Trees Pollute? A "TREE" Explains It All

David J. Nowak, Research Forester
USDA Forest Service, Northeastern Forest Experiment Station
SUNY–CESF, Syracuse, New York

Abstract: Urban tree professionals and volunteers need to understand the positive and negative effects of trees on air quality to adequately address concerns that trees contribute to air pollution. The mnemonic "TREE" is helpful in remembering how trees affect air quality. "T" is for Temperature and microclimate effects; "R" is for Removal of air pollutants; "E" is for Emission of volatile organic compounds; and "E" is for Energy conservation. The cumulative effect of these factors determines the overall impact of trees on air pollution.

INTRODUCTION

"Trees Contribute to Urban Smog Problem" (Cox News Service 1989); "Smog Check Your Trees" (Foster 1991); "Budding Theory: Trees Pollute Air" (Harper 1994). These are recent newspaper headlines implicating trees as contributors to city smog. Such news stories require that tree professionals and volunteers respond to a question of growing concern: Do trees contribute to air pollution?

It is true that trees can contribute to air pollution. However, it also is true that trees can reduce air pollution. The net effect of trees on air quality must be quantified to properly address this issue. This paper presents the mnemonic "TREE" as a tool to help urban tree professionals and volunteers remember the different influences of trees on air quality. "T" is for Temperature and microclimate effects; "R" is for Removal of air pollution; "E" is for Emission of volatile organic compounds; and "E" is for Energy conservation. Each of these factors are discussed as they relate primarily to ozone (O_3), a major component of "smog", but the principles explained also apply to other air pollutants. The cumulative effect of these four factors determine the overall impact of urban trees on air pollution.

OZONE

Tropospheric O_3 is a significant urban air pollutant. In 1990, 98 areas in the United States were in violation of the National Ambient Air Quality Standard for this pollutant (National Research Council 1991). High levels of O_3 in many urban areas are the result of a series of complex photochemical reactions and pollution transport factors. Volatile organic compounds (VOCs) and oxides of nitrogen (NO_x) are major precursor chemicals to the formation of O_3. VOCs react with NO_x to increase O_3 production (National Research Council 1991). VOC emission sources include gasoline, solvents, motor vehicle exhaust, and vegetation; important NO_x sources include motor vehicle exhaust and stationary combustion–system exhausts. Because vegetation is a source of VOCs, trees can contribute to the formation of O_3. However, trees also remove pollution and change the environment such that pollution emissions can be reduced.

T: TEMPERATURE AND MICROCLIMATE EFFECTS

In the process of transpiring water through leaf stomates, energy (latent heat of vaporization) is absorbed by the evaporating water. This energy is removed from the leaf and its environment, thereby helping lower local air temperatures. Tree shade can also reduce air temperatures by reducing radiation absorption and heat storage by various anthropogenic surfaces (e.g., buildings, roads). Reduced air temperatures can improve air quality because the emission of many pollutants are temperature dependent, that is, they increase as air temperatures rise. Increased air temperature also affects O_3 photochemistry, resulting in higher concentrations of

O_3 (Cardelino and Chameides 1990).

Besides providing for transpirational cooling, the physical mass and thermal/radiative properties of trees can affect windspeed, relative humidity, turbulence, albedo, and boundary layer heights. These changes in local meteorology and microclimate also alter pollution concentrations in urban areas.

R: REMOVAL OF AIR POLLUTION

Trees remove gaseous air pollution primarily by uptake via leaf stomates, though some gases are removed by the plant surface (Smith 1990). Once inside the leaf, gases diffuse into intercellular spaces and may be absorbed by water films to form acids or react with inner–leaf surfaces. The pollutants inside the leaf can alter plant metabolism and affect plant growth. Although pollutants often are damaging, some can be a source of essential plant nutrients. At high concentrations, pollutants often cause visible leaf damage.

Trees also remove pollution by intercepting airborne particles. Some particles can be absorbed into the tree (e.g., Ziegler 1973; Rolfe 1974), though most particles that are intercepted are retained on the plant surface. The intercepted particle often is resuspended to the atmosphere, washed off by rain, or drops to the ground with leaf and twig fall (Smith 1990). Consequently, vegetation is only a temporary retention site for atmospheric particles.

Pollution removal by urban trees was estimated for Chicago, Illinois (Nowak 1994). In 1991, trees in Chicago removed approximately 17 tons of carbon monoxide (CO), 93 tons of sulfur dioxide (SO_2), 98 tons of nitrogen dioxide (NO_2), 210 tons of ozone (O_3), and 234 tons of particulate matter less than 10 microns (PM10). Across the Chicago region of Cook and DuPage counties, trees removed an estimated 6,145 tons of pollution. During the in–leaf season, regional pollution removal by trees averaged 1.3 tons/day of CO, 4.0 tons/day of SO_2, 4.6 tons/day of NO_2, 9.8 tons/day of PM10, and 11.9 tons/day of O_3. The estimated value of pollution removal in 1991 was $1 million for city trees and $9.2 million for trees across the Chicago region.

Average hourly improvement (in–leaf season) in air quality from all trees in the Chicago region ranged from 0.002 percent for CO to 0.4 percent for PM10. The estimated maximum hourly improvement was 1.3 percent for SO_2, though localized, short–term improvements in air quality can be 5 to 10 percent or greater in areas with relatively high tree cover. In 1991, large (> 30 inches dbh), healthy trees removed approximately 3.1 pounds of pollution, approximately 70 times more than small trees (< 3 inches dbh).

E: EMISSION OF VOLATILE ORGANIC COMPOUNDS

Some trees emit volatile organic compounds such as isoprene and monoterpenes into the atmosphere. These compounds are natural chemicals that make up essential oils, resins, and other plant products, and may be useful in attracting pollinators or repelling predators (Kramer and Kozlowski 1979). Isoprene also is believed to provide thermal protection to plants by helping prevent irreversible leaf damage at high temperatures (Sharkey and Singsaas 1995). Tree VOC emissions vary with species (e.g., Guenther et al. 1994), air temperature, and other environmental factors (Tingey et al. 1991).

Emissions of volatile organic compound by trees can contribute to the formation of O_3 (Brasseur and Chatfield 1991). Because VOC emissions are temperature dependent and trees generally lower air temperatures, it is believed that increased tree cover lowers overall VOC emissions and, consequently, O_3 levels in urban areas (Cardelino and Chameides 1990). A computer simulation of June 4, 1984, ozone conditions in Atlanta, Georgia, revealed that a 20 percent loss in the area's forest could lead to a 14 percent increase in O_3 concentrations (Cardelino and Chameides 1990). Although there were fewer trees to emit VOCs, an increase in Atlanta's air temperatures due to the urban heat island which occurred concomitantly with the tree loss, increased VOC emissions from the remaining trees and anthropogenic sources, and altered O_3 photochemistry such that concentrations of O_3 increased.

E: ENERGY CONSERVATION

Trees reduce building energy use by lowering temperatures and shading buildings during the summer, and blocking winds in winter (e.g., Heisler 1986). However, they also increase energy use by shading buildings in winter, and may increase or decrease energy use by blocking summer breezes. Thus, proper tree placement near buildings is critical to achieve maximum building energy conserva–

tion benefits.

When building energy use is lowered, pollutant emissions from power plants are also lowered. While lower pollutant emissions generally improve air quality, lower NO_x emissions (e.g., from power plants) may lead to a local increase in O_3 concentrations under certain pollutant concentration conditions (National Research Council 1991).

CONCLUSION

Trees affect their surrounding environment in many complex and interacting ways that ultimately affect air quality both in cities and in rural areas. Understanding the ways in which trees affect air quality will allow tree professionals and volunteers to address the increasingly common topic of vegetation and air quality.

Researchers continue to gain a better understanding of each of the individual "TREE" topics, and are helping integrate these individual components into a comprehensive program to improve air quality. With respect to urban trees and O_3, preliminary results indicate that trees likely will improve urban O_3 air quality. The use of state-of-the-art computer models to integrate both the positive and negative aspects of trees on air quality will provide a better understanding of the relationship between urban trees and O_3 concentrations. This understanding will allow scientists to answer the question: will more urban trees improve or degrade city air quality?

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