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Urban vegetation can react with car emissions to decrease air quality in summer (Berlin)

Researchers have shown that emissions from vehicles can react with emissions from urban trees and other plants, resulting in a decrease in air quality in cities in summer; this reduces the otherwise positive impacts of urban vegetation. The study, conducted in Berlin, showed that during a July heatwave, 20% of ozone concentrations were due to emissions of volatile organic compounds (VOCs) from vegetation interacting with other pollutants. To reduce this effect, lowering emissions of these other pollutants is crucial.

The planting of trees and green walls in cities can provide a range of benefits, from providing shade in summer and acting as a sound barrier to increasing carbon storage and even enhancing well-being. However, in the presence of nitrogen oxides (NO_x) — produced mainly in vehicle emissions — some gaseous emissions from vegetation can in fact contribute to decreased air quality. This study is the first of its kind to quantify the relative contribution of urban vegetation to episodes of poor air quality in a mid-latitude European city. Planners of urban-greening programmes should be aware of these effects, note the researchers. The study was partly supported by EU COST Action FP1204 ("GreenInUrbs").

VOCs released by plants include hundreds of chemicals, many of which have an odour; they can be detected, for example, in the scent given off when grass lawns are cut. Only a few of them — for example isoprene, monoterpenes and sesquiterpenes — have a significant effect on air quality. In urban and suburban areas with substantial levels of NO_x, isoprene contributes to the formation of ground-level ozone, while the latter two chemicals can increase particulate matter ($PM_{2.5}$ and PM_{10}). Ozone and PM have damaging effects on human health, in particular causing respiratory problems.

Plants produce isoprene as part of a process to protect their cells against stresses such as drought and temperature fluctuation; emissions, therefore, increase with rising temperatures and in dry conditions. Eucalyptus, oak (*Quercus* spp.) and poplar (*Populus* spp.) trees are major producers of isoprene[1].

The researchers compared air quality over two summer periods (1 June–28 August 2006 and 1 June–28 August 2014) in the city of Berlin, which has relatively high vegetation cover (35% of land is classified as forest, parks and agriculture). In July 2006, the city experienced a major heatwave, defined as five or more consecutive days during which the daily maximum temperature exceeds the average maximum temperature for that time of year by 5°C or more. Average daily temperatures over a three-week period in that month were over 30°C; and in July 2014, they were 26–27°C.

In the 2014 study period, concentrations of VOCs were continuously measured in a central residential neighbourhood, and more samples were gathered in seven other locations in Berlin and one in the wider metropolitan area, representing air quality in the urban background, highway, urban forest and park environments.

The researchers then used modelling software[2,3] to investigate the contribution of vegetation emissions to the formation of ozone and PM. Simulations of air chemistry in each period were facilitated with inputs including data on anthropogenic emissions (e.g. NO_x, sulphur dioxide and PM), land-cover types (e.g. conifer forest) and published isoprene emissions factors for different types of trees. The latter indicate how much isoprene different types of trees emit, relative to leaf area. The researchers used inventories of street trees and forests in conjunction with these factors to estimate how much isoprene was emitted in the city in

Continued on next page.

1. These are not the only trees with high emissions of isoprene. A previous publication ranks popular urban trees relative to their VOC emissions (Figure 1): Churkina, G., Grote, R., Butler, T.M. & Lawrence, M. (2015) Natural selection? Picking the right trees for urban greening. *Environmental Science & Policy*, 47, 12–17.

2. Grell, G.A., Peckham, S.E, Schmitz, R., McKeen, S.A., Frost, G., Skamarock, W.C. & Eder, B. (2005). Fully coupled "online" chemistry within the WRF model. *Atmos. Environ.* 39(37): 6957–6975.

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Urban vegetation can react with car emissions to decrease air quality in summer (Berlin) *(continued)*

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each period, and how this contributed to ozone formation. The inventories of street trees were only used to corroborate emission factors used in the model; the researchers were not able to incorporate these inventories in the model calculations.

The researchers calculated the difference between ozone concentrations modelled with and in the absence of VOC emissions from vegetation, using 8-hour daily maximum values[3] as applied in EU air quality standards and the World Health Organisation (WHO) air quality guidelines. The modelled results showed that VOCs from vegetation make a significant contribution to ground-level ozone levels in Berlin in the summer. On average, vegetation was linked to 12% of ozone in the 2006 and 2014 total summer periods combined, but in July 2006 it was responsible for 20% of the ozone level on average, and for 17% in July 2014. The ozone response to VOC emissions from plants peaked at 60% on some days during the July heatwave.

A distinct increase was detected between the impact of plant VOCs in July and the two other months studied; in June and August, their contribution to ozone was only 6–11%. This corresponds to the increase in air temperature in July.

The study's results add to a body of evidence showing that VOC emissions from urban trees may exacerbate air pollution, say the researchers. However, trees also have other effects on ozone, for example trapping it in their leaves, which may decrease levels in the environment. Their effect on air pollution is, therefore, complicated — both lessening and enhancing.

The researchers also investigated the contribution of vegetation to PM, as VOCs can contribute to particle formation in air (aerosols). The findings were inconclusive, however, due to large variations in modelled aerosol concentrations.

It is also noted in the study that the isoprene emissions factors used led to an underestimation of these emissions, based on new calculations carried out by the researchers in evaluating the model. This is attributed to the high number of high isoprene-emitting trees found in Berlin, such as oaks, which are not accounted for in the emissions factors used. They conclude, therefore, that the actual contribution of plant VOCs to ozone levels in urban areas is probably higher than shown in results, and future modelling could be improved to better reflect the characteristics of vegetation.

Although VOCs from vegetation can contribute to air pollution during heat waves, meaning that green areas in Berlin could be hotspots for ground-level ozone in summer, the main way to lower ozone levels is to reduce vehicle emissions — the main source of the NO_x which reacts with VOCs to produce ozone — say the researchers. Radically lower levels of anthropogenic air pollution would offer urban residents the many beneficial effects of urban trees and plants in summer, rather than the dual effect highlighted by this study. Far from being a call to stop tree planting, the study emphasises that controlling NO_x pollution is essential to not detract from the many benefits of trees, such as reducing heat-island effects, increasing urban biodiversity, reducing the effects of climate change and more.

3. Guenther, A., Karl, T., Harley, P., Wiedinmyer, C., Palmer, P.I. & Geron, C. (2006). Estimates of global terrestrial isoprene emissions using MEGAN (Model of Emissions of Gases and Aerosols from Nature). *Atmospheric Chemistry & Physics,* 6(11): 3181–3210

4. This refers to the daily maximum surface ozone concentration, in parts per billion, backward averaged over 8 hour-long periods