Safe-by-Design within Supply Chain

Safe-by-Design (SbD) for nanomaterials (NMs) involves various groups along the supply chain: producers, users and final consumers. Addressing safety across the full life-cycle requires identifying groups with intervention opportunities, and understanding the sustainability, safety and ecological risk relevant to each group. Safety assessment within a material supply chain is considered complicated, regardless of whether or not it includes nanomaterials. This is noted by the European Commission, who have highlighted that sustainability and safety considerations are required within this process.

Actors in the nanomaterial (NM) supply chain

A simplified example of the actors across the lifecycle of a NM substance. Each actor will have different aims for their nano-enabled products (NEP) and reasons to use nanotechnology.

NM Manufacturer	NEP Manufacturer	NEP User	Recycling and recovery
Focus on supply of functional NMs, often of limited number of substances	Focus on supply of functional materials or articles. Flexibility in ingredients used.	Focus on effective and cheap product performance. Composition does not matter.	Known composition of waste preferred.

Safe-by-Design addresses the three pillars of product development

Safe chemical/material /product	Safe process	Safe use and end of life
Pillar 1 Minimise hazard properties whilst maintaining function	**Pillar 2** Ensure occupational, environmental and process safety	**Pillar 3** Minimise exposure and adverse effects during use and support waste hierarchy and circular economy

SbD and the Safe Innovation Approach (SIA) have recently been expanded to include sustainability by organisations such as the OECD. The OECD describes three pillars that must be considered across the whole lifecycle of a product (left).

Key goals for SbD from different stages within the supply chain

Supplier of individual nanoforms

Key SbD goals

- Optimise NM safety within performance criteria; providing a safe range of NMs might fit the companies portfolio best.
- Minimise risk to workers and environment from substance and process on own sites

Ability to impact 3 pillars of SbD

- Control over hazard in Pillar 1 for whole supply chain, but little control over risk beyond their own sites.
- Complete control over Pillar 2
- Good characterization can give Pillar 3 tools to optimize recycling (e.g. analytical techniques for detection.

NEP Manufacturer

Key SbD goals

- Optimise product safety, whilst keeping performance.
- Minimise risk to workers and environment from substance and process.

Ability to impact 3 pillars of SbD

- Little ability to influence hazard of their product in Pillar 1 but can decide which substances to use or provide hazard specifications to suppliers.
- Good control over exposure and risk (e.g. product that minimises leaching of substances)
- Extensive control over Pillar 2
- Significant control over Pillar 3 by choosing easily separable product components.

NEP User

Key SbD goals

- Choose a product that minimises risk to workers or themselves whilst performing according to specification.

Ability to impact 3 pillars of SbD

- As design is generally completed by the time it reaches this user, their key influence will be through how they make purchasing decisions.
- Pillar 2 largely defined by product design.
- Their prioritisation of product safety compared to price gives innovators more reasons to apply SbD.
- Pillar 3 can be reinforced by using the product as instructed and by maximising recycling of waste.

Recycling and recovery from NEPs

Key SbD goals

- Very similar to those of a manufacturer.
- Ability to impact 3 pillars of SbD
- Have less influence on the hazard of Pillar 1 compared to pristine NM manufacturers unless they can specify the composition of their raw materials through good analysis.
- Full control over Pillar 2 for their own process.
- Great control over Pillar 3 by providing a market for waste and hence a financial driver to make the safety of waste something to be considered during design.

The SbD4Nano e-infrastructure tool is primarily aimed toward NM manufacturers and will allow them to identify and consider impacts of greater importance to their downstream users.

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