vienna university
environmental geosciences

NANOPESTICIDES
State of knowledge, environmental fate and implication for assessment

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Nanotechnology and agriculture: Applications

Nanosensors
for pathogens or pesticide residues

Delivery of genetic material into plant cell

Fertilizers

Plant protection products
= Nanopesticides

Concept

NANOTECH + **PESTICIDES**

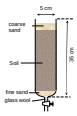
→ **Intentionally** applied (agriculture)

→ **Toxic** (e.g., insecticide)

FATE

Sorption **Degradation** **Leaching**





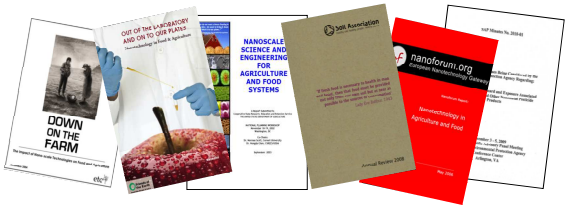
EFFECT

Efficacy **Hazard**


RISKS and/or **BENEFITS?**

Emergence of nano agrochemicals

Grey literature



General agreement: nanotech will revolutionise agriculture

Very controversial: environmental impact of nanopesticides

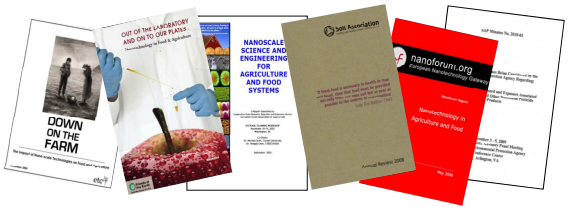
"Potential to **reduce contamination** through the reduction in application rates and limited runoff"
ETC, 2004

"Increased toxicity, bioavailability and longevity […] **new kinds of contamination**"
E.g. Friend of the Earth, 2008

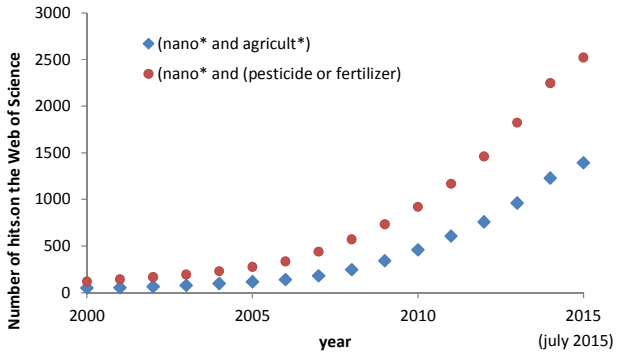
"Urgent **need for regulatory** system capable of managing many new risks"

Emergence of nano agrochemicals

Grey literature



Scientific literature



(Figure adapted and extended from Gogos et al., 2012)

Many communities with different perceptions

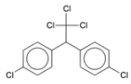
ENVIRONMENTAL SCIENTISTS

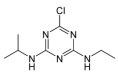
NANO COMMUNITY

Intentional and diffuse source of toxic nanoparticles

→ Emerging **contaminants**

PESTICIDE COMMUNITY


DDT


atrazine

→ One **solution** for mitigation

REGULATORS

Risk or **Risk/Benefit** assessment

Recent workshops and meetings

- **FAO/WHO** report, 2013

"*State of the art on the initiatives and activities relevant to **risk assessment** and risk management of **nano**technologies in the **food and agriculture** sectors*"

- **JRC-IPTS** workshop Nov. 2013 (Seville, E)

"***Nano**technology for the **agricultural** sector: from research to the field*"

- **IUPAC** workshop May 2013 (York, UK):

"***Nanopesticides**: regulatory evaluation of environmental **risks***"

- Special symposium at **ACS meeting** Aug. 2014

*"Fate, effects and **risks** of **nanopesticides**"*

- **SETAC Asia/Pacific** Keynote by Chief Regulatory Scientist of APVMA (Australian Pesticides and Veterinary Medicines Authority) (Sept 2014)

"***Nanopesticides** and veterinary nanomedicines: **regulatory challenge**?"*

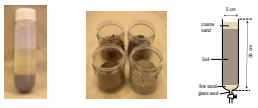
…

→ Need to support decision-making

Patent/literature analysis to evaluate state of knowledge

WHAT ARE NANOPESTICIDES?

FATE
Sorption Degradation Leaching



EFFECT
Efficacy Hazard

CAN WE ASSESS THE RISKS?
IS FRAMEWORK READY?

Kah et al. (2013)
Crit. Rev. Environ. Sci. Technol. 43:1823

Nanopesticides: State of Knowledge, Environmental Fate, and Exposure Modeling

M. KAH,[1] S. BEULKE,[2] K. TIEDE,[2] and T. HOFMANN[1]
[1]*Department of Environmental Geosciences, University of Vienna, Vienna, Austria*
[2]*Food and Environment Research Agency, Sand Hutton, York, England*

Kah and Hofmann (2014)
Environment International 63: 224-235

Review
Nanopesticide research: Current trends and future priorities
Melanie Kah *, Thilo Hofmann *
Department of Environmental Geosciences, University of Vienna, Althanstrasse 14, 1090 Vienna, Austria

Kookana et al. (2014)
J. Food and Env. Chem. 62, 4227-4240

Nanopesticides: Guiding Principles for Regulatory Evaluation of Environmental Risks

Rai S. Kookana,*[,†,‡] Alistair B. A. Boxall,[§] Philip T. Reeves,[∥] Roman Ashauer,[§] Sabine Beulke,[⊥] Qasim Chaudhry,[#] Geert Cornelis,[▼] Teresa F. Fernandes,[□] Jay Gan,[◆] Melanie Kah,[○] Iseult Lynch,[▲] James Ranville,[○] Chris Sinclair,[⊥] David Spurgeon,[■] Karen Tiede,[⊥] and Paul J. Van den Brink[○▲]

Analysis boundaries

"My" **nanopesticides** **=**

Called "Nano"

Nanometer range (< 1000 nm)

Novel properties related to size

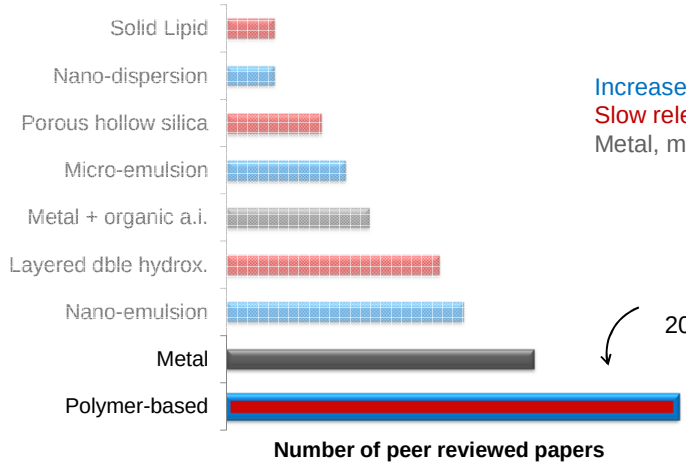
What are nanopesticides ?

Wide **variety** of products (development, ingredients, size, relevance etc…)

Increase solubility	Slow release	Nano metals/oxides
Microemulsion (6-50 nm) Nanoemulsion (20-200 nm) Nanodispersion (50-200 nm)	Polymer-based (spheres, capsules, gels and fibres) (10-300 nm) Solid lipid (200 nm - 100 µm) Clays and layered double oxides (µm) Porous hollow silica (50-200 nm)	as active ingredient Associated with conventional active ingredient

Nanopesticides ≠ single category

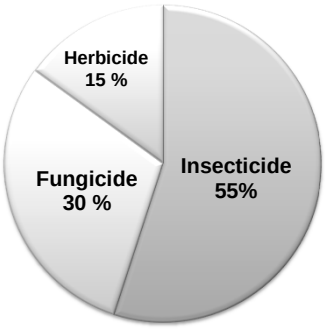
Trends in scientific literature



Increase solubility
Slow release
Metal, metal oxides

>50 %
2011-2014

Trends



Alternative AI
(essential oil,
pheromones)

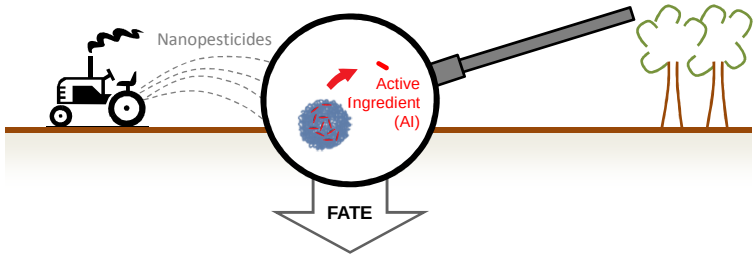
"eco-friendly" carrier
(biodegradable,
natural origins)

Which types of Nanopesticides will soon emerge on the market?

→ market and regulatory constrains

Price? Efficacy?
Risks/benefits?

Environmental fate of nanopesticides

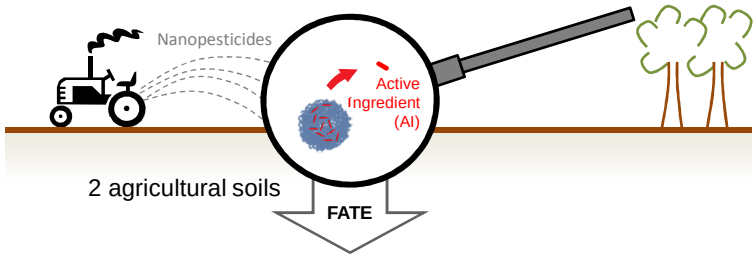


„The environmental fate of nanopesticides is a big black hole"
(Prof. Harper, Oregon State University, Jan. 2015)

What happens ?

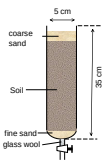
How to measure?

Fate of nanoformulated vs pure active ingredient

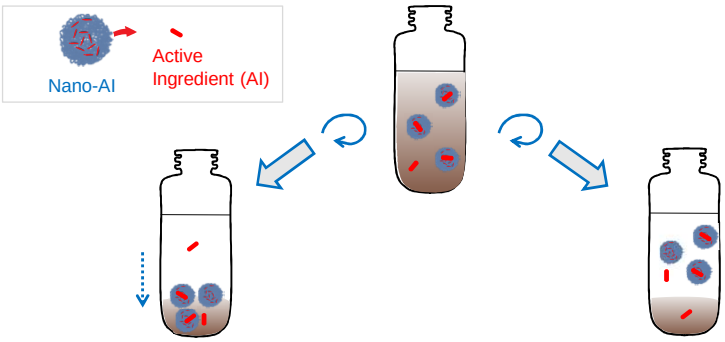


Solute approach
(equilibrium)

Sorption	**Degradation**	**Leaching**
OECD 106	*OECD 307*	*OECD 312*



Sorption in soil



Kd nano-AI > Kd AI

→ Nano-AI settling down?

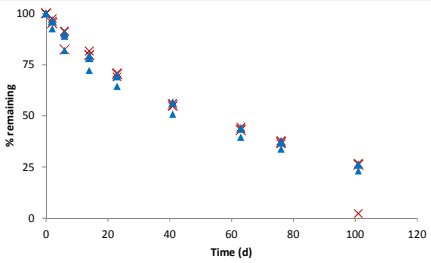
Kd nano-AI < Kd AI

→ Nano-AI remaining in suspension?

Nanoformulations affect interaction with soil (at least its measurement)

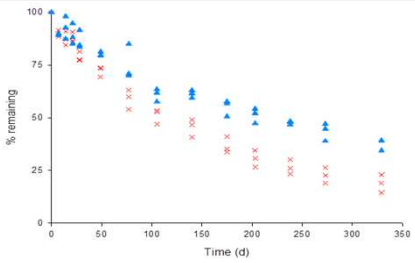
Kah et al. (2014) *Environ. Sci. Pollution. Res.* 21:11699-11707

Degradation in soil



No effect

→ rapid release of AI *and/or*
→ nano-AI subject to degradation



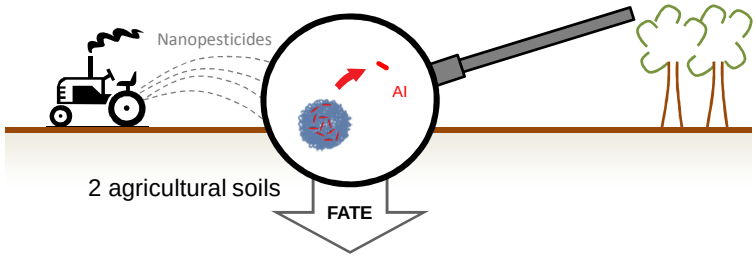
Slower **degradation** kinetics

→ toxicity of nanoformulation *and/or*
→ nano-AI protected

Nanoformulation can affect degradation kinetics

Kah et al. (2014) *Environ. Sci. Pollution. Res.* 21:11699-11707

Fate of nanoformulated vs pure active ingredient

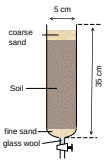


Solute approach *(equilibrium)* + **Nano approach** *(kinetic)*

Sorption *OECD 106*

Degradation *OECD 307*

Leaching *OECD 312*



Characterization
size distribution, zeta potential, aggregation behaviour

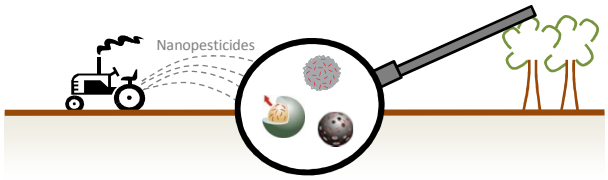
Fate
Attachmnent efficiency
Transformation/durability of carrier

Take home messages

- Nanopesticides = wide variety of products
- Current knowledge is not sufficient to evaluate benefit/risk

→ Analytical methods, fate/effect properties, modelling

- Solute, Nano or both?
- Nanotechnology has a lot to offer!



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