European Commission

Science for Environment Policy

Potential contamination of copper oxide nanoparticles and possible consequences on urban agriculture

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Researchers have assessed the phyto-toxic effects of copper nanoparticles on vegetables grown within urban gardens, comparing increasing doses of these nanoparticles to simulate potential aerial deposition to extreme pollution of CuO-NP in a range of increasing exposure periods. Lettuce and cabbage absorbed high amounts of copper nanoparticles, after 15 days of exposure, which interfered with photosynthesis, respiration and also reduced growth. Under the specific exposure conditions of the study the researchers indicate that metal nanoparticles could lead to potential health risks to humans from the contamination of crops from pollution.

Urban agriculture is becoming increasingly popular and can provide significant amounts of food. However, crops in urban areas are more likely to be exposed to chemicals in air pollution from traffic or industry. The increasing use of nanomaterials (in many areas such as manufacturing, technology, healthcare and agriculture) may have implications for agriculture, as nanoparticles can be taken up by plants through soil and air. Copper oxide nanoparticles are used in pesticides, herbicides, fertilisers, additives for soil remediation and as plant growth regulators. Crops may, therefore, be exposed through the soil or from atmospheric pollution, absorbed by leaves. This laboratory-based study examined the potential toxicity of copper oxide nanoparticles to leafy vegetables (lettuce and cabbage). Lettuce and cabbage were chosen for the study as they are widely cultivated in urban areas and have large leaves that can readily absorb atmospheric pollutants.

Lettuce and cabbage plants (*Brassica oleracea* var. *capitata* L. and *Lactucasativa* L. cv. *Batavia blonde dorée*) were exposed (through the deposition on leaves using an applicator brush) for 5, 10 or 15 days to copper oxide nanoparticles at concentrations of 10 or 250 milligrams (mg) per plant per day. A control group not exposed to any copper oxide nanoparticles was also assessed. Samples of the plants were harvested to analyse the metal accumulation within the plant tissues. The researchers measured the uptake of copper within the plants' leaves and roots using imaging techniques (i.e. optical microscopes and scanning electron microscopes) to assess the distribution of copper nanoparticles on the leaf surfaces. The researchers also measured the plants' biomass and gas exchange — important for both plant respiration and photosynthesis — in relation to copper intake.

The potential impact on human health from eating vegetables contaminated with copper nanoparticles was calculated by estimating the daily pollutant intake. This was calculated using the metal concentration within the leaves of the lettuce and cabbage at the different concentrations studied and assuming that an average adult weighing 60 kilograms (kg) ingests 13 grams (g) dry weight of vegetables a day). This daily pollutant intake was then used to calculate the maximum amount of contaminated plants that could be consumed without becoming unsafe to humans.

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After the 15-day treatment, lettuce had absorbed up to 3 773 mg of copper per kilogram (kg dry weight) and cabbage up to 4 448 mg of copper per kg dry weight, which was 310 and 428 times higher than the control plants. The imaging techniques showed that copper nanoparticles accumulated on the leaf surfaces or within the plants stomata — pores on the leaf surface which are responsible for gas exchange. At the highest doses (250 mg), copper nanoparticles affected the plant biomass and reduced the growth of the lettuce and cabbage. The water content of cabbage plants also decreased as copper nanoparticles increased, with 60% water content recorded for plants exposed to the 10 mg treatment and 35% for plants exposed to the 250 mg treatment. At low doses (e.g. at 10 mg for lettuce) the copper intake actually increased the plants' growth, as copper is an essential micronutrient. The researchers say that the level at which copper becomes toxic is dependent on the plant species. However, toxic impacts on the plants (e.g. stunting, cell death and loss of leaf colouration) occurred even at low copper doses in this study.

It should be noted that the study is based on a hypothetical high exposure conditions for copper nanoparticles and do not relate to the real residues of copper nanoparticles found within vegetables currently harvested for consumption. High levels of copper can cause damage to cell structures in humans and have toxic effects on human liver and lung cells; studies have shown that copper nanoparticles have a more toxic effect lung cells than micrometer-sized copper (II) oxide or other metal-based nanoparticles. The pollutant intake for people from exposed groups of plants ranged from 86 to 1 797 micrograms (µg) per kg a day, whereas for the control group it ranged from 1.4 to 3.4 µg/kg per day. For plants exposed to copper nanoparticles in accordance with high contamination doses applied in this study, the daily pollutant intake was calculated as 2–45 times higher than the Tolerable daily intake (TDI) for humans. The TDI is the daily amount of a chemical that has been assessed safe for humans on a long-term basis. The researchers say that the maximum acceptable daily intake of contaminated plant material can be easily reached by adults through vegetable consumption. Even if plant leaves are washed prior to consumption, nanoparticles can remain within the leaf cuticle or stuck to the leaf surface, say the researchers, who highlight — given the exposure conditions of the study — the potential human health risks of nanoparticles contaminating urban gardens.

The researchers say the effect of copper nanoparticles on plants has not been well studied. This study indicates that copper nanoparticles can be absorbed through the plants' leaves, demonstrating the susceptibility of certain vegetables to atmospheric pollution. Copper nanoparticles can potentially interfere with the plants' physiology, including photosynthesis, respiration and growth and, if the level of nanoparticles builds up to a high level, this could lead to adverse effects on humans when crops are consumed. Information on the actual concentrations of copper nanoparticles in the atmosphere is needed to understand whether the results of the study, achieved by artificial contamination of leaves, may apply to any real-world conditions.

The researchers also suggest that recent reports have found that only a portion of the total metal nanoparticle was bioaccessible (able to be absorbed) and thus recommend that further copper bioaccessibility measurements on various vegetable samples could be used to refine the assessment of the potential risks associated with human exposure.