Scientists enlist lichens to monitor air pollution

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Lichens. Credit: MIPT

An MIPT-based team of researchers has proposed analyzing lichen composition to assess atmospheric air quality when conventional monitoring stations are unavailable. They produced a case study of the

Xanthoria parietina lichen, whose samples were collected in Moscow, Nizhny Novgorod, and two towns outside Moscow—Dolgoprudny and Dubna. Sample analysis revealed their iron, copper, and manganese content, along with free radical concentrations of phenol and polyphenol—two types of compounds occurring naturally in lichens. The research findings were published in the *Journal of Applied Spectroscopy*.

"By showing that atmospheric air quality determines the concentration of radicals in lichens, we prove that electron paramagnetic resonance spectroscopy can be used for environmental monitoring in cities," says Associate Professor Svetlana Zhuravleva of the Department of Chemistry, MIPT. "This makes the method very convenient for those areas where air monitoring stations are not available. Even major cities populated by millions of people typically have no more than 10 such facilities."

Metal ions and free radicals of organic molecules are involved in enzymatic reactions vital to health. But excess ions and radicals disrupt cell metabolism and interfere with the natural balance of redox reactions by damaging proteins, nucleic acids, and the lipids in the cell membrane. As this damage builds up in the cells, it can lead to numerous serious diseases. Atmospheric air pollution in densely populated industrial cities is one of the chief factors implicated in the excessive metal ion and free radical counts in living cells. Researchers have estimated that in 2015, 16 percent of deaths globally resulted from diseases caused by poor environmental conditions. This is three times the number of deaths caused by AIDS, tuberculosis and malaria combined, or 15 times the number of people killed in wars and by other forms of violence.

The metals measured were magnesium and two transition elements—iron and copper. Their ions are capable of entering redox reactions, whereby they can give up or take on electrons with relative ease. If electron exchange in a redox process results in a metal ion

having an uneven number of electrons, one of them is bound to be unpaired. Such ions with unpaired electrons are called paramagnetic. Radicals are somewhat similar. This term is reserved for all other ions, atoms, and even whole molecules of organic or inorganic compounds that have an unpaired electron. The characteristic trait of radicals and metal ions is their very reactive nature; that is, they readily undergo chemical reactions with other molecules. As a result of an elevated concentration of such reactive species in living cells, abnormal chemical processes occur more often. They prevent individual cells and by extension the body as a whole from maintaining the state of dynamic equilibrium known as homeostasis. Prior research indicated that higher content of free radicals and paramagnetic metal ions in mammalian cells correlates with a deterioration of health.

"Lichens readily absorb compounds of metals from polluted atmospheric air. Besides that, they are autonomous and require no special conditions: Lichens can grow on trees, rocks, metal structures. They need no soil, minimum light and are thus abundant throughout Russia," explains MIPT Professor Eduard Trukhan, who holds an ScD in physics and mathematics. "All of this makes lichens a prime candidate for use in environmental monitoring and assessing the risks that pollution poses to the population."

To measure the content of metal ions and organic radicals in lichens, the researchers employed two analytical techniques. First, the total content of all reactive species with unpaired electrons was determined by means of electron paramagnetic resonance. After that, their individual concentrations were identified via optical emission spectroscopy.

The researchers compared the data they obtained with the air pollution index, a standard complex indicator of environmental quality. API values are measured, calculated, and publicly released by the Federal Service for Hydrometeorology and Environmental Monitoring of Russia and the

country's Ministry of Natural Resources and the Environment. API is calculated as the sum of average annual concentrations of pollutants expressed in terms of their maximum admissible concentrations, which are based on their hazard ratings. Air pollution in Dubna and Dolgoprudny is considered to be low (API lichen samples. To cite some data as an example, the concentration of organic radicals in samples from Moscow is 1.9 that in the samples obtained in Dubna, whose paramagnetic metal content turned out to be 5.6 times lower, compared to the Russian capital.

Pavel Bondarenko, a researcher at the Department of Chemistry, MIPT, highlights the relevance of the work: "This study provides the first ranking scale for grading environmental quality based on paramagnetic center concentration in lichens. It could be used to map urban pollution and identify those zones in cities that might pose danger for human health."

More information: P. V. Bondarenko et al. EPR Spectroscopy in Environmental Lichen-Indication, *Journal of Applied Spectroscopy* (2017). DOI: 10.1007/s10812-017-0523-2

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