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Micro- and Nanoplastics:
Applying Lessons from Nanoparticle Research to the Plastic Problem

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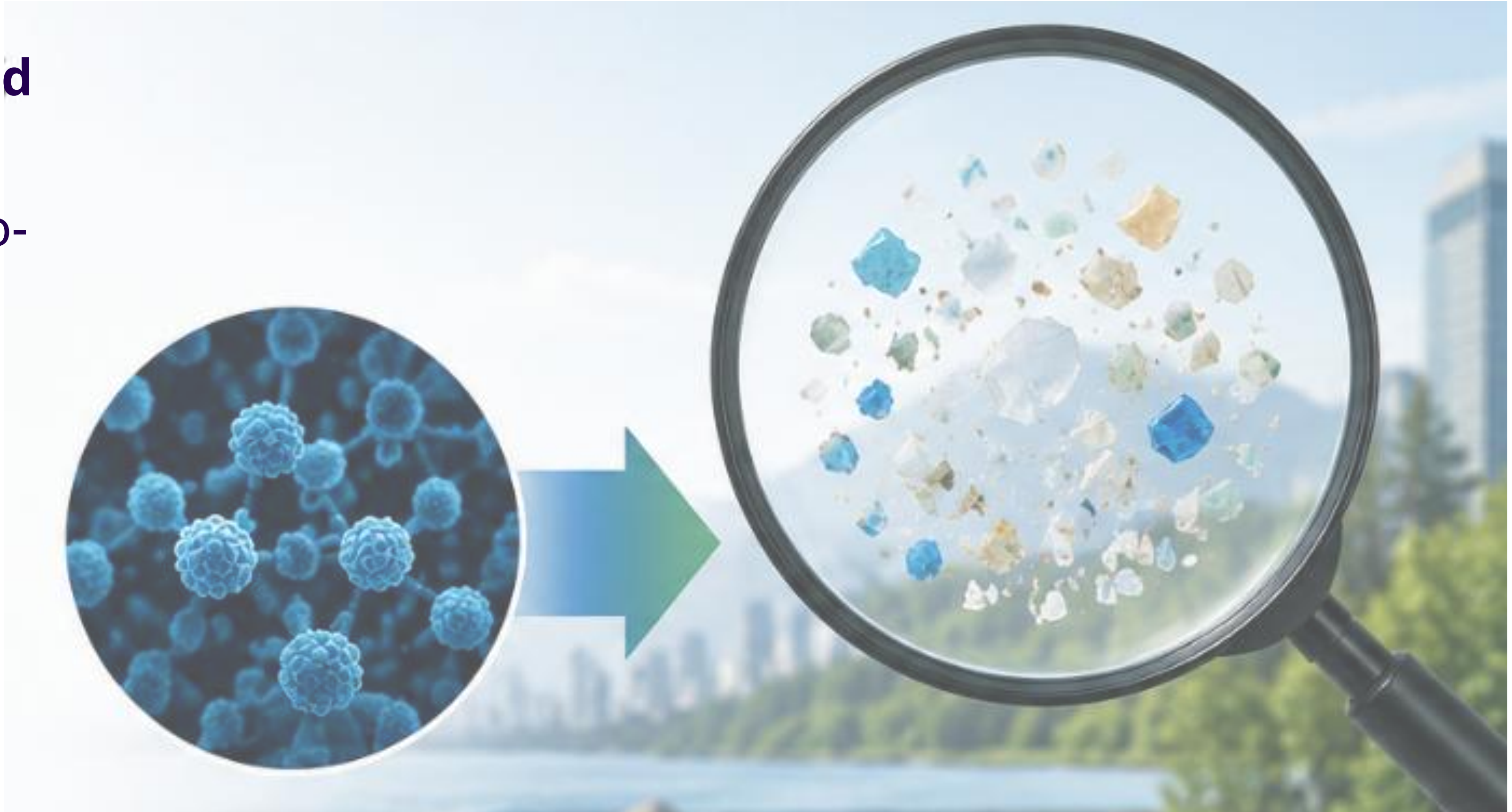
From Nanoparticles to Nanoplastics: Applying two decades of research

Nanoparticle research in the 2000s has already demonstrated how to:

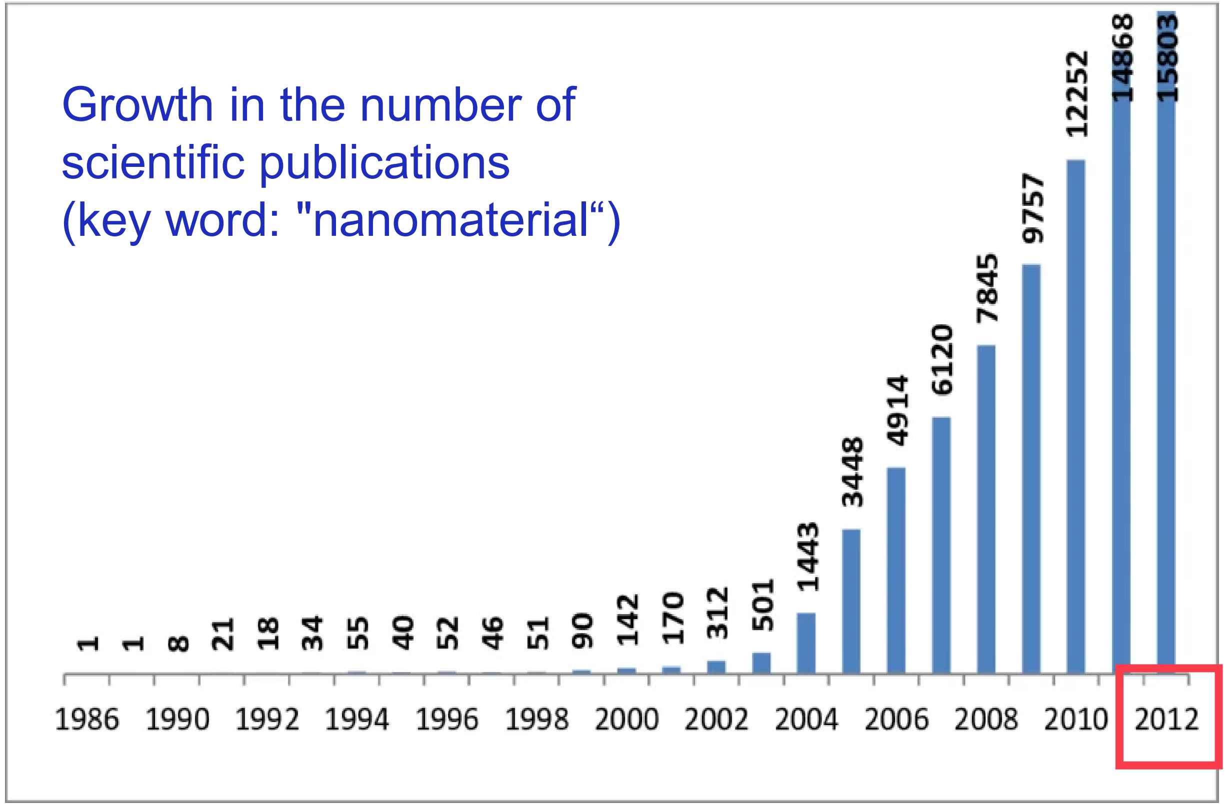
1. Classify and monitor difficult-to-measure particles
2. Manage uncertainty in risk assessment
3. Control exposure before exposure limits exist
4. Build policy while science continues to evolve



We are not starting from zero. We are starting from decades of nanotox and policy experience

Going back in time: A short history of Nano research

- Applications for engineered nanoparticles increased dramatically in early 2000s
- Led to national nanotech initiatives, with huge research intensity: roughly 2005–2015(ish)
- Significant interest in opportunities and applications…
- However, even more interest in potential human health impacts and pathways of toxicity – **societal concern**
- Regulatory challenges, particularly for consumer applications, and occupational exposures **(defining occupational exposure limits)**



Gaffet, E. et al. (2015). Assessment of the risks associated with nanomaterials: Issues and update of current knowledge.

Led to a growth in national research efforts

Switzerland: NRP 64: Opportunities and risks of nanomaterials” (2010-2015+)

CHF 12M	23	111	~150	5
total funding	research projects	researchers	publications (2017)	years of research

Studied across the life cycle: Fabrication → Use → Disposal

Medicine | Environment | Food & packaging | Energy | Construction

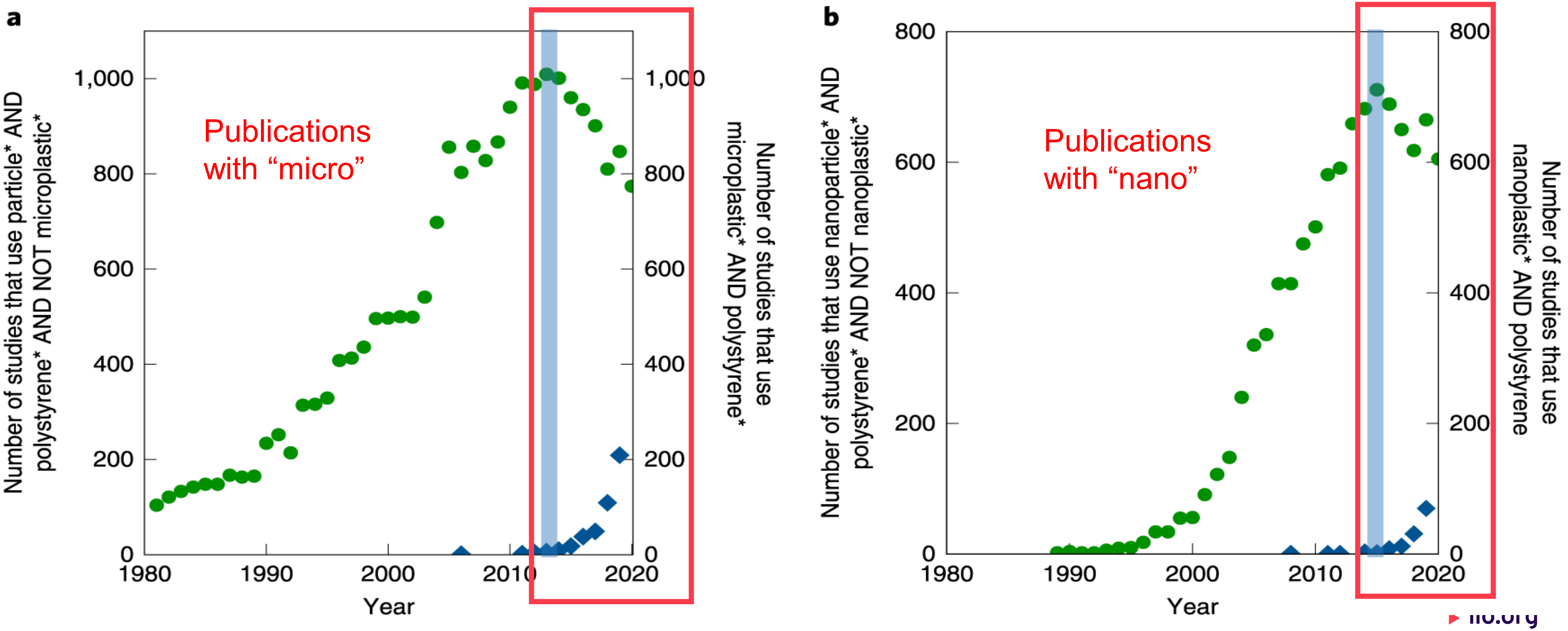
HOW HARMLESS ARE THESE NANOS?

Even if the opportunities outweigh the risks: any indications of potential risks must be thoroughly investigated – an over-zealous regulation, however, would be counterproductive.

*Whenever a new nanoparticle is identified or a new application of an established nanoparticle is pursued, carrying out a **risk re-assessment is essential to guarantee safety***

The research shift from nano "particle" to micro/nano "plastic"

As shown by terminology in publications



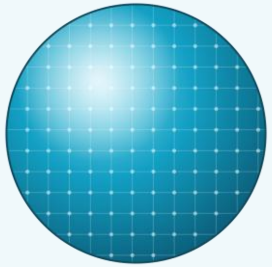
Gigault *Nat. Nanotechnol.* **16**, 501–507 (2021). https://doi.org/10.1038/s41565-021-00886-4

Engineered nanoparticle vs. micro / nanoplastic

Same core toxicological mechanisms — fundamentally different material

Properties and behaviors of nano-range materials cannot be extrapolated from their bulk counterparts
Both converge on the same toxicological pathways: oxidative stress · inflammation · frustrated phagocytosis · translocation

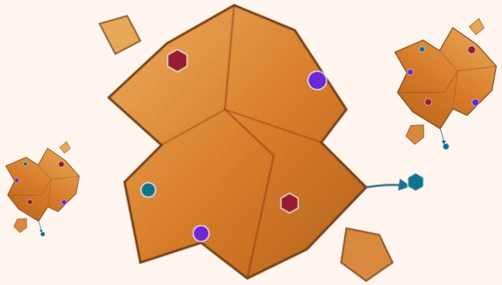
ENGINEERED NANOPARTICLE



- **Engineered & defined** — known size, shape and composition
- **Uniform & biopersistent** — behaves as a single, characterizable material
- **Hazard = the particle itself** — surface-area dose metric drives toxicity. However can also have a “biocorona”
- **Somewhat regulated** — OELs exist (nano-TiO_2; CNT 1 μg/m^3)

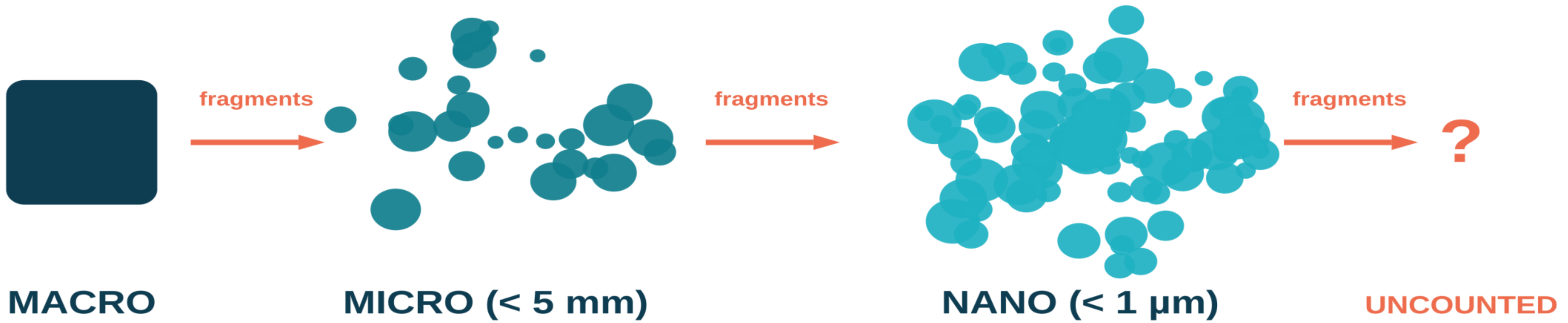
vs

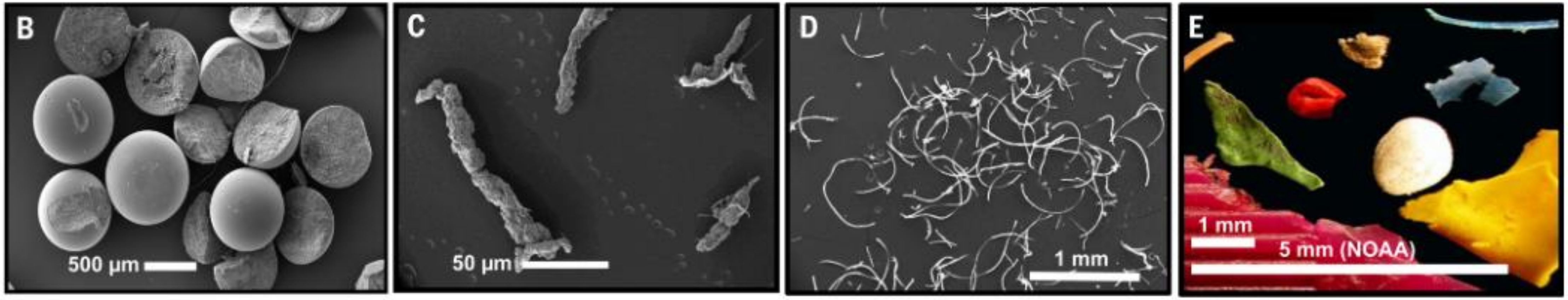
MICRO / NANOPLASTIC



- **Degradation fragment** — jagged, irregular, weathered edges
- **Highly heterogeneous** — varies in polymer type, additives (chemicals), size range, shape (morphology – fiber, sphere etc). Long term degradation
- **Trojan horse effect** — carries sorbed pollutants, metals (biofilm)
- **Largely unregulated** — no OELs

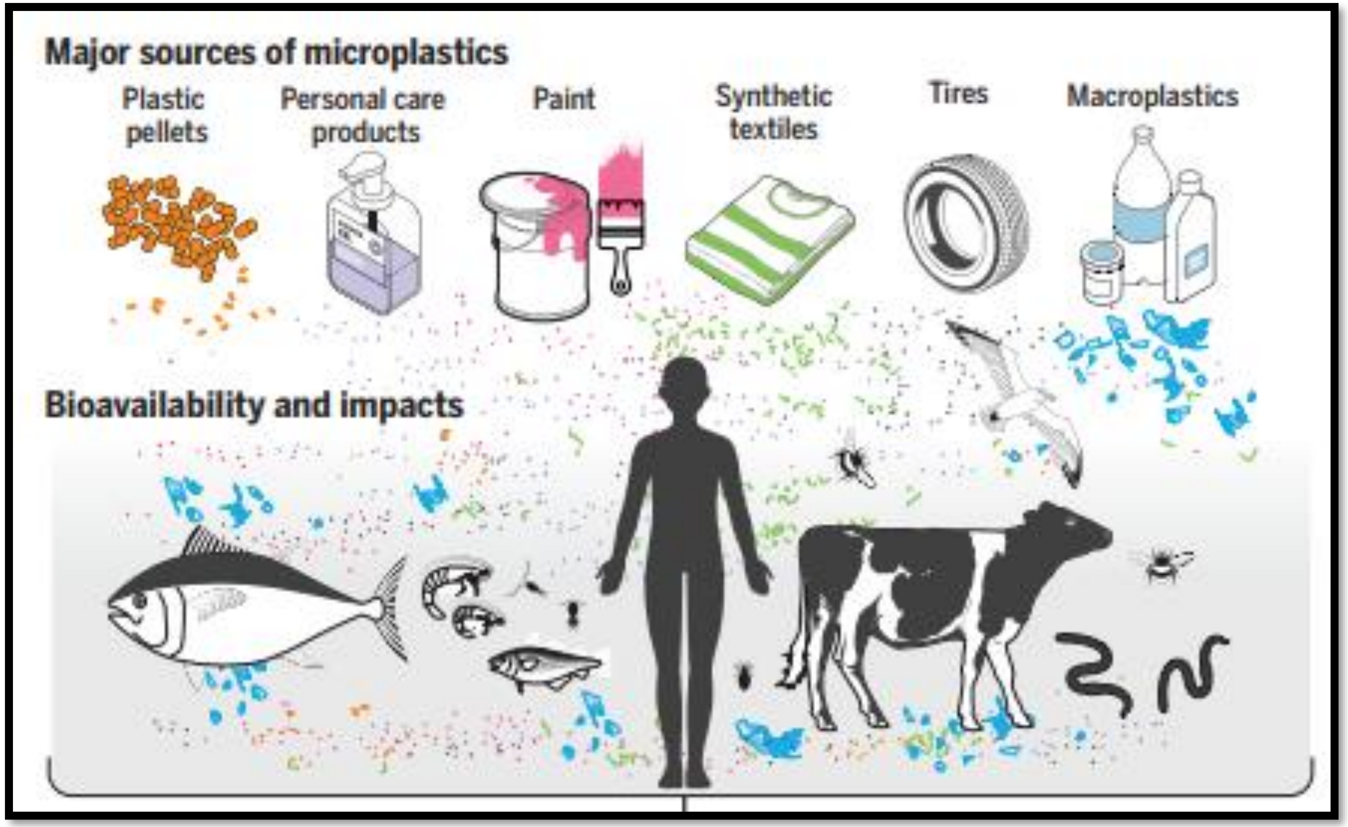
Hazard Identification: Natural degradation results in huge heterogeneity





Richard C. Thompson *et al.*,DOI:10.1126/science.adl2746 [Credits: Browne Plymouth Electron Microscopy Centre [(B) to (D)]; M. A. Browne (E)]

Exposure Assessment: Broad and Widespread



Richard C. Thompson *et al.*,DOI:10.1126/science.adl2746 [Figure credit: J. Beadon]

- The core message: exposure is daily, involuntary, and effectively unavoidable (exposure to engineered nanoparticles more limited).
- Environmental ubiquity, where MNPs are now detected across every environmental medium: air, drinking and surface water, soil, and the biosphere - including remote and indoor environments. There is no longer an unexposed **control population.**
- Based on estimates of particle releases: plastic-derived particle exposure is orders of magnitude larger than for NP exposure.

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Routes of Exposure: Translocation and systemic exposure of MNPs

Inhalation

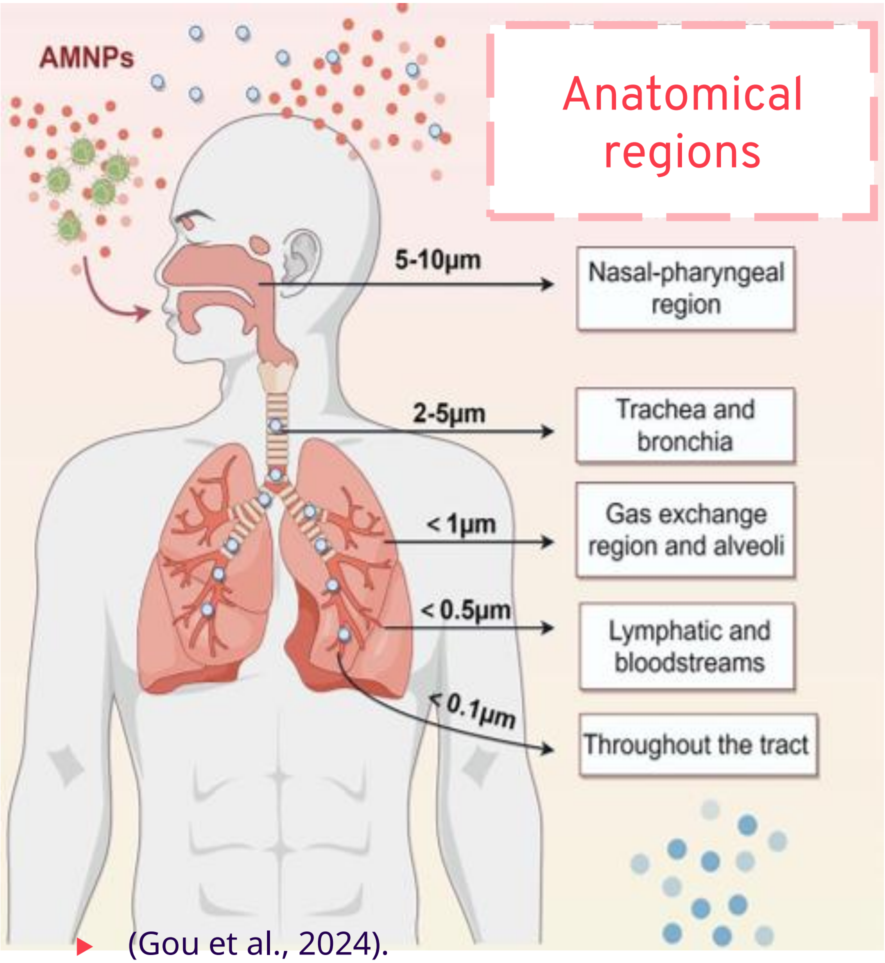
- Smaller the particle, deeper it reaches
- Deposition in the alveolar region
- Partial clearance via macrophages
- Some may translocate into circulation

Ingestion

- Uptake via the gastrointestinal tract
- Translocation mechanisms include epithelial uptake and Peyer's patches (Pan et al. 2026)

Dermal exposure

- Evidence of penetration is limited and inconsistent (Tang et al., 2013; Crosera et al., 2015; Xie et al., 2015; Jatana et al., 2016).



- (Gou et al., 2024).

Number of studies that confirm the presence of micro/nanoplastics in various organs

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Exposure Assessment: Occupational

For millions of workers, micro/nanoplastics represent a double burden of environmental and occupational exposure, compounded by the absence of any protective standards

Main exposure routes:

- Inhalation (airborne dusts and fibres)
- Ingestion (contaminated food, surfaces)
- Dermal contact (more limited evidence)

How exposure occurs (throughout lifecycle):

- Bottom-up: high-energy processes
  - Machining, 3D printing, heating (Walter et al., 2015; Stefaniak et al., 2018).
- Top-down: degradation of plastics
  - Waste, recycling, textiles, indoor dust (Wohlleben et al., 2013; Dris et al., 2017).

Same particles; double the dose; zero exposure limits

Case study: Occupational exposure to flock

Exposure context (Eschenbacher et al., 1999)

- Nylon flock: finely cut synthetic fibres used in manufacturing
- Exposure in five flock-processing facilities

Clinical findings

- **20 workers identified with interstitial lung disease.**
- **Histopathology**
  - Lymphocytic bronchiolitis and peribronchiolitis
  - Lymphoid hyperplasia).

Clinical outcomes

- Persistent cough and breathlessness
- Reduced lung function and gas exchange

Exposure–response evidence

- Improvement following removal from exposure
- Recurrence upon re-exposure

➢ **Occupational exposures as the early warning for public health and society**

Lessons Learned?

Twenty years apart, a similar conclusion

Conclusion

It is beyond doubt that humans are exposed to MNPs and that these enter our body. Increasing evidence indicates that this could negatively impact human health, but knowledge gaps limit our ability to draw hard conclusions. To perform reliable human risk assessment, improvement in methods for exposure assessment and effect assessment are urgently needed, together with well-designed clinical studies. This can be achieved only through robust scientific research by international and interdisciplinary collaboration of experts in the field. Although microplastics research is still an emerging field, the current state-of-science and societal concerns warrant the development of strategies to reduce exposure to MNPs and protect environmental and human health.

1. *Exposure is certain*
2. *Harm is plausible*
3. *But knowledge gaps limit hard conclusions*
4. *We need harmonized methods and collaboration*

Lamoree, M.H., van Boxel, J., Nardella, F. et al. Health impacts of microplastic and nanoplastic exposure. Nat Med 31, 2873–2887 (2025). https://doi.org/10.1038/s41591-025-03902-5

Lesson Learned 1: Establish clear terminology and harmonised methods early

- **Engineered nanoparticles** are different from **microplastics** which are different from **nanoplastics** – We cannot extrapolate cleanly across disciplines
- What we can do is establish clear terminologies and harmonised methods for microplastics and nanoplastics.
- Definitional clarity provides infrastructure for data sharing and regulation where its needed most (OELs).
- Defining terms and metrics early is what lets results be pooled across labs; inconsistent definitions and reporting units make studies impossible to compare.
- No standards, no reliable evidence base. Without internationally recognised methods and reference materials, much of the published literature can't be relied on, and large research investments lie idle because the step to application can't be taken (NRP 64, 2017).

Lesson Learned 2: Bridge the divide been environmental scientists, human toxicologists and regulators

- The central organisational lesson of the nanotox field is that the **problem spans across too many disciplines** for any single community/expertise to solve alone.
- A key lesson from 20+ years of nano is that international, interdisciplinary teams can tap into expertise that is sparsely distributed across the world (Gigault et al., 2021).
- The same authors make this concrete for nanoplastics, arguing that research groups should actively draw in nano expertise through hiring and visiting researchers rather than re-inventing methods.
- NRP64 found that risk governance stalls without active collaboration with scientists: regulatory conditions remain ineffective as long as no reliable test equipment exists to prove a nanomaterial is even present, which is ultimately a call for scientists and regulators to act together (SNCF, 2017).

Lesson Learned 3: Engage stakeholders and society to achieve real-world impact (+Risk communication)

- In uncertainty there is always fear. This is where engaging stakeholders and ensuring adequate risk communication is key.
- Scientific findings cannot protect anyone on their own. Impact comes from sustained, two-way engagement with the people who make, regulate, handle and live with these materials, and from communicating risk honestly, including what isn't yet known.
- NRP64: Focused on risk communication just as much as scientific methods. Steering committee included risk communication experts as well as a dedicated communication strategy to bridge the gap between scientific findings and broader society.
- Social dialogue at the ILO: If we want effective implementation of standards, we need to ensure everyone is on-board from policy conception – key to success.

Lesson Learned 4: Do not start from scratch – Leverage existing frameworks, tools and standards

- Nanoplastics is a relatively young field next to mature ones. The methods, frameworks and institutions already exist; the task is to connect to them, not rebuild from zero.
- Know what transfers and what doesn't – issue of heterogeneity
- Leverage governance framework that already exist, especially with current geopolitics. Do we have to wait for a Plastics Treaty? Basel Convention; Global Framework on Chemicals; Science Policy Panel; OECD test guidelines; ILO standards
- Don't wait to start applying policy – there will never be perfect science. Critical lesson learned from nano research on Occupational Exposure Limits (OELs).
- Control banding, precautionary matrices and substitution principles were built for hazards we couldn't yet quantify — exactly the nanoplastics situation. Reuse them rather than building parallel systems (NRP 64, 2017).

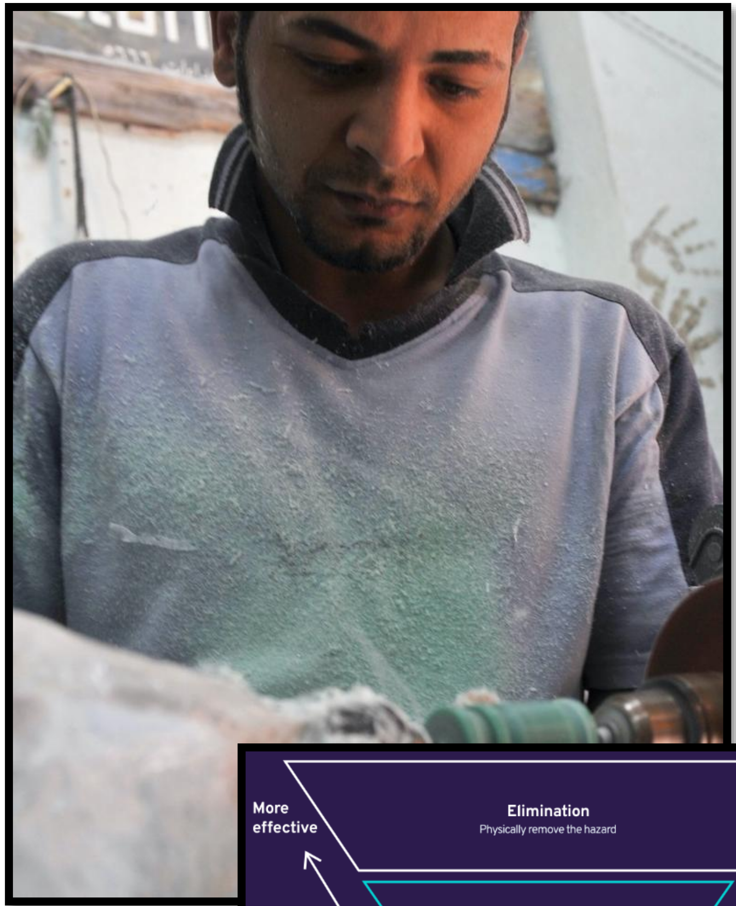
What is in our (OSH) toolbox?

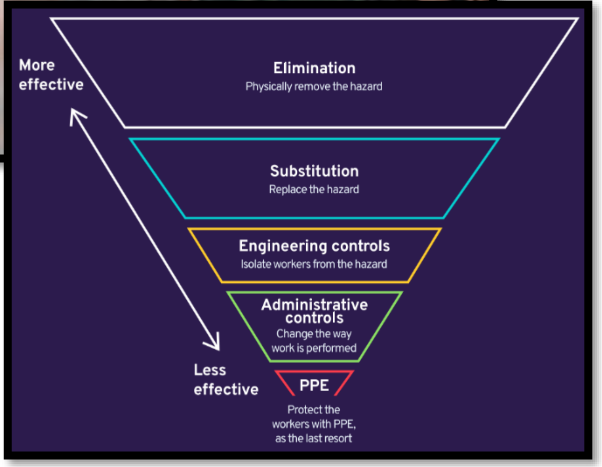
- **International labour standards and key principles**
  - Key conventions on ensuring the right to a safe and healthy working environment and chemicals (ILO C155, C187; C170).
  - Operationalized through OSH management systems (ILO 2001)

- Implementing preventive and protective measures for plastics in order of the **hierarchy of controls**

- Precautionary risk management
  - Minimise exposure where there is plausible risk; Treat novel materials as potentially hazardous.

- Globally Harmonized System for Classification and Labelling (GHS)





The Global Framework on Chemicals (GFC)

The GFC provides concrete entry points to prevent and minimize exposure to micro- and nanoplastics

- Leveraging global policy action on chemicals
- The framework supports preventive and protective action where risks are likely present
  - Target D7 – OSH practices across supply chains
  - Targets D2 / D4 – Safer alternatives
  - Target E6 – Link chemicals and labour policies
- The GFC includes a mechanism to raise emerging issues at the international level:
  - "Issues of concern" process enables targeted attention

Thank you

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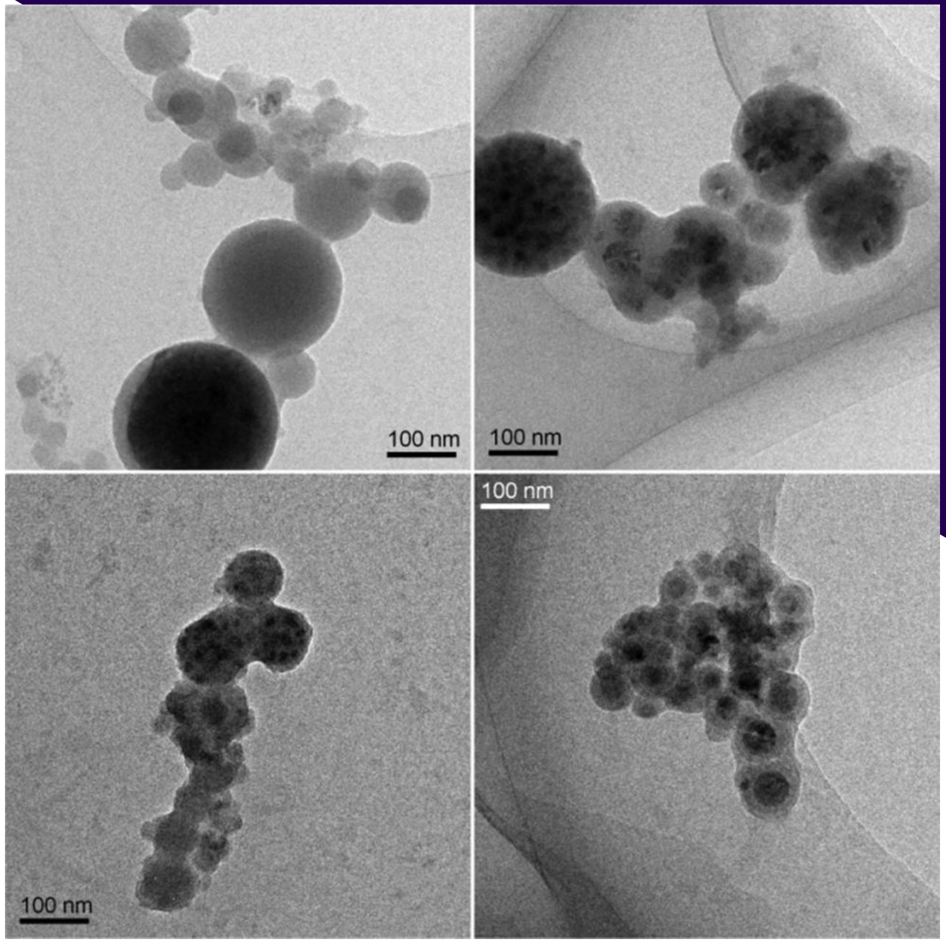

Welding fume nanoparticles in exhaled breath condensate. Graczyk (2016)