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Trees and air pollution

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Smog may be contributing to the decline of sugar maples, one of Northeast Ohio's iconic trees — and our high-mileage lifestyle is a big cause

By Mary Topa, PhD
Director of Research, The Holden Arboretum

Tropospheric or ground-level ozone is the primary constituent of smog, and it is the most widespread phytotoxic air pollutant in the United States. Unlike ozone in the upper atmosphere (stratosphere), which has a beneficial effect of it shielding us from the harmful effects of UV radiation, tropospheric ozone probably has the most negative impact of all air pollutants on tree health and growth.

On average, tropospheric ozone is increasing at 0.5–1 percent per year. However, tropospheric ozone is considered a regional pollutant, and urban areas are major sources of ozone precursors that can travel hundreds or thousands of kilometers.

Trees in the urban landscape and in rural communities or in forests downwind of major metropolitan areas are often subjected to some of the highest levels of smog during peak season. Known as a summertime pollutant, tropospheric ozone is a gas composed of three oxygen atoms (O3), and is a product of a photochemical reaction between oxides of nitrogen and volatile organic compounds (VOCs) in the presence of sunlight. Consequently, tropospheric ozone levels are highest on hot sunny days, peaking generally between noon and 7 p.m. Since vehicles can account for as much as half of the VOCs and oxides of nitrogen, areas in moderate non-attainment or worse status, such as the Cleveland/Akron area, are included in Ohio's E-Check Vehicle Emissions Testing Program.

Plants as bio-indicators for ozone

Because plants are generally more sensitive than humans to ozone, many of our air pollution laws are based on decades of research conducted on plant species that vary in their tolerance to ozone. Certain plant species have been used as bio-indicators of tropospheric ozone levels in field studies across the United States. The overall effects of ozone in plants are that it damages tissues and accelerates cellular aging in leaves, not unlike what happens when ozone enters our lungs. Ozone enters the leaf through open stomata. Once in the leaf, ozone reacts with water to form highly reactive, oxygen free radicals, damaging membranes and directly inhibiting photosynthesis. Plants may close their stomata so that ozone cannot enter the leaf; however, this avoidance mechanism also prevents atmospheric CO2 from entering the leaf and carbon fixation rates decline. Plants that are more tolerant to ozone synthesize antioxidant compounds that scavenge these oxygen free radicals before damage occurs, and often repair tissue if damaged.

In some tree species that are more tolerant to ozone, there will be no visible sign of foliar injury; however, a reduction in growth often occurs because newly-fixed carbon is reallocated to antioxidant production and injury repair mechanisms. Although Acer saccharum (sugar maple) has been considered moderately ozone tolerant, some of my research has shown that ozone not only accelerates visible signs of leaf senescence in sugar maple, but that leaf physiological processes such as photosynthesis start shutting down in August under ozone levels typical of what we find at Holden. This significant decline in photosynthesis in mid-to late August reduced the seasonal carbon fixation for some maple trees by as much as 25-30 percent and reduced growth in some plants by as much as 50 percent by the end of a three-year exposure regime.

Smog as a background stress

Trees are long-lived perennial organisms that have a carbon storage system (similar to a savings

account) that they can tap into during times of stress. Ozone is a background stress for many urban-influenced trees, and it is one that negatively impacts a tree's ability to fix and store carbon. Any reduction in stored carbon can not only reduce growth, but increase a tree's susceptibility to other stresses such as pest or pathogen invasion.

Smog is an air pollutant stress that is often overlooked as one of the multiple, interacting causes of sugar maple decline, most likely because, until the last decade, sugar maple was thought to be fairly tolerant to ozone. Trees in moderate ozone attainment areas, such as the Cleveland/Akron area, will have high ozone as a background stress until further reductions in tropospheric ozone precursors occur. Consequently, selecting tree species that are tolerant to smog is essential for urban areas, particularly since urban trees and shrubs have the ability to remove significant amounts of air pollutants, and improve environmental quality and human health.

Recent integrated studies have suggested that management of the urban tree canopy cover could be a viable strategy to improve air quality with increased tree cover leading to greater removal of pollutants such as ozone, small particulates, nitrogen dioxide, and sulfur dioxide. One study by Nowak, Crane and Stevens in Urban Forestry and Urban Greening ("Air pollution removal by urban trees and shrubs in the United States", Volume 4, pp 115-123, 2006) has estimated that urban trees remove over 711,000 metric tons of air pollutants a year ($3.8 billion value).

So the next time you have to take your car in for an E-Check inspection, do so willingly, and then go one step further — plant a tree.

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