SCIENCE FOR ENVIRONMENT POLICY

Nanopesticides may have the potential to increase food production — but are they environmentally safe?

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Grillo, R., Fraceto, L.F., Amorim, M.J.B., Scott-Fordsmand, J.J., Schoonjans, R. and Chaudhry, Q. (2021) Ecotoxicological and regulatory aspects of environmental sustainability of nanopesticides. Journal of Hazardous Materials, 404: 124148. doi: 10.1016/j.jhazmat.2020.124148.

As the world's population increases, so does the need for environmentally sustainable ways to increase food production. Nanopesticides are growing in popularity, as they appear able to achieve the same results as traditional agrochemicals when applied at lower amounts. However, regulatory and ecotoxicological research gaps remain. A literature review now identifies these gaps, and suggests the steps needed to enable sustainable nanopesticide use on a global scale.

Advances in nanotechnology have resulted in increasing research into nanopesticides[1], which contain active pesticide ingredients in the form of nano-sized — one-billionth of one metre — particles able to deliver novel formulations with greater efficacy (either directly or following dissolution).

Nanoscale formulations can increase the stability of a pesticide once applied or facilitate its slow release over time for better control in the field. Such pesticides have been shown to improve the efficacy of various herbicide (weed-killing), nematicide (worm-killing), acaricide (mite- and tick-killing), bactericide (bacteria-killing) and fungicide (fungi-killing) formulations and could thereby help increase agricultural food production whilst lowering costs to the farmer. Further research is needed, however, to ensure that these substances are used in an environmentally sustainable manner.

At present, there are gaps in assessing the risks associated with nanopesticide use, including their potential to exert toxic effects on non-target organisms — including not only plants and soil organisms, but also humans, who consume the crops to which they are applied. Currently, there are no specific methodologies standardised to study the toxicity of nanopesticides or which make allowances for the particular properties they may have. In Europe, nanomaterials are subject to stringent risk assessment, regulation (both cross-sectoral/horizontal and sector- or product-specific/vertical), and authorisation before going to market, including Plant Protection Products Regulation, regulations on residues in food and feed and the chemicals legislation, for example REACH.

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Nanopesticides may have the potential to increase food production — but are they environmentally safe? (continued)

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Pesticides are regulated in terms of both active substances and formulations and no nanomaterial-based pesticide is currently listed in the EU Pesticides Database of active substances approved for use in Europe.

The literature review presented here now provides a thorough discussion of the regulatory requirements for nanopesticides; identifies key ecotoxicological considerations to aid development of nanopesticides that are safe and sustainable for agricultural use; explores how environmental risk is assessed for nanopesticides; and discusses current levels of knowledge about the composition, fate and impact of these pesticides on the environment (considering plants and soil invertebrates, aquatic and aerial organisms).The review identifies a number of gaps — notably, the fact that it is not just the ingredients of a nanopesticide that require attention, but also the fate and toxic environmental effects of these ingredients when combined in a nanoscale formulation (as these effects may differ greatly from similar non-nano pesticides)[2]. In addition, risk assessments must consider several nano-specific aspects in addition to the normal risk-assessment criteria for pesticides. The researchers identify a 'minimum set of ecotoxicity tests for nanopesticides', including the following priority requirements:

- A precise definition of 'nanopesticide' to help define regulatory boundaries and avoid non-nanopesticides being wrongly considered nanopesticides;
- adapting current testing guidelines to account for the properties and behaviour of materials at the nanoscale, and standardisation of the testing guidelines for nanopesticides to align with existing worldwide guidelines on nanomaterials;
- environmental testing of nanopesticides over longer time frames and against appropriate organisms, as the potential effects of nanopesticides, or their degradation products, may manifest over longer exposures before a worst-case scenario can be detected;
- a better mechanistic understanding of the hazards posed by nanopesticides, or their breakdown products, to help predict potential long-term effects and allow design of more efficient, safe and environmentally sustainable nanopesticides.

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The review highlights that most research to date has focused on identifying the beneficial aspects of nanopesticide use, which are indeed substantial, with these substances potentially able to increase the efficacy, and thereby reduce the level of usage, of pesticides in food production. However, to realise the benefits of nanopesticides for the agri-food sector, future research must consider the specific nanoscale features that may pose novel risks, suggest the researchers. Such features must be incorporated into existing hazard assessment frameworks to enable a more complete and robust understanding of risk — and, by extension, facilitate new technological developments that result in safer and more sustainable nanopesticide products.

1. The review notes that there has been a ten-fold increase in research publications on nanopesticides from 2009 to 2019 — from just over 100 papers (2009) to over 1 000 (2019). However, despite this rapid growth in research, few 2019 studies contained a thorough consideration of the potential ecotoxicological risks of using nanopesticides (less than 50 papers).

2. Moreover, nanopesticide mobility in the soil depends mainly on its surface charge, cation species (i.e. ions which have a positive electrical charge), the type of soil and the fact that the soil sorption capacity of pesticides can be modified when they associated with nanoparticles/nanocarriers — which may increase or decrease their toxicity.