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Nanoparticles Are Everywhere, Even Inside Trees

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The presence of natural nanomaterials in the Earth system has always been abundant since billions of years. Since the Industrial Revolution and the advent of nanotechnology, new types of nanomaterials are released into the atmosphere, water and soil as a byproduct from human activities and as engineered nanoparticles (NPs) from NP-based products. To understand the consequences of NP pollution, numerous studies are assessing the fate, transport and interaction of NPs in humans, organisms and environmental systems.

Trees have been used for phytoremediation and as bio-monitors of current and past pollution as they can store various contaminants in the roots, stems and leaves. Seemingly, trees must have been exposed to naturally occurring NPs since they first evolved. Recent evidence of foliar uptake and transport of silver NPs in trees increased the attention on understanding the interactions between NPs and trees. Today, still not much is known about the mechanisms of uptake of these particles, neither the risks related to their exposure, as a function of size and chemical properties of the NPs. This assessment will contribute to enlighten the potential role of trees in mitigating the NP pollution and related impacts.

In the framework of studying trees as bioindicators of pollution, we used gold (Au) NPs as model NPs to investigate their uptake and transport in European beech and Scots pine trees. We found that Au NPs were taken up by roots and leaves, while a small fraction was transported to the stem in both species. Gold was transported from leaves to roots but not *vice versa*. 2D X-ray fluorescence imaging of a beech leaf, complemented by 3D confocal XRF microscopy, revealed Au NPs hotspots sparsely distributed over the entire scanned part of the leaf. While several Au NPs were mostly trapped on the leaf surface, abundantly associated with trichomes along the midrib and lateral veins, a small number of Au NPs could penetrate the leaf, probably through the stomata.

Our results show that trees can absorb NPs. Now we need to understand how they translocate them to different tree compartments.

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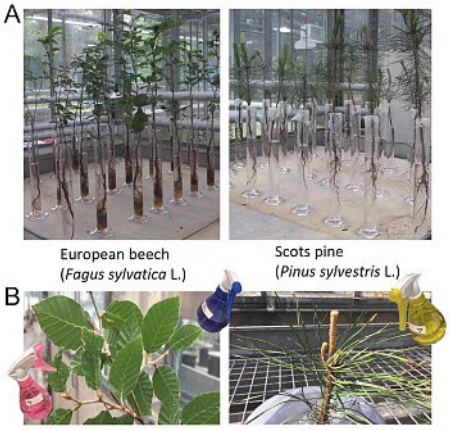
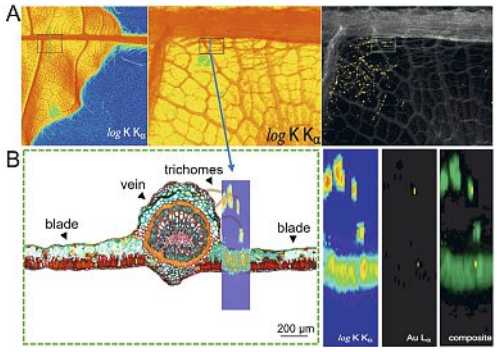


Experimental design to investigate the (A) root and (B) leaf uptake and transport of Au NPs in European beech and Scots pine trees. The NPs were hydrophonically applied to the roots and sprayed to the leaves in a greenhouse chamber at the WSL Swiss Federal Research Institute.



Microscopic, two- and three-dimensional chemical imaging. 2D XRF images show the distribution of gold nanoparticles on leaf and petiole of European beech (top row). A tomographic sub-volume (indicated by the square), obtained by confocal X-ray microscopy, revealed two isolated gold nanoparticles, one in the leaf blade and one inside/on a trichome (bottom, right). The schematic representation of the section of beech leaf indicates the position of the tomographic slice shown in both panels. The 2D/3D chemical imaging was conducted at the microXAS beamline at the Swiss Light Source of the Paul Scherrer Institute.

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