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Relative environmental impact of nanosilver in products may be marginal compared with impacts of other components

A new study has analysed the environmental impact of 15 products containing nanosilver, highlighting the contribution of this novel material to the items' overall environmental burden. The findings show that nanosilver impacts, such as fossil fuel depletion and human-health impacts, are relative to content, and can be marginal when considered in the context of the product's other materials. Based on their results, the researchers recommend considering the overall impacts and benefits of nano-enabled products in evaluation and environmental guidance on their development.

Silver nanoparticles have been in use for over a century in photography and as an antibacterial treatment. Wound dressings based on nanosilver technology have been more effective than conventional antibiotic creams[1], for example leading to lower levels of infections. They may also reduce energy use from washing textiles by keeping clothes fresh. However, silver nanoparticles — especially at smaller sizes — could be toxic to humans, animals and fish[2], which is of concern, as they are released into the environment from products, for example during clothes washing.

While previous studies have dealt with the release of particles under various conditions[3], this new study looks not only at the release rates from 15 products, but also uses life-cycle assessment to determine the overall environmental impact of the products (e.g. ozone depletion and ecotoxicity effects). As the advantages of nano-enabled products are not usually achievable with conventional, non-nano-enabled materials, it is difficult to compare the two directly, the researchers note. Instead, this study concentrates on identifying patterns in life-cycle impacts and releases that could inform nanosilver specification, incorporation or concentration guidelines. The assessment technique used also permits the relative contribution of impacts associated with nanosilver to be compared with the impact of the other materials and processes used to produce the items.

The 15 products were chosen based on their commercial availability. Six were purchased — four types of wound dressing, a plastic food container and a sock containing silver (sock no. 1) — while nine were modelled based on previous literature — a fleece baby blanket, a plastic children's cup, a cuddly toy, a medical mask, a medical cloth, a towel, a T-shirt, a resealable plastic food storage bag and another sock (sock no. 2) of a different composition from the purchased sock.

Information on the composition of products was gathered from labels and specifications, while scanning electron microscopy (SEM) and energy-dispersive X-ray spectroscopy (EDX) analysis was used to confirm the presence and type of nanosilver in purchased products. The silver concentration was determined using acid digestion and release rate based on leaching measured during the use phase (for example during washing or in simulated skin contact).

Environmental impacts were assessed with the US Environmental Protection Agency's Tool for the Reduction and Assessment of Chemical and Other Environmental Impacts (TRACI) 2.1 method. Impact categories considered in TRACI include global warming potential, human health impacts from air pollutants, ecotoxicity and fossil fuel depletion. In this study, use phase and end-of-life stage impacts were not evaluated — only impacts from raw material extraction and manufacture. Life-cycle impacts — looking at material and energy inputs — were modelled with the SimaPro 8.1 software package (PRé Consultants), for a US-based scenario.

1. Fong, J., *et al*., (2005). A silver coated dressing reduces the incidence of early burn wound cellulitis and associated costs of inpatient treatment: comparative patient care audits. *Burns*, *31*(5), 562–567.

2. http://ec.europa.eu/health/scientific_committees/emerging/docs/scenihr_o_039.pdf

3. e.g. Wagener, S. *et al*., 2016. Textile functionalization and its effects on the release of silver nanoparticles into artificial sweat. *Environmental science & technology*, 50(11), 5927–5934.

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Relative environmental impact of nanosilver in products may be marginal compared with impacts of other components *(continued)*

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The contribution of nanosilver to product impacts ranged from 1–99%, being chiefly due to electricity use and emissions from silver mining. In products with low amounts of silver (the blanket, sock no. 2, T-shirt and towel), the relative impacts of silver were low. Sock no. 1 had a higher silver concentration than sock no. 2 and its textile composition was less resource-intensive, so the relative contribution of nanosilver was noticeable. However, most impacts for these items were linked to other materials used in production of the fabrics (e.g. xylene) and the fabric manufacturing process itself (e.g. electricity used in processing).

The medical cloth and mask had the highest concentration of nanosilver, which dominated all impact categories: ozone and fossil fuel depletion through emissions and resource use associated with particle synthesis; and smog and acidification impacts through the silver extraction and refining process. Noncarcinogenic health impacts from the cuddly toy were affected by the release of arsenic ions to groundwater during the silver mining process.

In general, the researchers concluded that of the products studied, those with nanosilver concentrations of <0.005% show minimal to negligible impacts associated with nanosilver. In those products studied that had concentrations of 0.005–3%, the contribution of nanosilver was highly dependent on the composition of the products. For studied products with concentrations >10%, nanosilver impacts dominated all environmental categories. The contribution was highest in the fossil-fuel depletion and global warming categories, partly due to the heating required to process nanosilver. Silver nanoparticles also contributed to the smog impact category as a result of nitrogen oxide emissions from the blasting processes during silver extraction. The impacts are significantly affected by the chemicals and energy consumption used in producing nanosilver, the study found[4].

The researchers also analysed the particles released relative to the initial nanosilver concentration for each product. Releases from one of the wound dressings, Aquacel, were the greatest (by percentage) due to the material dissolving in contact with solutions, enabling release rates of up to 5% of the overall nanosilver content. Releases from textiles were found to be highly dependent on their fabrication method and how the nanosilver was incorporated; for example, releases were higher where particles were surface-bound. Releases from food packaging were found to be up to 2% of overall content, although by mass, the food container produced the highest release, at 7.92 mg. The study concludes that solid polymer materials lose more silver during washing compared to fibrous materials.

Most releases to water would be subject to waste-water treatment, which filters out more than 90% of silver[5]. While there are ecotoxicity impacts to consider, related to this, the researchers argue it is important to consider earlier life-cycle impacts, as well. For example, the overall environmental burden of nano-enabled products may be dominated by manufacturing impacts, the study shows, especially related to the production of conventional materials such as cotton or plastic resin. Assessment should therefore be careful to consider the impacts of nano-enabled products overall, not focusing solely on marginal impacts due to nanomaterials, argue the researchers. They also note that the potential environmental benefits of using nanosilver should be considered, and also that prospective assessment of new technologies should be carried out prior to the commercialisation of products, to ascertain their environmental impact and guide their development.

4. Methods such as flame-spray pyrolysis were shown to have the highest levels of impacts, while a chemical reduction method with sodium borohydride appeared to be more favourable overall.

5. Walser, T., *et al.* (2015). Life-cycle assessment framework for indoor emissions of synthetic nanoparticles. *Journal of Nanoparticle Research*, 17(6), 245.