

Science for Environment Policy

Changes that occur to nanoparticles in the environment are key to understanding their impact

Available evidence from the last decade, describing the nature, behaviour and effect of engineered nanoparticles (ENPs) in the environment, has been reviewed. It identified factors that influence ENP distribution and fate and highlighted the existence of significant research gaps which, if filled, would help in understanding the impacts of long-term accumulation of nanomaterials and the changes that occur to them when they are released into the environment.

ENPs are chemically synthesised nanoparticles (within the size range of 1–100 nm), derived from engineered nanomaterials. ENPs are designed and synthesised to have enhanced mechanical, catalytic, optical and/or electrical properties and are increasingly used in products and appliances from a range of industries, including manufacturing, electronics, pharmaceuticals, cosmetics and cleaner-energy production. From 2000 to 2008 the global market for ENPs grew from \$125 million to \$12.7 billion USD (101 million to 10.3 billion euros). This rapid growth means ENPs are increasingly released into the environment. It has been estimated that between 9% and 37% of ENPs are emitted directly into the atmosphere, with the remaining 63–91% going to landfill.

Findings of the review include the following: the most common ENPs in the environment include titanium dioxide, silver, zinc oxide and carbon nanotubes, with over 80% deposited in the soil or landfills; ENPs can be taken up by living organisms and can have various toxic effects, such as reducing cell growth and damaging DNA, which can cause both environmental and human health hazards.

This study reviews scientific research on ENPs in order to understand their impact on the environment. The review outlines the different types of nanoparticles and examines what happens to different ENPs in the [soil](#), air and [water](#), as well as the hazards of exposure to different ENPs. ENPs released into the environment will begin to age which can change their chemical stability. The researchers also reviewed studies into how these chemical changes can affect the environmental impact of ENPs.

ENPs comprise inorganic, organic, polymer and various other forms, such as graphene nano-foils. ENPs can be both directly applied to the environment (e.g. in [fertilisers](#)) or indirectly (e.g. via sewage sludge or the effluent from waste plants). Various environmental factors (such as precipitation, temperature, pH and sunlight) as well as characteristics of the materials themselves (e.g. chemical and mineral structure or organic composition), can influence what happens to nanoparticles in the environment. For example, the retention of ENPs in the soil can depend on whether the nanoparticles attach and aggregate (group together) with similar or different materials, which is determined by the chemical properties of the particular nanomaterial and the given environment. For example, the presence of minerals within a clay soil can affect the aggregation of silver or titanium dioxide nanoparticles.

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1. Tippayawat, P., Phromviyo, N., Boueroy, P. & Apiwat Chompoosor, A. (2016). [Green synthesis of silver nanoparticles in aloe vera plant extract prepared by a hydrothermal method and their synergistic antibacterial activity](#). *Peer J*, 2016; 4: e2589.

2. It should be noted that completed and existing EU-funded projects over the last five years have been/are focused on the research gaps highlighted by the study. The possible environmental exposure and health effects of nanomaterials are addressed by [GUIDEnano](#), [SUN](#) (Sustainable Nanotechnologies), [NanoMILE](#) (Engineered NANOMaterial Mechanisms of Interactions with Living systems and the Environment) and [NanoSolutions](#) projects funded under the [EU Seventh Framework Programme](#). Current projects running under [Horizon 2020](#) focus on continuing to fill many of the identified gaps: [NanoFASE](#) (Nanomaterial Fate and Speciation in the Environment) focuses on how ageing and transformations affect environmental fate, behaviour and exposure; the recently started [GRACIOUS](#) (Grouping, Read-Across, Characterisation and classification framework for regulatory risk assessment of manufactured nanomaterials and Safer design of nano-enabled products) makes efforts to identify properties and knowledge that would allow predictive grouping of nanomaterials in terms of “what they would look like, where they would go, and what they would do”.

The changes that can occur to nanomaterials within the environment can alter their bioavailability. Bioavailability refers to how easily a substance can be absorbed by living organisms. Bioavailable ENPs are more readily taken up by aquatic and terrestrial species and can potentially bioaccumulate and biomagnify through the food chain, leading to potential toxic effects. It has recently been shown that inhalation by humans of ENPs, such as from [air pollution](#), is more dangerous than exposure via other routes, such as through the skin from cosmetics (e.g. of titanium dioxide or zinc oxide).

The researchers identify a number of challenges and research-and-development gaps in relation to toxicity of ENPs, citing a lack of:

- *in vivo* studies, which better reflect natural conditions;
- research on green synthesis of nanoparticles (i.e. using biological methods, such as those involving microorganisms or plants to manufacture nanomaterials¹) and its cost-effectiveness (in order to make more sustainable and safer products);
- long-term studies on ENP interactions with different environmental compartments and processes;
- evaluations of the effects of various factors on the bioavailability and ecotoxicity of ENPs;
- investigations into the long-term impacts of large-scale production of nanoparticles.

In particular, the researchers say that risk-assessment guidelines are not sufficiently developed to account for the ageing, exposure and long-term accumulation of nanoparticles in the environment. Different and new ENPs may lead to a range of environmental risks and, therefore, understanding the production and releases of different nanomaterials is important.

Overall, this review identified an urgent need for additional research on the nature, behaviour and effects of ENPs in the environment, and the risks they possibly pose to environmental and human health². The researchers say that the sustainable development of nanotechnology is vitally important in order to ensure environmental safety and that an improved evidence base is required to inform future policy and guidelines relating to ENP production, management and disposal practices.

