UT Extension

SP657

Impacts of Air Pollution on the Urban Forest

Christopher M. Oswalt
Graduate Research Assistant
Forestry, Wildlife & Fisheries

Wayne K. Clatterbuck
Associate Professor
Forestry, Wildlife & Fisheries

An average human breathes around 3,400 gallons of air each day. Included in each breath can be numerous noxious chemicals as well as suspended particles. Consequently, human lungs must cope with this pollution. It is well known that air pollution is hazardous to human health and of enormous concern today. However, the "lungs" of our urban areas, trees growing in and around our cities, must also contend with air pollution. Just as air pollution impacts humans, air pollution affects trees in a variety of ways.

Pollution has long been identified as harmful to trees. Historically, impacts of air pollution were primarily local in scale (trees impacted by a nearby industrial area).Yet today, trees are being affected on both the local and regional scale. Entire urban areas and even rural area trees are experiencing adverse impacts of air pollution.

Trees help cleanse the air by reducing levels of carbon dioxide (CO_2) and removing pollutants, while releasing oxygen through **photosynthesis**. Air pollution directly injures trees by damaging living tissue, primarily foliage, and impairs photosynthesis and the ability to respirate. Air pollutants also weaken trees, predisposing them to further damage by insects and disease. Some air pollutants can also indirectly impact tree health by altering ecosystem processes such as soil chemistry and nutrient cycling. The result is decreased tree vigor and growth that can culminate in tree death.

Identifying Air Pollution Injury

Air pollution may cause short-term damage, which can be immediately visible, and long-term damage, which can lead to gradual tree decline. Signs of tree injury from air pollution generally appear first in the foliage. Leaves or needles may begin to appear discolored, spots may occur between the veins or the tips may appear burned. Air pollution injury is often difficult to identify because symptoms are similar to other injuries such as nutritional deficiencies and drought. Additionally, long-term damage generally

Robert Anderson

Ozone damage to maple.

Tim Tigner

Ozone damage to black cherry.

Trees that are known to be relatively tolerant of air pollution	Trees that are known to be relatively intolerant of or sensitive to air pollution
• Arborvitae • Boxelder • Douglas-fir • Flowering dogwood • Northern red oak • Willow oak	• American elm • Lombardy poplar • Willow • White pine • Virginia pine

predisposes a tree to other environmental stresses, making diagnosis difficult due to the masking effects of the additional stress. Some tree species are more susceptible to air pollution than are others.

The Causes

Some of the major air pollutants and their primary sources are:

- Carbon dioxide: Burning oil, coal or natural gas for energy.
- Sulfur dioxide: Burning coal to generate electricity.
- Hydrogen fluoride and silicon tetrafluoride: Aluminum and phosphate fertilizer production, oil refineries and steel manufacturing.
- Nitrogen oxides (NOx): Burning fossil fuels and automobile exhausts.
- Ozone: Chemical reactions of sunlight, NOx and volatile organic compounds (occurs naturally and found in products such as paints, solvents, gasoline, adhesive and others)
- Methane: Burning fossil fuels, livestock waste or landfills.
- Chloroflorocarbons: Air conditioners, refrigerators or industrial foam.
- Particulates: Dust, ash, pollen and smoke.

The major phytotoxic (detrimental to plants) air pollutants are ozone, sulfur dioxide and nitrogen oxides.

Ozone

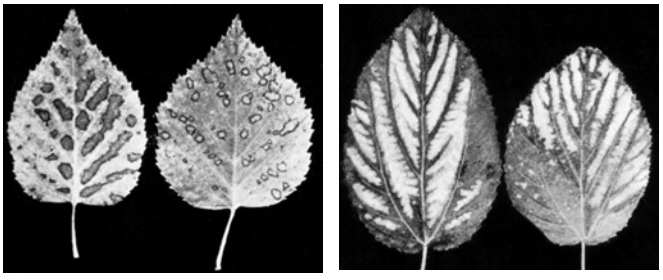
Ozone is not generally emitted directly into the air; instead, ozone (O_3) is formed through a chemical reaction in the Earth's lower atmosphere, the troposphere. Volatile organic compounds (VOCs) react with nitrogen oxides (NOx) in the presence of heat and sunlight to create ground-level ozone. Ground-level ozone is damaging to human and plant health and is the major component of smog. A few major sources of NOx and VOCs are motor vehicle exhaust, industrial emissions, gasoline vapors and chemical solvents.

Ozone enters the tree through stomatal openings on the leaf. Ozone then reacts with leaf tissues to inhibit photosynthetic processes. The amount of ozone entering the tree will depend on the ozone concentrations in the area. Unfortunately, metropolitan areas and the mountains of East Tennessee experience some of the highest concentrations of ground-level ozone. On deciduous trees, a common symptom of ozone stress is purple speckling on upper surfaces of leaves. On coniferous trees, symptoms include yellow mottling on needles, shorter needles and loss of needles. Other general visible symptoms on both hardwoods and pines include chlorosis (yellowing) and premature leaf-drop. While damage from high concentrations of ozone does not commonly kill trees (although it can), it is an additional stress on the health of trees. Ozone also disrupts carbohydrate transport to the leaves. This increases the concentration of sugars in the leaves and makes the foliage more susceptible to insect attack.

Sulfur Dioxide and Nitrogen Oxides

In addition to being a component of ground-level ozone, nitrogen oxides, along with sulfur dioxide, are the primary causes of acid deposition or "acid rain." Sulfur dioxides are produced primarily by the burning of coal and oil to generate electricity, from smelting ore that contains sulfur and in the manufacturing of sulfur-based products.

Much like ozone, acid rain rarely kills a tree. Instead, acid rain weakens the tree by damaging leaves and limiting the uptake of nutrients. At lower pH levels (more acid soil) the majority of macronutrients become unavailable for tree growth. Acid rain facilitates the leaching of beneficial nutrients from the soil and at the same time increases the release of substances such as aluminum that are more toxic to trees and plants. (Refer to UT Extension publication SP 534 on *Nutrient Deficiencies in Trees* for more information.) Therefore, the effect is a "one-two punch" that can severely impact the ability of trees to grow.



Katz, Ledingham and McCallum

Sulphur dioxide injury on birch and dogwood.

You Can Help

The most serious forms of air pollution are difficult to prevent without a community effort. Minimize the air pollution you produce by keeping your automobiles tuned, limiting your use of internal combustion engines and obeying local open-burning ordinances. Planting more trees can

Trees with a range of ozone tolerance and sensitivity.

Tolerant	Intermediate	Sensitive
Abies balsamea - Fir, balsam	*Acer negundo* - Boxelder	*Catalpa* spp. - Catalpa
Abies concolor - Fir, white	*Cercis canadensis* - Redbud, eastern	*Fraxinus americana* - Ash, white
Acer saccharum - Maple, sugar	*Liquidambar styraciflua* - Gum, sweet	*Fraxinus pennsylvanica* - Ash, green
Betula pendula - Birch, European white	*Pinus echinata* - Pine, shortleaf	*Gleditsia triacanthos* - Honeylocust
Cornus florida - Dogwood, white	*Pinus sylvestris* - Pine, Scotch	*Juglans regia* - Walnut, English
Ginkgo biloba - Ginkgo	*Quercus coccinea* - Oak, scarlet	*Liriodendron tulipifera* - Poplar, tulip or yellow-poplar
Ilex spp. - Holly	*Quercus velutina* - Oak, black	*Malus* spp. - Crabapple
Juglans nigra - Walnut, black	*Syringa* spp. - Lilac	*Pinus nigra* - Pine, Austrian
Nyssa sylvatica - Gum, black	*Ulmus parvifolia* - Elm, lacebark	*Pinus strobus* - Pine, eastern white
Picea abies - Spruce, Norway		*Pinus taeda* - Pine, loblolly
Picea pungens - Spruce, blue		*Pinus virginiana* - Pine, Virginia
Pinus resinosa - Pine, red		*Platanus occidentalis* - Sycamore, American
Pseudotsuga menziesii - Fir, Douglas		*Quercus alba* - Oak, white
Quercus robur - Oak, English		*Quercus palustris* - Oak, pin
Quercus rubra - Oak, red		*Salix babylonica* - Willow, weeping
Taxus spp. - Yew		*Sorbus aucuparia* - Mountain ash, European
Thuja spp. - Arborvitae		
Tilia americana - Linden or Basswood, American		
Tilia cordata - Linden, little-leaf		

Adapted from: Appleton and others, 2000.

Trees with a range of sulfur dioxide tolerance and sensitivity.

Tolerant	Intermediate	Sensitive
Acer saccharinum - Maple, silver	*Acer negundo* - Boxelder	*Amelanchier* spp. - Serviceberry
Acer saccharum - Maple, sugar	*Acer rubrum* - Maple, red	*Betula* spp. - Birch
Ginkgo biloba - Ginkgo	*Pinus nigra* - Pine, Austrian	*Fraxinus pennsylvanica* - Ash, green
Juniperus spp. - Juniper	*Populus deltoids* - Cottonwood	*Pinus strobus* - Pine, eastern white
Picea pungens - Spruce, blue	*Quercus alba* - Oak, white	*Populus nigra* 'Italica' - Poplar, lombardy
Quercus palustris - Oak, pin	*Sorbus aucuparia* - Mountain ash, European	*Salix nigra* - Willow, black
Quercus rubra - Oak, red	*Syringa* spp. - Lilac	*Ulmus parvifolia* - Elm, lacebark
Thuja spp. - Arborvitae	*Tilia americana* - Linden or Basswood, American	
Tilia cordata - Linden, littleleaf	*Ulmus americana* - Elm, American	

Adapted from: Appleton and others, 2000.

also help. When planting new trees, assess your landscape before planting. If planting near streets, highways and roads, consider planting trees that are more tolerant of common air pollutants. In addition, the USDA Forest Service (Nowak citation) suggests the following for managing your urban forest landscape:

- Increase the number of healthy trees (increases pollution removal).
- Sustain existing tree cover (maintains pollution removal levels).
- Sustain large, healthy trees (large trees have greatest per-tree effects).
- Use long-lived trees (reduces long-term pollutant emissions from planting and removal).
- Use low-maintenance trees (reduces pollutant emissions from maintenance activities).
- Reduce fossil fuel use in maintaining or controlling vegetation on property (reduces pollutant emissions).
- Plant trees in energy-conserving locations (reduces pollutant emissions from power plants).
- Plant trees to shade parked cars (reduces vehicular VOC emissions).
- Supply ample water to vegetation (enhances pollution removal and temperature reduction).
- Plant trees in polluted areas or heavily populated areas (maximizes tree air quality benefits).
- Avoid pollutant-sensitive species (increases tree health).
- Use evergreen trees for particulate matter reduction (year-round removal of particles).

Sources

Appleton, B., J. Koci, R. Harris, K. Sevebeck, D. Alleman and L. Swanson. 2000. *Trees for Problem Landscape Sites – Air Pollution*. Virginia Cooperative Extension and Virginia Tech University Publication Number 430-022. Blacksburg, VA. 4 p.

Clatterbuck, W.K. 1999. *Nutritional deficiencies in trees*. University of Tennessee Extension Publication SP 534. Knoxville, TN. 4 p.

Katz, M., G.A. Ledingham and A.W. McCallum. 1939. *Symptoms of injury on forest and crop plants*. Pages 51-103, In: Effect of Sulphur Dioxide on Vegetation. National Research Council of Canada, Ottawa. 447 p.

Canadian Forest Service. Date Unknown. *Sulphur oxide injury*. Insects and Diseases of Eastern Canada's Forests. Natural Resources, Canada. (www.cfl.scf.rncan.gc.ca/collections-cfl/fichemaladie_e.asp?id=45)

Nowak, D. J. *The effects of urban trees on air quality*. Date unknown. U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station, Urban Forestry Unit, Syracuse, NY. (www.fs.fed.us/ne/syracuse/TREE%20Air%20Qual.pdf)

U.S. Department of Agriculture, Forest Service, Forest Inventory and Analysis, Ozone Monitoring Program. (www.fiaozone.net/)

John Skelly

Ozone damage to yellow-poplar.

Canadian Forest Service

Foliar necrosis on ash caused by sulfur dioxide.

Andrew J. Boone

Ozone damage to white pine.

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