Moving towards a safe-by-design approach for ENM: linking relevant properties to safety

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topic points

- ***safe-by-design*** in the context of ENM
- the main pillars of SbD: LCA and risk assessment
- how ***design*** may influence quality and safety of nano-enabled products

Introductory

We are now facing a dilemma and a change in safety paradigm:

- based on what we have (existing (eco) toxic data) – WoE - we have to do the best we can to protect human health and environment

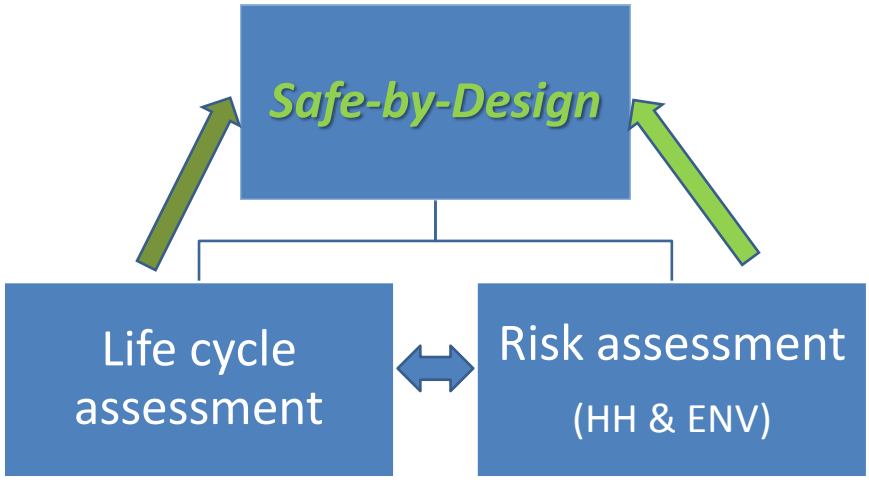
with

- keeping pace with innovation

Safe-by-Design in the context of ENM

a. *Functionality and safety considered in an integrated way*
b. *Early identification of uncertainties and potential risks along the ENM life-cycle (production, use and end-of-life process)*
c. *Shared governance in the context of risk and safety (technology developers, risk assessors, stakeholders (STO))*

main pillars of SbD



Safe-by-design *(LCA + Risk assessment)*

Environmental, worker and consumer protection across the value chain

SbD on-going projects: NanoREG I and II, ProSafe

ProSafe

- specifically dedicated to develop tools in collaboration with SME and IND partners to implement ***safe-by-design*** at an early stage in the product development

- *Understanding the features that make some nanotechnology products hazardous and others much safer will allow the design of the nanotechnology products of the future* (Hubbs et al, 2013)

- Functionality with less hazardous materials

- *what is on the market?*

France

- Mandatory register of NM (June, 2013) showed **282.014 tons** produced and **222.090 tons** imported, total **482.582 tons** placed on the market

Carbon black	**275.000 tons**
Silicon dioxide	**155.000 tons**
Calcium carbonate	**34.500 tons**
Titanium dioxide	**14.321 tons**
Aluminium dioxide	**2.193 tons**
Vinyl chloride	**1.568 tons**
Total placed on the market	482.582 tons

La Palice..

- ***Only nanomaterials and their products with known and acceptable risks should enter the market***

HOWEVER:

- *Risks are not "black or white"*
- *Risks are assessed in an iterative process, building upon:*
  - *Hazard*
    vs
  - *Exposure*
- *Risks (type and magnitude) vary across the material/product life cycle*

- *we know*

a. NM interactions with biological systems are relevant to human exposure and physiological response
b. design and surface modifiers may change potential hazardous properties of NPs
c. important to identify the relevant exposure scenarios across the lyfecycle of the NPs/NM and products

- *exposure*

a. occupational – direct inhalation exposure to dry particles, manipulation of composites (M&L operations)
b. consumers – dermal exposure to food contact materials, treated articles (e.g. textiles)
c. environment – water/waste/recycling processes

• *toxicity*

- *early toxic events* - often directly related to chemical characteristics: structure and/or ph-ch properties that promote interaction of the substance with biological targets
- *later toxic events* are less chemical-specific and more a consequence of progression of earlier key events (e.g. regenerative proliferation resulting from cytotoxicity, inflammatory processes)

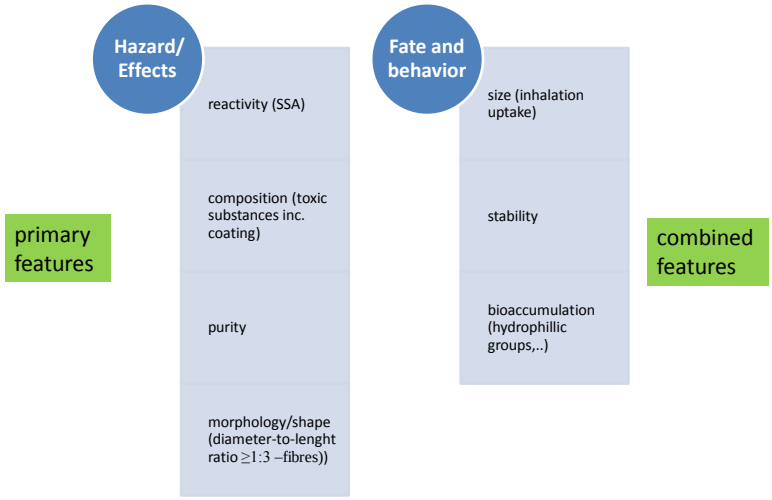
- *NP/ENM Advanced Outcome Pathways (AOP)??*

• *fate and behavior*

biological behavior of NPs is often fundamentally different than the biological behavior of larger particulates:

- translocation between tissues is generally increased,
- many NPs tend to circulate within the lymphatics, a feature which also distinguish NPs from traditional pharmaceuticals,
- NPs tend to use intracellular and extracellular transport (yet this last one less understood)

- *ph-ch properties ➞ drivers for toxicity (exposure route)*



- *how **design** may influence quality and safety of nano-enabled products*

a. quality and safety of nanoproducts depend on the stable embedding of NP and NM
b. the stability, thus the durability of the functionality, mainly depends on the affinity between the surface of the NP and the matrix.
c. to improve the embedding of NP dispersed in the matrix, their surfaces should be functionalized with groups that match with the matrix
d. for this, surfactants can be used which have high affinity with both NP and matrix, influencing stability

factors that can affect the stability of NP integration in a product

Factors for stability	tends to higher when:	tends to be lower when:
1. Compatibility between NP and their matrix material (fibre polymer and coating)	NP exhibit high wettability	NP exhibit low wettability
2. Location of NP in the product	NP are fully embedded in the matrix	NP are partly or completely on the material surface
3. Bond between NP and the matrix	Bonds are covalent	Bonds are non-covalent
4. Intrinsic properties of the NP • Photocatalytic activity • Stability of NP against ageing	NP are not photocatalytic NP exhibit high stability	NP are photocatalytic (in organic substances) NP exhibit low stability
5. Resistance of matrix material to abrasion or chemical attack	Matrix is resistant	Matrix is not resistant
6. Functional barrier	Funcional barrier is present (coating, plastic layer)	Functional barrier is absent
7. Close systems e.g. fuel cells, batteries, solar cells	System fully contained	System is not contained

Source: LICARA Nanoscan Tool

- *lifecycle thinking: exposure and release*

a. in what forms can NP be released during lifecycle?

- pristine ENP, originally embedded in the product
- aged NP, after chemical transformation, coating degradation
- new nanoscale particles of host matrix formed by mechanical forces (e.g. grinding, milling)
- new nanoscale particles: aggregates/composite particles of host matrix or embedded NP
- dissolved forms, hence no longer NP

- *lifecycle thinking*

b. good knowledge of up and downstream production processes may help to further reduce waste and NP emissions
c. knowing about product's use phase may help to design it adapting to its wearing processes and to sensitive environments e.g. if intended to be used in natural water bodies, no ecotoxic NP should be released

- *sustainability*

- to improve product stewardship
- better compliance with regulations
- gain of competitive advantages

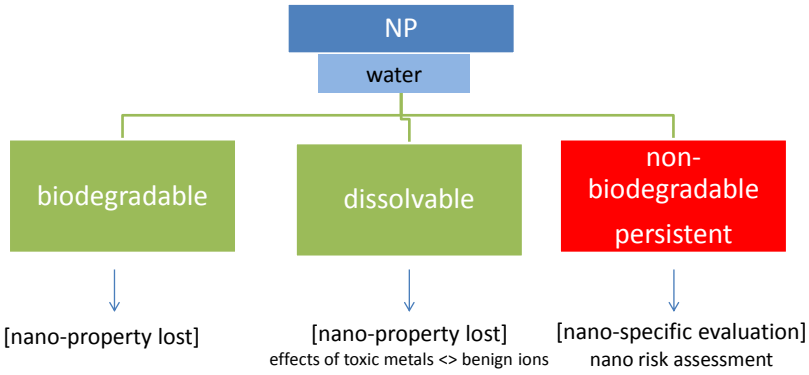
- *HH risk: potential for release of ENM from nano-related activities*

nano-related activity	potential human exposure	risk management measures to reduce exposure
Spraying nano-enable coatings	High	Ventilated spray cabin, face mask
Handling large amounts of powdered NM	High	Enclosed systems, ventilation, face mask
Batch mixing of powdered NM with liquid	Medium	Enclosed systems, reducing mixing speed, ventilation, face mask
Brushing of nano-enabled coatings	Low	n.a.
Careful use of solid nano-enabled products	Low	n.a.

source: LICARA Nanoscan tool

- *ENV risk assessment*

- **effects of NP on organisms are determined by the composition of the particles themselves and the compartment used for transport**



- *NM behavior in technical systems*

Waste water treatment plants	Vast majority (around 95%) of NM are removed from water and end up in sludge. Applying sewage sludge to soils represents one of the major flows of NM into the environment
Waste incineration plants	European waste incineration plants are equipped with flue gas cleaning system that remove the vast majority (>99.9%) of the nanoparticulate fraction. NM therefore end up in filter ash or bottom ash and subsequentely go to the landfill
Landfills	The behavior of NM in landfills is so far unknow
Recycling	No data are yet available about the fate of NM during recycling but is expected that release may occur to some extend during recycling operations as product matrices may be destroyed

source: LICARA Nanoscan tool

- *conclusions*

- Still a lack of knowledge on the complete set of ph-ch properties and how they relate to observed biological responses
- More experimental data is needed to establish a framework to allow targeted hazard grouping of ENMs
- This will allow to proactively predict and mitigate the risks by optimizing their ph-ch profile in the design and development phase > Safe-by-Design

- *conclusions*

- This calls for quantitative tools based on WoE approach where criteria are elicited (inc. socio-economic) by different STO to support decision-making
- Multicriteria decision assessments (MCDA) with data mining/integration techniques should be looked for to implement SbD

THANK YOU!