

Tiny nanopesticides promise big gains to farmers

by *Sophie Schmidt*

New research has helped bring nanopesticides—tiny capsules capable of big impact—one step closer to regulatory approval.

Farmers are some of the biggest innovators in our country—whether it's embracing new technologies, adapting to a changing and variable climate, feeding a growing population with less arable land than ever before, or combatting evasive agripests.

It's no surprise that novel nanopesticides, tiny capsules that deliver chemicals targeted to the leaves or the roots of plants, have piqued the interest of the agricultural community in the past five years or so.

Nanopesticides not only promise to help farmers combat diseases and pests more effectively, but also reduce the environmental footprint of agriculture, which are both crucial aspects of sustainable agriculture.

Nanopesticides could help reduce the environmental footprint of agriculture by offering the same or improved plant protection from a lower rate of chemical application.

Nanopesticides: more with less

The beauty of their unfathomably small size (a hundred nanometres—or about a hundredth of the size of a single sheet of paper) is that nanopesticides have a disproportionately high surface area-to-volume ratio, making them highly efficient at delivering only a tiny volume of pesticide to plants in a targeted manner.

They're also capable of controlled release, with the active ingredient released slowly or in some cases, when most needed. Their nanocage or capsule (so-called nanocarrier) structure helps protect the precious chemical, making it more effective for a longer time. The net effect? The same or improved plant protection from a lower rate of application.

The potential of nanopesticides to improve the environmental footprint of farming is huge—both reducing the amount of toxins put in the environment, and bolstering yields by minimising losses.

So what has stopped nanopesticides from storming the market? A lack of a clear and reliable regulatory framework—that helps clearly identify the consequences to both human and environmental health—has, up until now, limited the approval of these products by regulatory agencies.

Tiny particles, big dreams

For CSIRO researcher Dr Rai Kookana, 30 years of

research into contaminants and pesticides has just culminated in a very satisfying result—as a co-author of a new paper in *Nature Nanotechnology* that provides guiding principles for the regulatory evaluation of nanopesticides.

The paper was developed under a project funded by the International Union of Pure and Applied Chemistry (IUPAC) and led jointly by Kookana and Dr Linda Johnston (National Research Council, Canada).

Drawing from their international contacts around the world, the project team worked in close collaboration with industry and government (regulatory agencies) to develop a comprehensive framework for assessing potential human health impacts of nanopesticides.

This approach will help overcome potential barriers for regulators and industry globally, taking into account, for example, differing international regulatory requirements as well as community concerns about nanopesticides.

The project team, including Rai Kookana, Wendy Bruce, Shareen Doak, Linda Johnston, Melanie Kah, Vladimir Gubala, student observer, Hemda Garelick, Jordan Dinglasan, Reinhilde Schoonjans, Andrea Haase. Photo taken during Workshop on Nanopesticides Project in London (2019).

Many researchers, if prompted, can point to a pivotal moment in their childhood that piqued their research interest. Growing up on a farm in India during the 1970s was Kookana's moment.

Kookana witnessed first-hand the impact that earlier pesticides like Aldrin and Dieldrin had on the environment and public health. These were used on crops like corn and cotton and experienced a production boom after World War II.

These chemical compounds were eventually outlawed under the Stockholm Convention on Persistent Organic Pollutants (POPs) due to their toxic properties, resistance to degradation and ability to bioaccumulate in the environment. But this treaty was only finalised in 2001.

POPs, as well as some other toxic conventional pesticides were proven or suspected in some cases to have devastating impacts on biodiversity, including decimating global populations of honeybees, birds, and other wildlife, and causing chronic health conditions in humans. Their legacy continues to be unearthed to this day.

Enter nanopesticides

In Australia and many other countries, improved regulation and monitoring of new pesticide products



has minimised some of the more acute risks (such as those posed by POPs), and has generally led to improved environmental and health management. However, farmers have continued to battle problems with modern pesticides, such as chemical resistance, leaching into the environment and safety to human health.

Dr Melanie Kah at the University of Auckland is the lead author of this paper, as well a long-term collaborator of Kookana and former distinguished Visiting Scientist at CSIRO.

“In the past two decades, the research community started looking to chemical alternatives including nanopesticides, which offer a safer and more promising future in their ability to target weeds, worms, mites, ticks, bacteria, and fungi,” says Kah.

Dr Linda Johnston at International Union of Pure and Applied Chemistry (IUPAC), a co-author of the paper, is an expert in quantifying the nature and characteristics of nanoparticles in relation to their potential impact on human health.

“Nanopesticides, like other alternatives, are subject to rigorous safety testing to prevent unintended consequences,” says Johnston.

In Australia, the Australian Pesticides and Veterinary Medicines Authority (APVMA) has been at the forefront of this initiative. It’s important to note that some types of nanopesticide products are rapidly coming onto the market and have started gaining traction with farmers.

“One of the big drawcards of nanopesticides is the protection they offer to plants as well as to the non-target organisms in the environment. This is primarily because of their greater effectiveness and lower

toxicity,” explains Kookana.

“They are also known for their improved uptake by plant and reduced wash-off during a rain event.”

“At the same time, some of their unique properties mean that they may pose a different set of risks to humans and the environment, and as such, demand their own safety chemical safety frameworks,” adds Kah.

Risk and rewards

While nanopesticides sound highly promising, they also carry risk, as they are considered potentially toxic. Image: Ella Maru Studio.

While nanopesticides sound highly promising, they also carry risk, for example, potential exposure to dangerous chemicals that are able to be absorbed into organ tissue and bloodstreams, or across placental barriers.

And while they have many environmental benefits, like targeted delivery, and reducing environmental degradation, their nanomaterial structure is considered to be “potentially toxic”, according to Johnston.

It’s further complicated by the slow-release system of some types of nanopesticides, a result of their nanocarrier mechanism. Nanocarriers involve coating the useful pesticide ingredient within a protective shell coating.

This shell allows for the biologically active pesticide chemical to be released into the environment under specific conditions (such as light, temperature, or pH), improving its efficacy against the pest and disease as well as protecting from degradation and leaching.

A framework for ecological risk assessment for nanopesticides has already been published, but some



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The project team, including (from left) Rai Kookana, Wendy Bruce, Shareen Doak, Linda Johnston, Melanie Kah, Vladimir Gubala, student observer, Hemda Garelick, Jordan Dinglasan, Reinhilde Schoonjans, Andrea Haase. Photo taken during Workshop on Nanopesticides Project in London (2019).

key knowledge gaps remained around what impacts they might exert on humans. That's where this new framework comes in.

"One of the key takeaways in the framework is that not all nanopesticides are created equal," says Kah.

"While some products may have exceptional properties, others may not, or may not (or may not retain them for a long time). The range of products that we have to deal with in developing this framework was eye-opening."

What the framework promises

The new framework study, led by the University of Auckland, focusses on human health risk assessments for nanopesticides, as well as nanofertilisers.

Kookana emphasises that that the framework doesn't attempt to provide an exhaustive list of the effect of nanopesticides on humans, or frame nanopesticides as the 'silver bullet' of agrichemicals.

The hope is it will be used as a starting point for understanding and addressing the concerns about nanopesticides.

The paper provides a decision tree and pathway to risk assessment, keeping in mind the different stages of human exposure—at mixing and loading, application and post-application, with each stage involving different dilutions and forms of the pesticide, or exposure opportunities.

The framework also helps industry to understand what questions the risk assessor has in mind and what

data and information need to be provided to satisfy the regulatory requirements.

"Our study is an important step towards an approach for nanopesticides that can be accepted by regulatory agencies when assessing their toxicological impacts," says Kookana.

"It highlights the potential for nanotechnology and also points out the collective challenges that the scientific community, industry and government agencies face."

With this sound science now publicly available, Kookana believes that regulators and industry will be able to take the next step forward in realising the full potential of this innovation. 🇬🇧

More information

1. Kah, M., Johnston, L.J., Kookana, R.S. *et al.* Comprehensive framework for human health risk assessment of nanopesticides. *Nat. Nanotechnol.* **16**, 955–964 (2021). <https://doi.org/10.1038/s41565-021-00964-7>

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