Keeping pace with pesticides: nano-sized particles can lead to big changes

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Introduction to Nanopesticides

The chemical that makes pesticides toxic is called its "active ingredient."

Nanopesticides, which are formulations incorporating particles less than 1000 nanometers in diameter, can modify the active ingredient using to:

- Reduce human exposure
- Increase effectiveness
- Minimize environmental harm

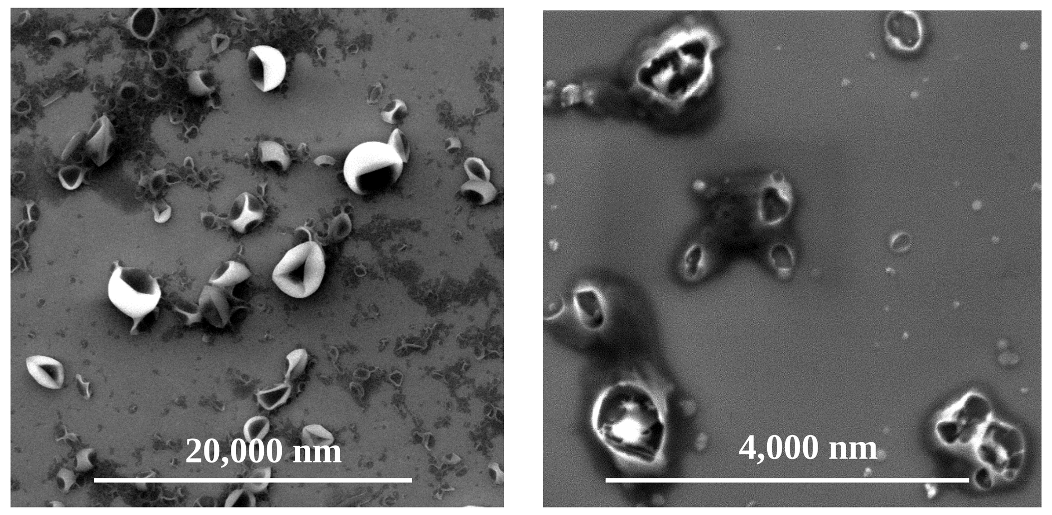


Figure 1. Scanning electron microscope images of two different nanopesticide formulations based on encapsulating spheres (left) and wet-milled granules (right).

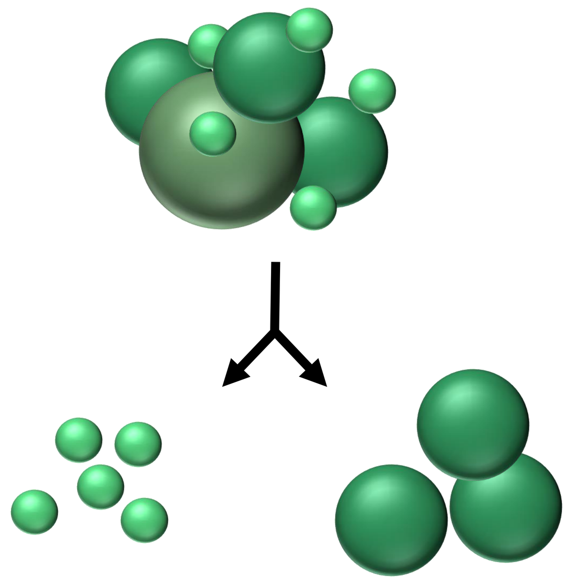
While some nanopesticides are known to behave differently than conventional pesticides, their capacity to alter the environmental risk of pesticides is unclear.

We sought to investigate two primary questions about nanopesticides:

1) **Can nanoparticles influence the transport of pesticides in the environment?**
2) **Does the particle size of a nanopesticide influence its risk?**

Isolation and Separation

Most pesticides are a complex mixture of nano and non-nano ingredients. A combination of centrifugation and filtration isolates particles ranging from 110 to 800 nanometers (1,000x smaller than the diameter of a human hair). These are then separated into a small fraction and large fraction.



Small Fraction **(SF)**

Large Fraction **(LF)**

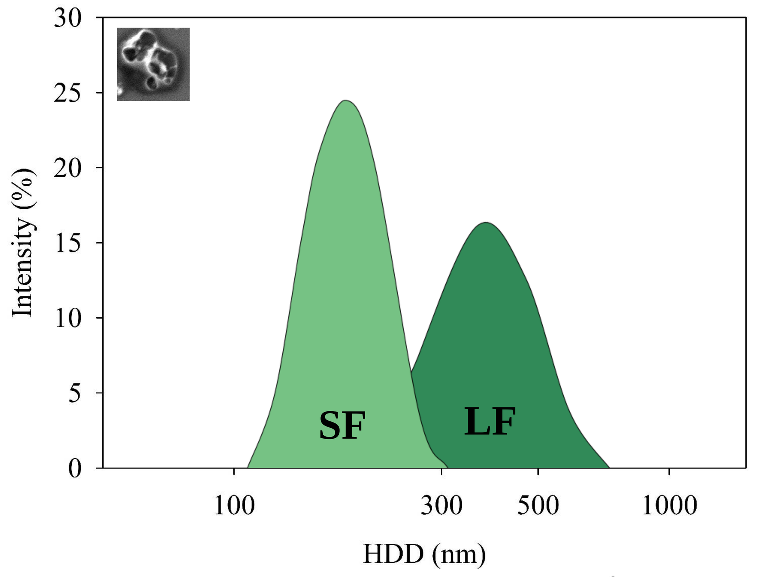
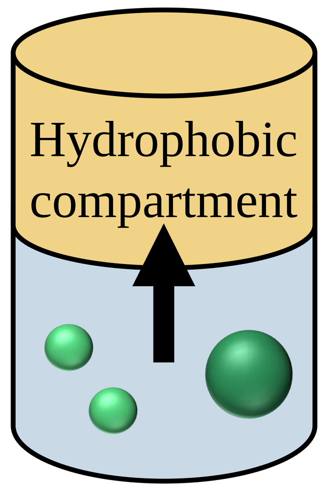


Figure 1. Nano-sized components of a pesticide mixture separated into two distinct fractions.

Environmental Transport

Pesticide hydrophobicity

A chemical's movement in the environment is largely dictated by it's hydrophobic ("water fearing") properties. Hydrophobic pesticides cling to soil or plant material, reducing the likelihood of washing away with rainfall.



Extraction vessel

Placing nanopesticides in a specialized extraction vessel, we quantify how long it takes for the active ingredient to move from water into the hydrophobic compartment.

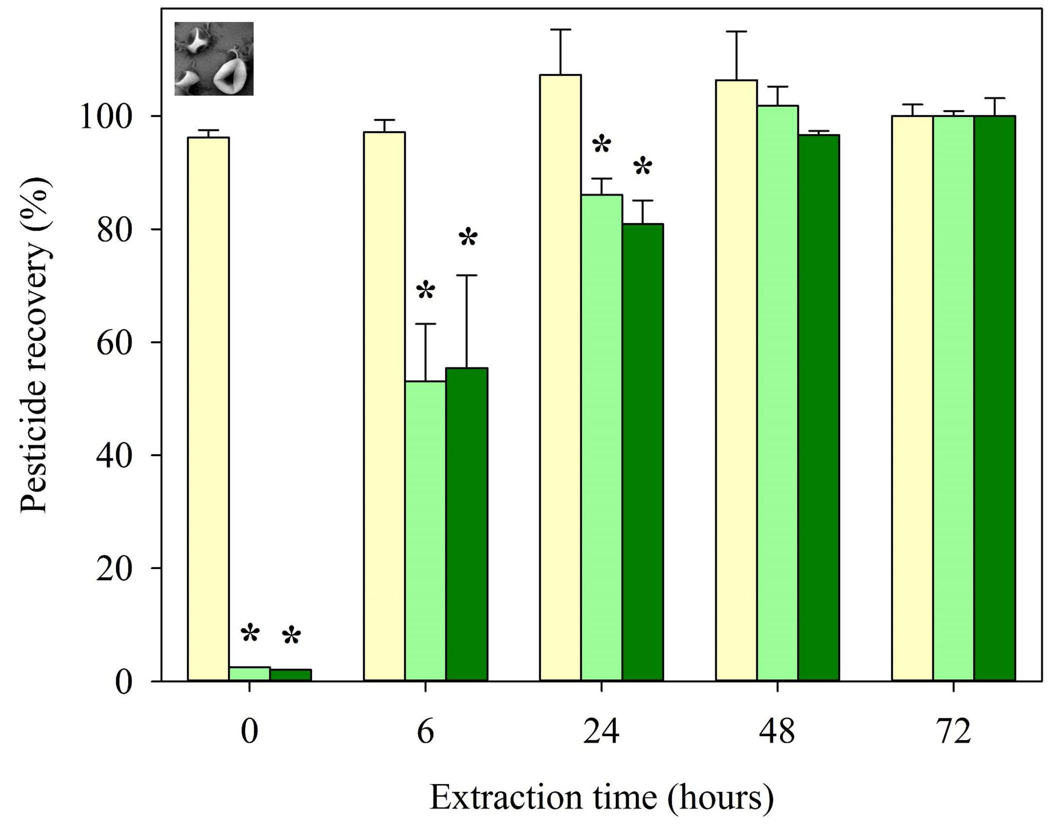


*Figure 2. Recovery of the active ingredient from water at various time points for a conventional, non-nano formulation **(yellow)**, the small nano fraction **(light green)** and large nano fraction **(dark green)**. * indicate significant differences from the conventional pesticide ($p<0.05$).*

Nanopesticides change hydrophobicity

In this case, both the small and large fractions of the nanopesticide formulation significantly inhibited the hydrophobic movement of the active ingredient for up to 24 hours.

Effects on a Non-Target Species

***Daphnia* toxicity assay**

Daphnia, small filter feeding animals that live in freshwater, are exposed to pesticides for 48 hours across a range of concentrations.

Calculating an EC_{50}

An EC_{50} is the concentration of pesticide required to produce an effect for 50% of the organisms. A lower EC_{50} indicates higher toxicity.

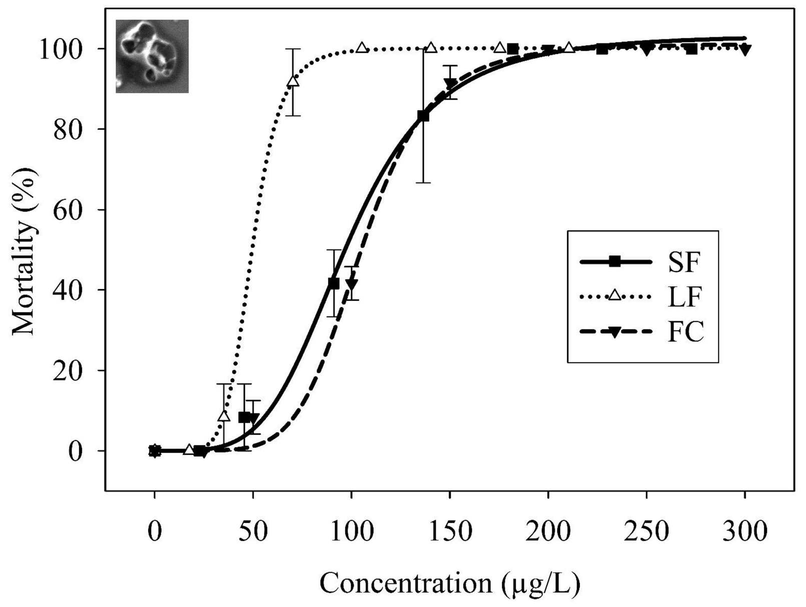


Figure 3. Example dose-response curve for a nanopesticide.

Toxicity Profile

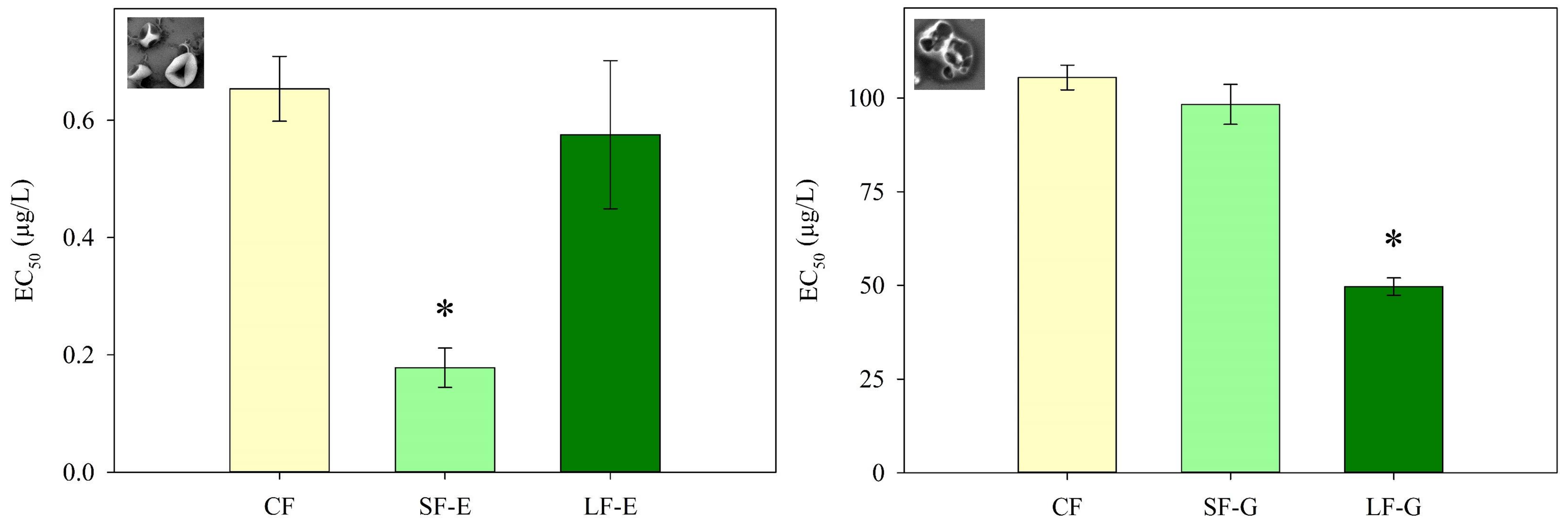


*Figure 4. Comparison of EC_{50} values for nanopesticides in the encapsulated formula (left) and the wet-milled formula (right). * indicates significant difference from the conventional formulation (CF) ($p<0.05$).*

Changes in toxicity are size- and product-dependent

The smaller fraction of the encapsulated nanopesticide (~450 nanometers) and the larger fraction of the granular nanopesticide (~400 nanometers) each increased toxicity.

The other fractions (~200 nanometers and ~750 nanometers) were no different from the conventional formulation.

Impact to Environmental Risk

Masking pesticide hydrophobicity

By inhibiting the hydrophobic nature of these products, nanopesticides may be more likely to travel with water and potentially contaminate nearby waterways.

Size-dependent toxicity

For the two nanopesticides tested, particles approximately 400-450 nanometers in diameter increased risk to *Daphnia*, potentially based on filter feeding behavior. This is a "Goldilocks" zone; particles larger or smaller than this were not different from the conventional formulation.

Nanopesticides may increase environmental transport and, for some size ranges, increase risk to unintended organisms.

Acknowledgements

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