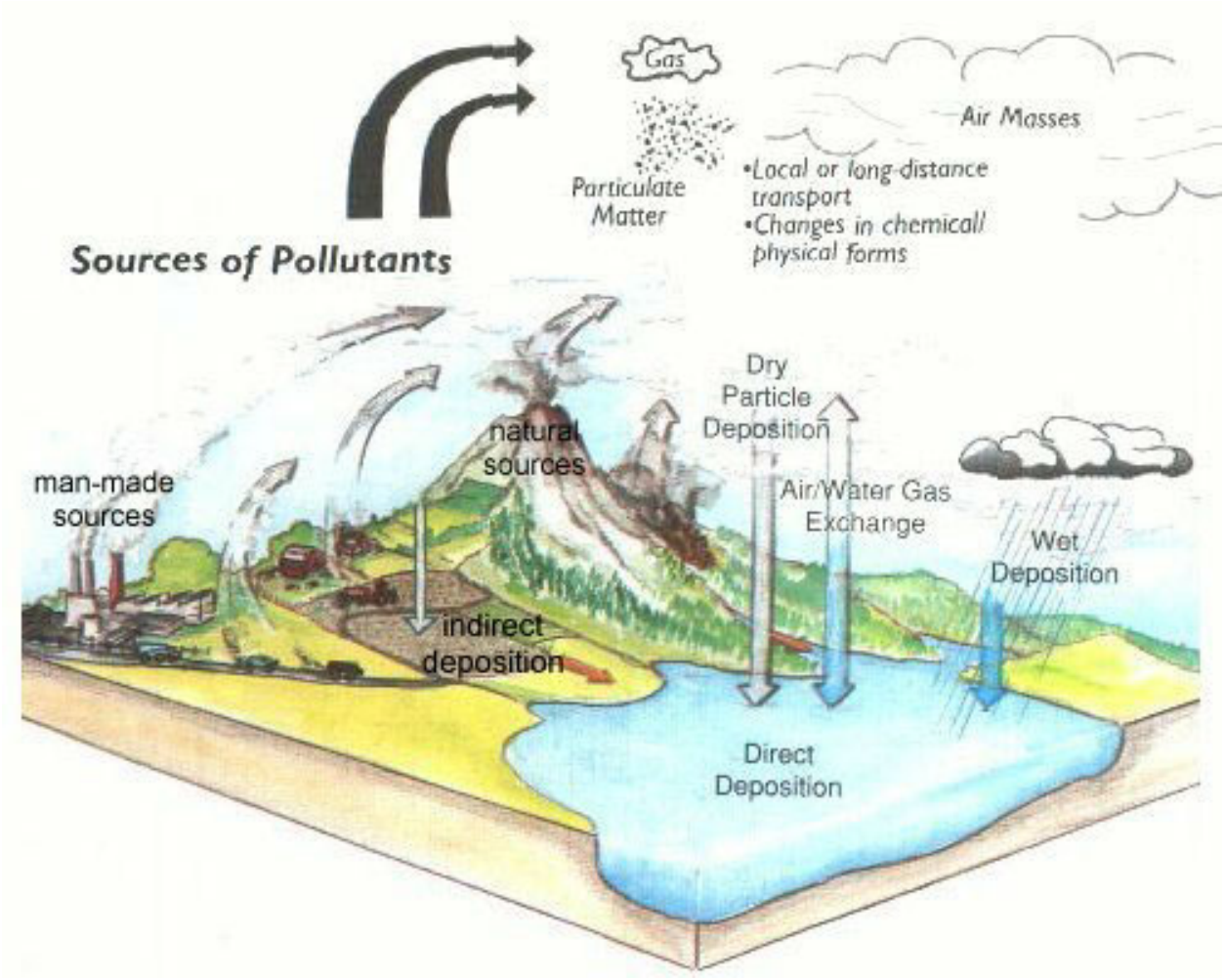
Atmospheric Deposition Initiative

What is atmospheric deposition and how does it occur?

Pollutants released into the air are carried by wind patterns away from their place of origin. These pollutants come from man-made sources such as the burning of fossil fuels, industrial processes, cars and other forms of transportation, fertilizer, and the volatilization of animal wastes. Air deposition can also come from natural sources of emissions. For example, up to 25% of the mercury emitted worldwide is released naturally as part of the global mercury cycle. Depending on weather conditions and the chemical and physical properties of the pollutants, pollution can be carried significant distances from its source and can undergo physical and chemical changes as it travels. Some of these chemical changes include the formation of new pollutants such as ozone, which is formed from nitrogen oxides (NO_x) and hydrocarbons.

Atmospheric deposition occurs when pollutants in the air fall on the land or water. Pollution deposited in snow, fog, or rain is called wet deposition, while the deposition of pollutants as dry particles or gases is called dry deposition. Air pollution can be deposited into water bodies either directly from the air onto the surface of the water, or through indirect deposition, where the pollutants settle on the land and are then carried into a water body by runoff or through natural processes such as the movement of groundwater through the soil.

Any chemical that is emitted into the air can become an air deposition problem. Some of the common ones include different forms of nitrogen (in high concentrations), mercury, copper, polychlorinated biphenols (PCBs), polycyclic aromatic hydrocarbons (PAHs), chlordane, dieldrin, lead, lindane, polycyclic organic matter (POM), dioxins, furans, toxaphene, hexachloro-benzene, hexachlorocyclohexane, and diazanon. Even chemicals that are no longer in use in the U.S. (such as PCBs) can be deposited because they are emitted from incinerators that burn contaminated garbage or from contaminated sites, or blown in from other countries.



Which pollutants pose the greatest problems?

Persistent Bioaccumulative Pollutants: Pollutants that persist in the environment for many months or years, and which accumulate in plants, fish, and wildlife are called "persistent bioaccumulative pollutants." Persistent means that the pollutant does not break down or become non-toxic easily (or at all) in the environment. Bioaccumulative means that the pollutant concentrates in the bodies of animals, including humans, that ingest contaminated food on a regular basis. One of the most common persistent bioaccumulative pollutants is mercury. Others

include metals such as lead and cadmium; pesticides such as chlordane, DDT, dieldrin, lindane and toxaphene; and industrial pollutants such as PCBs, dioxins, and furans. The tendency of these substances to linger in the environment and to build up in plant and animal tissues poses the greatest risk to human health and the environment. People and other animals generally receive the highest doses of these pollutants when they eat contaminated foods, especially contaminated fish. To reduce the risk to humans from this pollution, States and Tribes issue fish advisories cautioning people to limit their consumption of fish with high levels of pollutants such as mercury, PCBs, and DDT.

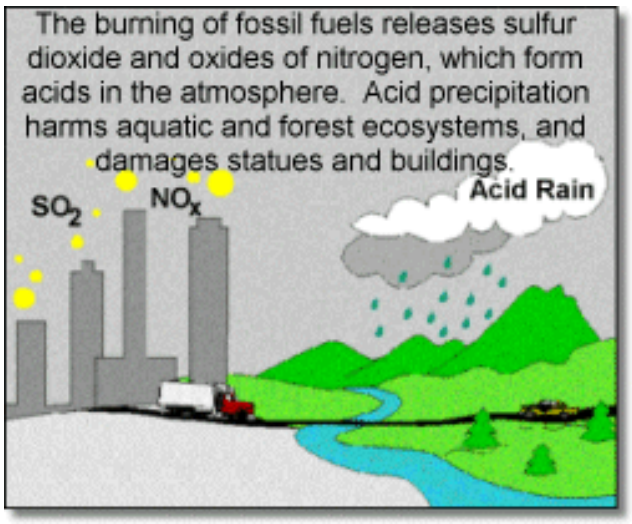
Nutrient Pollution: Nitrogen is a nutrient essential for plant growth and is naturally cycled through land, water, and the air. However, it is a pollutant when it becomes overabundant in ground or surface waters, in soil, or in the air. This is what has happened in many coastal waters in the eastern U.S. where high levels of nitrogen in the water have been linked to a condition known as eutrophication. Some of the effects of eutrophication include low levels of dissolved oxygen, outbreaks of algal blooms (some of which may be harmful or toxic), reduced visibility, and other ecosystem disturbances. Nitrogen pollution can find its way into surface or ground waters directly through sewage treatment plant discharges, septic systems, and runoff from farms, lawns, and city streets. Nitrogen compounds are also emitted into the air by cars, trucks, electric utilities, and industry where they can be deposited on land or directly into water bodies.

What are the effects of atmospheric deposition?

Mercury: Mercury has long been known to be a toxic, persistent, bioaccumulative pollutant with a wide range of ecosystem and human health effects.

> ***Mercury poisoning:*** The primary health effects from mercury are on the development of the brain and nervous system of children who eat contaminated fish, and in fetuses whose mothers eat contaminated fish. It is likely that subtle nervous system and developmental effects (such as attention deficit disorder) occur in children chronically exposed to relatively low concentrations of mercury. Exposure to high concentrations of mercury over a long period of time can also result in brain damage in adults. It is also thought that serious nervous system and reproductive disorders are occurring in some populations of fish-eating birds and mammals.

Nitrogen: is an essential nutrient for life -- it is a fertilizer that we add to lawns, gardens, and farms. But in excess amounts, nitrogen has proven to be a significant problem, especially in nitrogen-sensitive waters such as bays and estuaries. Excess nitrogen contributes to a decrease in overall water quality, and has been linked to increases in the occurrence of harmful algal blooms such as "red tides" and "brown tides," and outbreaks of Pfiesteria. Excess nitrogen also alters the food web and the ecological make-up of coastal and other aquatic ecosystems. Nitrogen is linked to the following human health and environmental problems:



Ozone: Ozone is made in the lower atmosphere by a chemical reaction between volatile organic carbons (VOCs) (carbon chain compounds that are released from a large variety of activities, including fossil fuel combustion) and nitrogen oxides (NO_x). Ozone warning and alert days have become regular summer occurrences in urban areas throughout the country. Ozone causes serious respiratory problems, especially in populations that are already under stress, including the very young, elders, and those with respiratory illnesses such as asthma. Even people outside of these high risk groups are subject to symptoms such as headaches, sore throats, coughing, and shortness of breath. Because people are advised to limit or forego outdoor activities during these times, the quality of life is reduced for all people subject to ozone warning and alerts.

Acid rain: Sulfur dioxide and NO_x are the two key air pollutants that cause acid rain. As lakes and streams become acidified, the number of plants and animals present decreases. In some cases, life dies out altogether. The health of forested areas is also affected by atmospheric deposition of sulfur and nitrogen which can put stress on sensitive tree species and result in the loss of soil nutrients and plant diversity. Acidification of streams and lakes also appears to mobilize toxic metals, such as aluminum and mercury, which present an additional risk to fish and fish-eating populations.

Eutrophication (over enrichment of nutrients): An increase in nitrogen concentrations in estuaries and other coastal waters often leads to low oxygen (hypoxia) or no oxygen (anoxia) in bottom waters due to the decomposition of algal blooms. Hypoxia in Long Island Sound and the Gulf of Mexico has become a recurring event with significant economic consequences. Eutrophication is also a cause of the loss of diversity in the sea floor community (including seaweeds, seagrasses, and corals), and among planktonic organisms. Planktonic algae are the basis of marine food webs and a change in the dominant species can have a domino effect throughout the food web. In cases where nuisance algae come to dominate the algal community, toxic or nuisance algal blooms result. Over-enrichment of nutrients appears to be at least partly

Levels of nitrates that exceed EPA drinking water standards can pose human health risks.

to blame for the more frequent occurrences of nuisance algal blooms and the resulting extensive die-offs of fish and shellfish in estuaries and coastal waters.

Nitrification of drinking water: There has been a dramatic rise in nitrogen concentrations in drinking water supplies, much of which comes from air sources as well as fertilizer and animal wastes. In the major rivers of the northeastern U.S., nitrate concentrations have risen three- to ten- fold since the early 1900s (Vitousek et al., 1997). Nitrates are a human health hazard if they are present in high concentrations (greater than 10 milligrams of nitrate per liter of water). This acute nitrate contamination is linked to a condition that occurs primarily in infants called methemoglobinemia, or "Blue Baby Syndrome." The condition is rare, but it occurs when oxygen in hemoglobin (the compound that carries oxygen from the lungs through the body) is replaced by nitrite and causes mild to severe oxygen deprivation, which can result in brain damage and death. Researchers are also investigating a possible link between high levels of nitrate in drinking water and non-Hodgkins lymphoma, a cancer of the lymphatic system. These health effects are expected to become more widespread if the geographic distribution and extent of nitrate contamination continues to rise.

How much water pollution is coming from the air?

Mercury: It has been estimated that anthropogenic mercury emissions have tripled the mercury concentration in the air and in the surface of the ocean since 1900 (Mason et al., 1994). Canadian researchers have estimated the amount of direct deposition to the surface of the Great Lakes at 83% of the total mercury load to the Lakes (Shannon and Voldner, 1995). Another researcher estimated that 50% of the mercury in the Chesapeake Bay comes from air deposition directly to the surface of the Bay (Mason et al., 1997)

Nitrogen: Since 1940, human activity has doubled the rate of nitrogen cycling through the global atmosphere (Vitousek et al., 1997). Depending on the water body and watershed being considered, it is estimated that roughly a quarter of the nitrogen in an estuary comes from air sources. Each watershed is different, but extensive modeling and monitoring in the Chesapeake Bay watershed have produced the following estimates of the sources of nitrogen in that particular watershed (Alliance for the Chesapeake Bay, 1997):

Estimated Sources of Nitrogen in the Chesapeake Bay	
water-borne point sources, e.g. industry, sewage treatment plants, etc.	25%
runoff from land, e.g., farms, lawns, city streets, golf courses, etc.	50%
air sources, e.g., electric power plants; cars, trucks, boats, and other mobile sources; municipal waste combustors, etc.	25%

This estimate of air sources includes indirect air deposition that reaches the bay as runoff from forests, streets, farmland, and anywhere else it is deposited. Some other estuaries have also attempted to estimate how much of the nitrogen in their water comes from air sources, including both direct and indirect deposition. Some of these estimates are given below.

Percent of Nitrogen Entering Selected Estuaries Estimated to Come From Air Sources (both direct and indirect deposition) *	
Tampa Bay	28%
New York-New Jersey Harbor	38%
Albermarle-Pamlico Sounds	38%

*source: National Estuary Programs

Where is the air pollution coming from?

Mercury: Mercury cycles through the atmosphere continuously and is deposited world-wide, making it hard to track. A further complication is that mercury can settle out from the air to the water and then revolatize to the atmosphere again and again, traveling like a grasshopper until it comes to rest in colder climates. The EPA estimates that combustion of mercury-containing material accounts for 86% of the mercury emissions in the U.S. that is broken down as follows: coal-fired electric utility boilers contribute approximately 33%; municipal waste combustion contributes around 19%; coal and oil-fired commercial/industrial boilers contribute about 18%; medical waste incinerators contribute approximately 10%, hazardous waste combustion contributes approximately 4%, and residential boilers contribute approximately 2%. Another 10% of the total emissions come from manufacturing such as chlor-alkali, Portland cement, and pulp and paper manufacturing. The remaining 3% comes from area sources including laboratory uses, dental preparations, and landfills; oil-fired electric utilities; sewage sludge incineration; wood-fired boilers; and miscellaneous sources including geothermal power (Mercury Study Report to Congress, 1997). In addition to these domestic emissions, a significant amount of mercury enters the United States from other countries because of the global transport of mercury. Worldwide, researchers say that approximately 34% of the mercury emitted into the atmosphere comes from coal combustion.

Sources of U.S. Mercury Emissions *	
coal-fired electric utilities	33%
municipal waste combustion	19%
coal and oil-fired commercial/industrial boilers	18%
medical waste incinerators	10%
manufacturing	10%
other sources	10%

*source: Mercury Study Report to Congress

Nitrogen: The burning of fossil fuels -- oil, coal, and gas -- is responsible for much of the increase in global nitrogen, in the form of nitrogen oxides (NO_x). Electric power plants, industry,

and mobile sources like cars and trucks are the main users of fossil fuels. Other sources of nitrogen include burning of forests and other plant material, volatilization of ammonia from fertilized fields, and ammonia released from domestic animal wastes such as hogs or chickens.

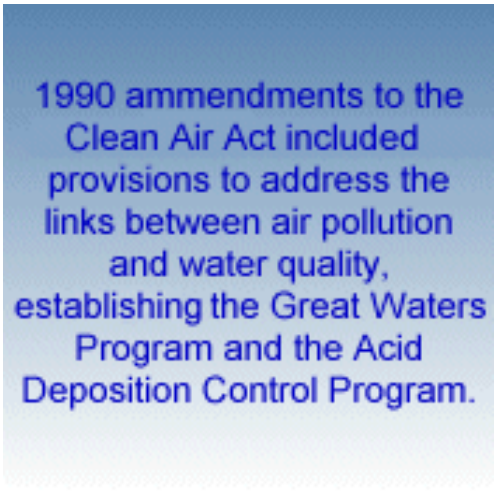
In the Chesapeake Bay airshed, it is estimated that 37% of the nitrogen entering the bay from air sources comes from electric utilities; 35% from cars and trucks; 6% from industry and other large sources of fossil fuel-fired boilers; and 21% from other sources such as ships, airplanes, lawnmowers, construction equipment, and trains (Alliance for the Chesapeake Bay, 1997).

Sources of Nitrogen Entering the Chesapeake Bay from the Air *	
electric utilities	37%
cars and trucks	35%
industry and other fossil fuel-burning point sources	6%
other sources	21%

*source: Alliance for the Chesapeake Bay

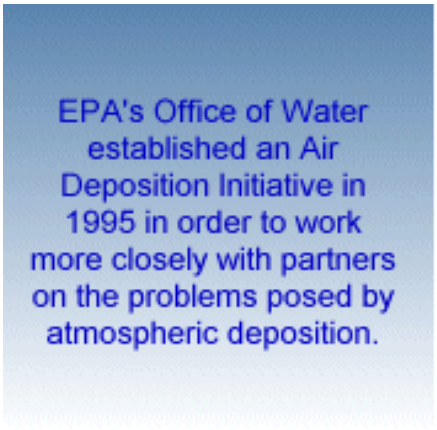
What is EPA doing about atmospheric deposition?

Clean Air Act: Since 1970, when the Federal Clean Air Act was first passed, emissions of many air pollutants have declined largely due to regulatory requirements from the National Emission Standards for Hazardous Air Pollutants and the National Ambient Air Quality Standards.



In response to mounting evidence indicating that air pollution contributes significantly to water pollution, Congress added the Great Waters Program (section 112(m)) and the Acid Deposition Control Program (Title IV) when it amended the Clean Air Act in 1990. The Great Waters Program, a joint program including EPA and the National Oceanographic and Atmospheric Administration (NOAA), is designed to study and address the effects of air pollution on the water quality and ecosystems of the Great Lakes, Lake Champlain, the Chesapeake Bay, and estuaries that are part of the National Estuary Program or the National Estuarine Research Reserve System. The Acid Deposition Program has resulted in the enactment of regional air pollution controls for sulfur and nitrogen to address broad ecological concerns, including those described above. The Agency also has many other ongoing activities associated with reducing persistent bioaccumulating toxics and nitrogen deposition in the following programs and Offices:

- Office of Air
- Great Waters Program
- Persistent Bioaccumulative Toxics
- AIRNOW
- Mobile Source Reduction
- Ozone
- Hazardous Waste Combustion
- Fish Consumption Advisories
- Chesapeake Bay Program Office
- Great Lakes Program Office



Office of Water's Air Deposition Initiative: In 1995, EPA's Office of Water established an "Air Deposition Initiative" to work with EPA's Office of Air and Radiation to identify and characterize air deposition problems with greater certainty and examine solutions to address them. The Air and Water Programs are cooperating to assess the atmospheric deposition problem, conduct scientific research, provide innovative solutions to link Clean Air Act and Clean Water Act tools to reduce the deposition of these pollutants, and communicate the findings to the public. To date, most efforts have focused on better understanding of the links between nitrogen and mercury emissions and harmful effects on water quality and the environment. Significant work has also been done towards quantifying the benefits to water quality of reducing air emissions and developing sensible, cost effective approaches to reducing the emissions and their ecosystem and health effects.

1998 "NO_x SIP Call" Rule: On September 24, 1998 EPA finalized the "NO_x SIP Call" rule which requires 22 eastern states and the District of Columbia to prepare State Implementation Plans (SIPs) to reduce nitrogen oxide (NO_x) emissions from sources such as coal-fired utilities. This rule will address regional transport of ground-level ozone (ozone is formed from NO_x and hydrocarbons in the atmosphere). Many benefits will result from reduced NO_x emissions in the areas of public health, air quality and visibility, acid rain, agriculture, and nutrient pollution in coastal waters. Excess nitrogen in coastal waters is responsible for excessive algal growth, which reduces levels of oxygen and light, which in turn can harm fish, shellfish, aquatic vegetation and coral reefs. Furthermore, outbreaks of Pfiesteria, a toxic organism, have been associated with excessive nutrient loadings in coastal waters.

The reductions in NO_x emission expected from the rule will significantly reduce nitrogen loadings into eastern coastal waters and portions of western Florida. By 2007, EPA estimates the NO_x reductions achieved will prevent 40 million pounds per year of nitrogen from being deposited in coastal areas. By reducing the amount of nitrogen deposited from the air, states and municipalities will be able to save $237 million annually that would have otherwise been spent on other controls to meet their nitrogen reduction goals (e.g. storm water controls for urban and agricultural runoff).

What can you do?

You can do many things to protect water quality from pollution resulting from air deposition, but the single most important thing you can do is to reduce your use of fossil fuels by reducing your consumption of energy. Fossil fuels emissions, either from utilities or automobiles, are responsible for 72% of the NO_x emissions in the Chesapeake Bay area. Energy efficiency will, in the long run, prevent many tons of nitrogen and toxics from entering the air in the first place. Besides curbing atmospheric deposition, conserving energy has other important benefits-- energy conservation helps to prevent smog, greenhouse gas emissions, and other air quality problems, and saves you money on utility bills.

☆ Use energy wisely and conserve energy when possible:

- Buy energy efficient products, from home appliances to cars, and limit their usage.
- Insulate your home and use passive solar techniques to reduce reliance on fossil fuels.
- Choose an energy source that has a low impact on the environment. Electricity and natural gas produce less pollution than wood-burning stoves and fuel oil.
- Participate in recycling programs-- recycling conserves energy and natural resources.
- When shopping, look for products that contain recycled materials.
- Keep the thermostat at 80 degrees in the summer and 68 degrees in the winter.

☆ Curb car emissions:

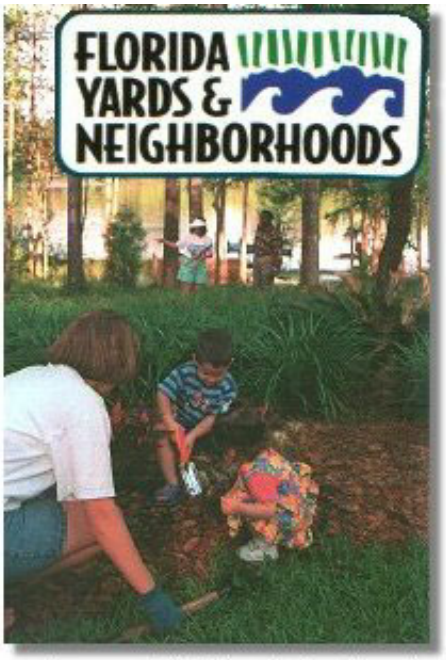
- Keep your car tuned and drive at optimum speeds for gas consumption.
- Drive only when necessary and plan trips wisely to minimize miles driven.
- Consider tele-commuting to work.
- When possible, car pool, walk, bicycle, or use public transportation instead of driving.

☆ Buy products which use non-toxic materials (e.g., buy non-mercury thermometers).

☆ Properly dispose of household hazardous waste, including items containing mercury, such as thermometers, thermostats, old batteries, latex paint, and florescent bulbs. Many communities have household hazardous waste collection days to safely dispose of these items. For dates and times, contact your local city or county government environmental protection office. Never burn these items, as burning releases the toxic chemicals that can be inhaled or deposited.

- ☆ Encourage maintenance of stream buffers, forests, and wetlands to help reduce runoff of nitrogen into water.

- ☆ Consider using a push mower or electric lawn mower to cut your lawn. Limit your use of lawn and garden fertilizers and pesticides, and use these materials as directed on the package—a little extra won't improve your lawn, but it will pollute the air and water. Look into environmentally-friendly landscaping that uses native plants, limits the use of fertilizers and chemicals, and saves water. For more information about environmentally-friendly lawn and garden care, talk to your local native plant nursery, native plant organization, county, agriculture, or university extension agent.



environmentally-friendly landscaping

- ☆ Learn more about air quality issues affecting water quality so that you can:
  - ♦ Encourage your local officials to approve only development that will result in reduced energy consumption because of smarter transportation patterns, e.g., planning living areas close to where jobs are.
  - ♦ Communicate knowledgeably regarding air quality protection measures to regulatory agencies and local, state, and national elected officials.