NANOTECHNOLOGY FACT SHEET

What is "Nano"?

Nanotechnology is the control or manipulation of natural or engineered matter to make use of properties and phenomena that are dependent on the size and structure on a near-atomic or nanoscale, which is defined as being around 1 to 100 nanometers (nm, or 10^{-9} meters) in at least one length dimension. At the nanoscale, matter can exhibit unique properties that affect physical, chemical, and biological behavior, and at the heart of nanotechnology is researching, developing, and utilizing these properties.

Nanotechnology results in materials, systems, and processes that have distinct nanoscale features and are thus typically labeled with "nano" such as nanodevices, nanopores, nanomaterials, nanoparticles, nanofibers, nanofilms, and nanofiltration. Nanotechnology has led to scientific advancements in many areas, such as medicine, consumer products, energy, materials, water purification, and manufacturing.

Opportunities for Innovation

Nanoscale-specific properties of nanomaterials and other nanotechnologies, such as their electronic, optical, or chemical-reactive qualities, are key to research and commercial applications. For example, the global nanomaterials market was valued at $16.3 billion in 2021 and is expected to reach $62.8 billion by 2031, yielding a compound annual growth rate of 14.6%. North America will remain the market-leading region for several years as it has significant ongoing research and development activities in nanomaterials. Nanotechnologies are widely utilized in industrial and consumer products, including drug-delivery systems, stain resistant clothing, solar cells, cosmetics, and food additives.

An investment in research and development could expand these applications in burgeoning areas, such as catalysis, medicine, CO_2 capture, renewable energy production and storage, and other sustainability solutions, such as ultrasensitive detection of contaminants. Other important research areas include the development of standard test materials and ways to collect, separate, and filter nanoparticles. A critical area of research is the development of analytical techniques and other approaches to characterize the variety of nanomaterial types and the variation within types as well as their transformations in environmental or biological matrices, which can complicate the characterization process and functionalities.

Environmental, Health, and Safety (EHS) Considerations

The increase in the production and use of nanotechnologies has raised questions about their potential adverse effects due to greater exposures of workers, consumers, and the environment. Workers within nanotechnology-related industries have the potential to be exposed to uniquely engineered materials with novel sizes, shapes, and physical and chemical properties. Occupational health risks associated with the manufacture, use, and disposal of nanotechnologies are not yet well understood or easily predicted.

The unique properties of nanotechnologies may lead to specific health effects. For some nanomaterials, responses have been observed in cell cultures and animals, and there are strong indications that their distinct surface area, surface chemistry, and other surface properties are

responsible. More research is still needed on dominant exposure routes, potential exposure levels, and respective outcomes.

It is challenging to do a risk assessment of nanotechnologies due to their diverse chemical makeup and properties.

Depending on the environment where a nanomaterial is present (for example, lung fluid, surface water, or air), its surface properties may change, affecting its behavior, thus it may be challenging to make predictions about such behavior and potential effects. Other challenges in evaluating risk include 1) lack of capabilities to monitor rapid changes in current, emerging, and potential nanotechnology applications and to identify and address the potential consequences for EHS risks; and 2) poor understanding of toxicological profiles, exposure scenarios, and adequate models for investigating EHS risks, leading to great uncertainty in describing and quantifying nanomaterial hazards and exposures.

Significant research is still needed on the impact of nanomaterials in the environment, including identifying and quantifying nanomaterial releases and the populations and environments being exposed, understanding processes that affect potential hazards and exposure, examining nanomaterial interactions in complex systems ranging from subcellular to ecosystems, and developing adaptive strategies to minimize negative impacts.

References

- International Organization for Standardization (ISO) TC 229 Definition for Nanotechnologies: https://www.iso.org/committee/381983.html
- International Organization for Standardization. (2015). Nanotechnologies — Vocabulary — Part 2: Nano-objects (ISO Standard No. 80004-2:2015). https://www.iso.org/standard/79525.html
- Nanomaterials Market by Material Type, by End Use Industry: Global Opportunity Analysis and Industry Forecast, 2021-2031, Allied Market Research (2022). https://www.researchandmarkets.com/reports/5670998
- A Research Strategy for Environmental, Health, and Safety Aspects of Engineered Nanomaterials; Committee to Develop a Research Strategy for Environmental, Health, and Safety Aspects of Engineered Nanomaterials; National Research Council ISBN 978-0-309-25328-4, PAPERBACK (2012); PDF is available from The National Academies Press at http://www.nap.edu/catalog.php?record_id=13347
- Building a Safety Program to Protect the Nanotechnology Workforce: A Guide for Small to Medium-Sized Enterprises. http://www.cdc.gov/niosh/docs/2016-102/
- Current Strategies for Engineering Controls in Nanomaterial Production and Downstream Handling Processes. http://www.cdc.gov/niosh/docs/2014-102/
- National Nanotechnology Initiative. http://www.nano.gov; http://www.nano.gov/you/environmental-health-safety
- Research on Nanomaterials. https://www.epa.gov/chemical-research/research-nanomaterials

Adopted, June 2023