plasticheal

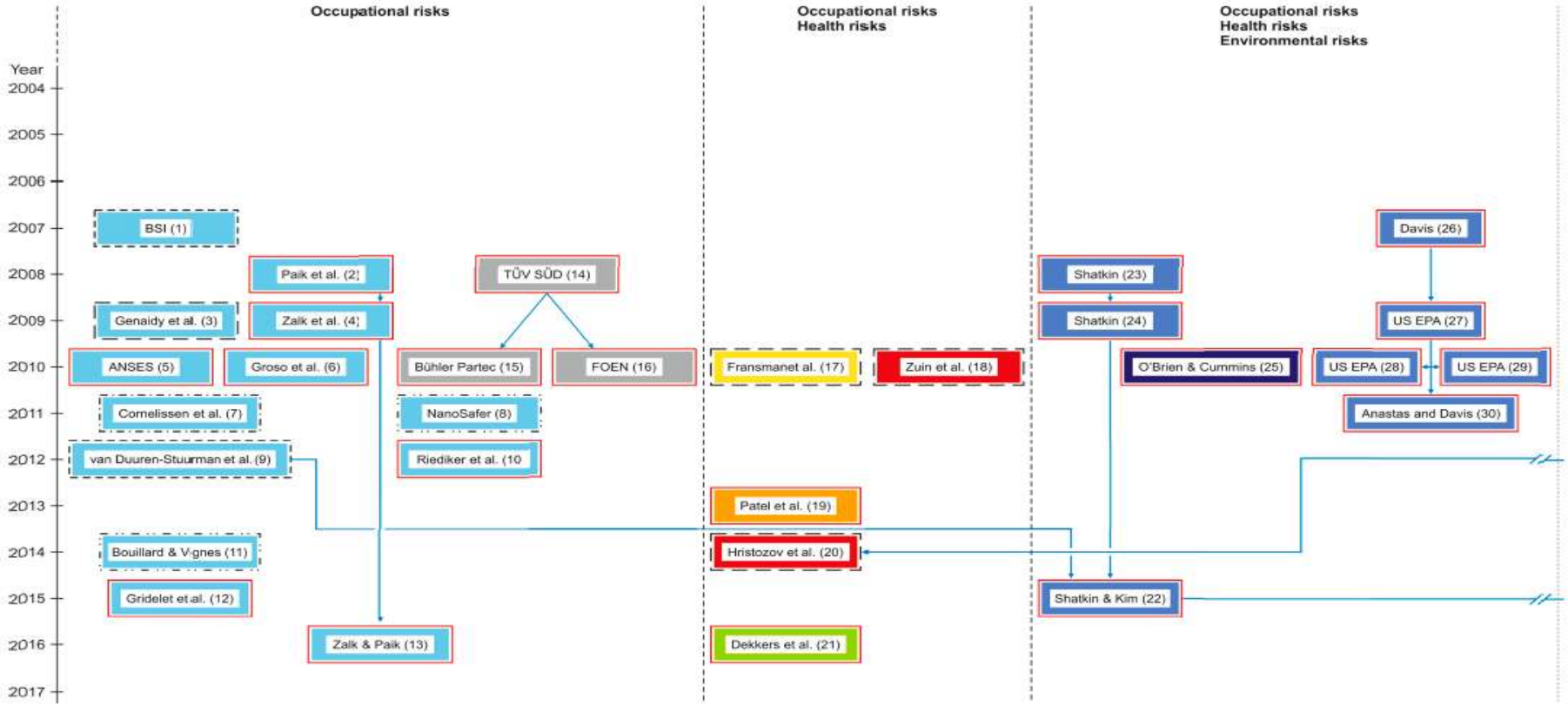
Risk assessment of nanomaterials - overview on existing frameworks

DTU
Steffen Foss Hansen

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 965196

Purpose

- Explore whether some of the many nanorisk assessment frameworks can be used for human health risk assessment of MNPs?


Occupational risks
Occupational risks
Health risks
Occupational risks
Health risks
Environmental risks
Year
2004
2005
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BSI (1)
Paik et al. (2)
Genaidy et al. (3)
Zalk et al. (4)
ANSES (5)
Groso et al. (6)
Cornelissen et al. (7)
van Duuren-Stuurman et al. (9)
Bouillard & Vignes (11)
Gridelet et al. (12)
Zalk & Paik (13)
TÜV SÜD (14)
Bühler Partec (15)
FOEN (16)
NanoSafer (8)
Riediker et al. (10
Fransmanet al. (17)
Zuin et al. (18)
Patel et al. (19)
Hristozov et al. (20)
Dekkers et al. (21)
Shatkin (23)
Shatkin (24)
O'Brien & Cummins (25)
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Davis (26)
US EPA (27)
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Anastas and Davis (30)

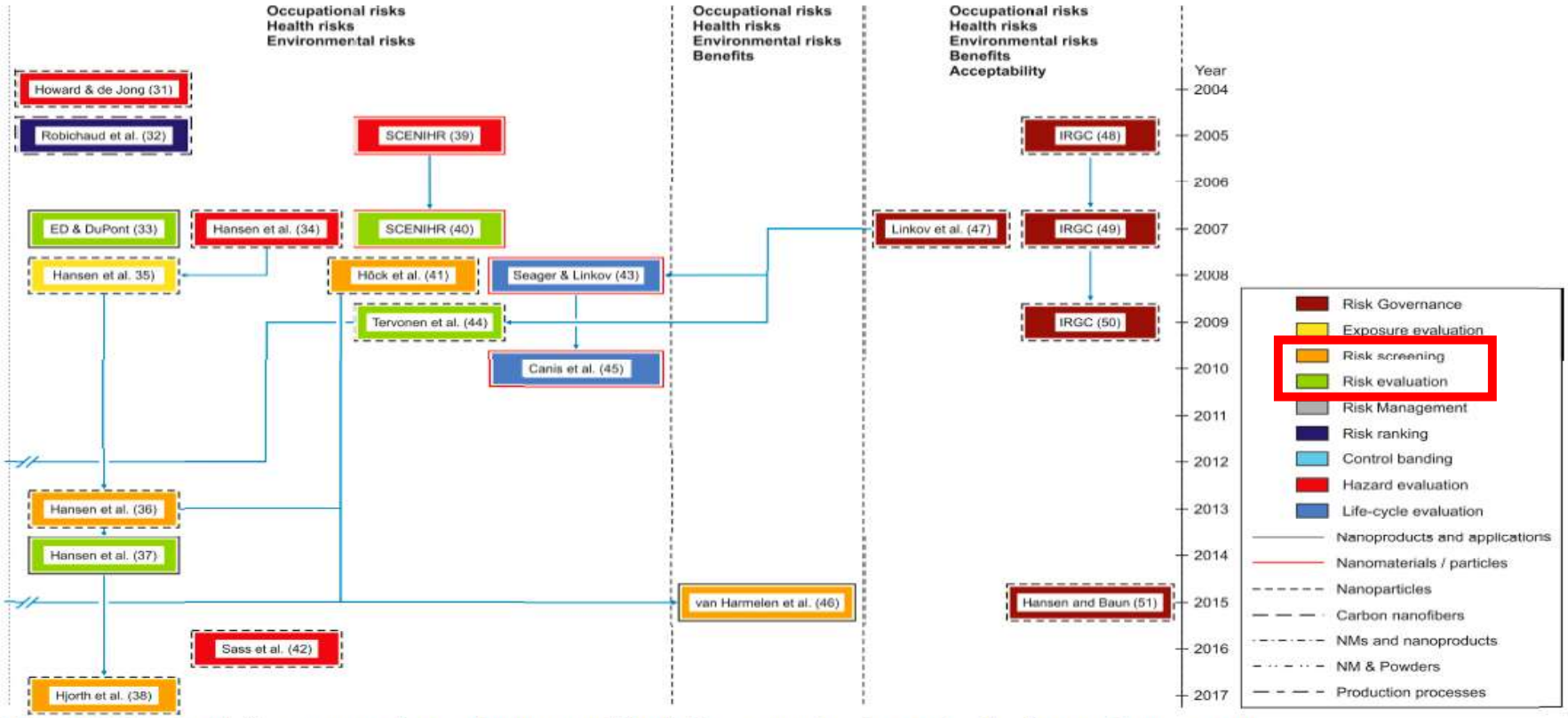


Figure 21: Alternative decision-support tools or supplements to traditional risk assessment have been explored and proposed in recent years.

1) BSI 2007, 2) Paik et al. 2008, 3) Genaidy et al. 2009, 4) Zalk et al. 2009, 5) Ostiguy et al. 2010, 6) Groso et al. 2010, 7) Cornelissen et al. 2011, 8) Kristensen et al. 2010, Jensen et al. in prep. 9) van Duuren-Stuurman et al. 2012, 10) Riediker et al. 2012, 11) Bouillard and Vignes 2014, 12) Gridelet et al. 2015, 13) Zalk and Paik 2016, 14) TüV SüD 2008, 15) Bühler Partec (2010), 16) FOEN (2010), 17)Fransman et al. 2010, 18) Zuin et al. 2010, 19) Patel et al. 2013, 20) Hristozov et al. 2014, 21) Dekkers et al. 2016, 22) Shatkin and Kim 2015, 23) Shatkin 2008, 24) Shatkin 2009, 25) O'Brien and Cummins 2010 26) Davis 2007, 27) US EPA 2009, 28) US EPA 2010a, 29) US EPA 2010b, 30) Anastas and Davis 2011, 31) Howard and de Jong 2004, 32) Robichaud et al. 2005, 33) ED and Dupont 2007, 34) Hansen et al. 2007, 35) Hansen et al. 2008a, 36) Hansen et al. 2013a, 37) Hansen et al. 2014, 2017c, 38) Hjorth et al. 2017b, 39) SCENIHR 2005, 40) SCENIHR 2007, 41) Höck et al. 2008, 42) Sass et al. 2016, 43) Seager and Linkov 2008, 44) Tervonen et al. 2009, 45) Canis et al. 2010, 46) van Harmelen et al. 2015, 47) Linkov et al. 2007, 48) IRGC 2005, 49) IRGC 2007, 50) IRGC 2009, 51) Hansen and Baun 2015.

Swiss Precautionary Matrix, ED & DuPont and MCM risk-...

Name	Swiss Precautionary Matrix	Nanorisk framework	MCM risk-based classification system
Reference	Höck *et al.* (2008, 2011, 2013)	ED & Dupont (2007)	Tervonen *et al.* (2009)
Focus/	Workers, consumers, environment	Workers, consumers, environment	Human and environment
Scope	Nanoparticles	Applications	Nanoparticles
Method	Qual. /quan.	Qual. /quan.	Qual. /quan.
Strategy	Hazard evaluation + Exposure assessment + Assessment of risk handling need	Describe, evaluate, decide, update; life-cycle, hazard-, exposure-, risk profiles	Selection of criteria, identifying options, ranking and selecting optimal option(s)
Exposure assessment input parameters	1) Type of exposure (air, liquid or in a matrix); 2) Amount of nanomaterial a worker is normally exposed to during a day; 3) How much nanomaterial can a worker be exposed to in a worst case?	Among others: 1) Number and locations of manufacturing sites; 2) Current and expected production; 3) Industrial function; 4) Maximum concentration used; 5) required controls, etc.	Not applicable
Scale assessment of exposure level	Airborne exposure scaled by the 2 last parameters; normal/ accidental conditions	Not specified	Not applicable
Hazard evaluation input parameter	Redox activity and/or catalytic activity; Stability in physiological and environmental conditions	Short-term tox; skin sensitization + pene-tration; genetic toxi-city tests; biological fate + behavior; chro-nic inhalation/Inge-stion /dermal tox stu-dies; developmental, reproductive, neuro, genotox and EDS- studies	Agglomeration and aggregation; Reacti-vity; critical func-tional groups; particle size, and contaminant dissociation, size; bioavailable and bioaccumulation po-tential and toxic potential
Scale evaluation of hazard evaluation	Input parameters are scored btw 1-9	Not specified	Mean size of particles in units of nanome-ters. Other criteria scored from 1 to 5 via expert judgment
Risk evaluation	Total score of the precautionary need V = N * (W * E + S) and classified as "A" (V= 0-20) and "B" (V> 20)	Evaluation of nature, magnitude and probability of risk types	Classification into extreme, high, medium, low, and very low risk categories
Risk handling	Unspecified	Focusing on minimizing exposure	Unspecified
Special circumstanc es	Nanoscale ≤ 500 nm; Unknown parameters assigned max high-risk score; Actual/ estimated daily/ worst case	Sharing of product info, hazard, exposure and risk profiles with stakeholders is recommended	Uses an outranking model termed Stochastic multicriteria acceptability analysis (SMAA-TRI)
	considers workers, consumers, environment taking a life-cycle perspective	communicate information	:vel of rency in selection of criteria which enables the users to define their own criteria
Weaknesses	Dubious use of default values for redox activity or catalytic activity; Unclear why unknown parameters are assigned 100% of the high-risk score; Questionable quantitative derivation of whether there is a precautionary need for action; Overall classification scores seems arbitrary	High data requirements often not available; unclear how to evaluate nature, magnitude and probability of risk types, as independent validation by stakeholders is hard to obtain	Low level of transparency in the qualitative assignment of scores between 1 and 5 to various nanomaterials. Unclear how specific weight bonds were assigned

Is this information available for MNP?

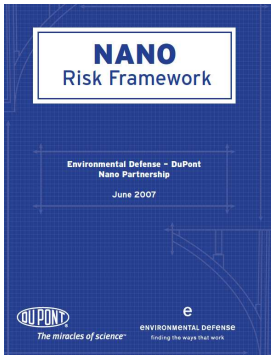
Information available wrt plastics?

- **Redox activity and/or catalytic activity**
  - Available for plastics?
  - Yes (e.g. Phenol–formaldehyde resin and PS (Chen et al., forthcoming, https://doi.org/10.1016/j.fmre.2022.03.015))

- **Stability in physiological and environmental conditions**
  - Available for plastics?
  - Yes (e.g. PE, PET, PLA (Chamas et al. 2020, https://dx.doi.org/10.1021/acssuschemeng.9b06635)

https://www.bag.admin.ch/bag/en/home/gesund-leben/umwelt-und-gesundheit/chemikalien/nanotechnologie/sicherer-umgang-mit-nanomaterialien/vorsorgeraster-nanomaterialien-webanwendung.html

ED & DuPont NanoRisk Framework



Hazard input information	Available for plastic?
Short-term tox	Yes - MP acute respiratory toxicity (Zhang et al., 2021), Cytotoxicity (Liang et al., 2021), Gastrointestinal toxicity (Jin et al., 2019; Qiao et al., 2019), NP Neurotoxicity Gambardella et al., 2018. NP Hepatotoxicity (Lusher et al., 2017)
Skin sensitization + penetration	
Genetic toxicity tests	Yes - MP Chronic immunotoxicity (Jin et al., 2019; H. Sun et al., 2021; M. Sun et al., 2021; T. Sun et al., 2021), NP Genotoxicity – Lusher et al., 2017
Biological fate + behavior	See figure of and next slide
Chronic inhalation/ingestion/dermal tox studies	Yes - MP Carcinogenicity – Martin et al., 2017, NP Nephrotoxicity (Gherkhbolagh et al., 2018) NP Cardiovascular toxicity (H. Sun et al., 2021; M. Sun et al., 2021; T. Sun et al., 2021), NP Hepatotoxicity (Lusher et al., 2017)
Developmental, reproductive, neuro and EDS- studies	Yes - MP Reproductive toxicity (Sobhani et al., 2021), Embryotoxicity (Uhrin and Schellinger, 2011), NP Reproductive toxicity (An et al., 2021)

https://nanotech.law.asu.edu/Documents/2011/06/6496_Nano%20Risk%20Framework_534_2973.pdf

Biological fate & behavior

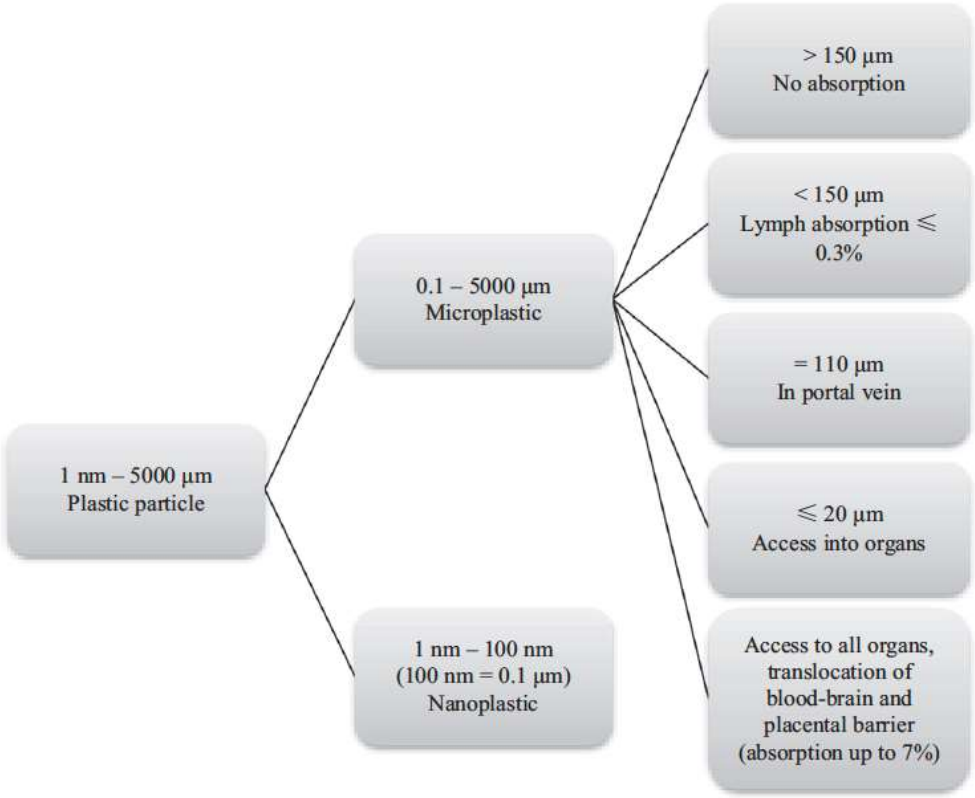
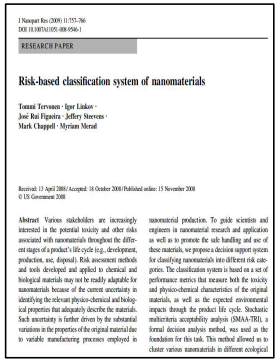


Fig. 3. Relationship between the fate of microplastics and nanoplastics in mammals and particle size.

Risk-based classfication system of nanomaterials



J Nanopart Res (2009) 11:757–766
DOI 10.1007/s11051-008-9546-1

RESEARCH PAPER

Risk-based classification system of nanomaterials

Tomi Tervonen · Igor Linkov · José Rui Figueira · Jeffery Steevens · Mark Chappell · Myriam Merad

Received: 13 April 2008 / Accepted: 18 October 2008 / Published online: 15 November 2008
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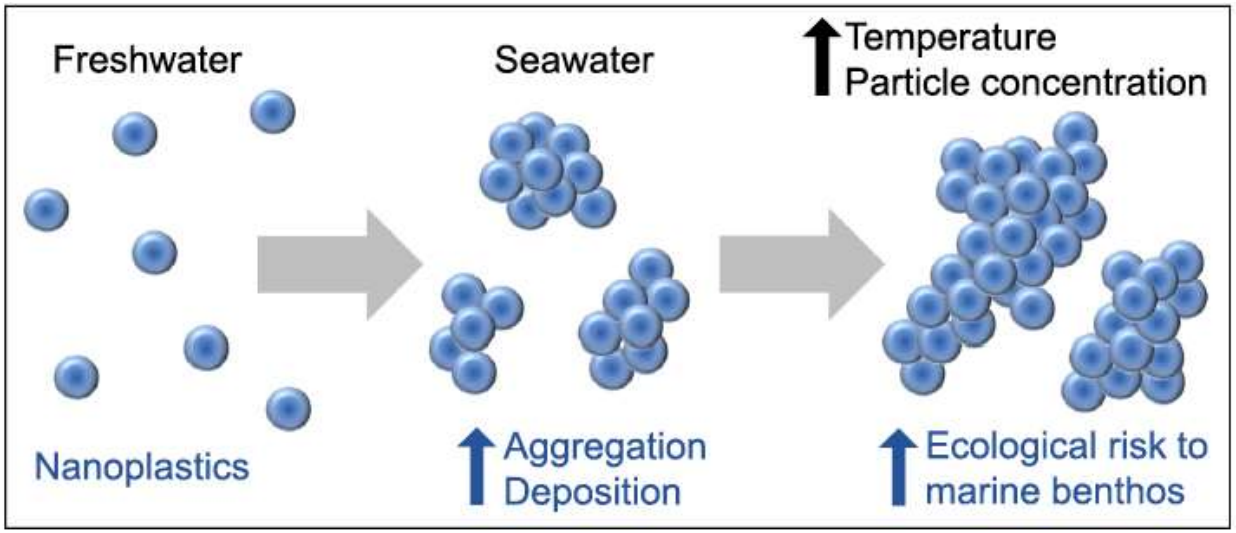
Abstract Various stakeholders are increasingly interested in the potential toxicity and other risks associated with nanomaterials throughout the different stages of a product's life cycle (e.g., development, production, use, disposal). Risk assessment methods and tools developed and applied to chemical and biological materials may not be readily adaptable for nanomaterials because of the current uncertainty in identifying the relevant physico-chemical and biological properties that adequately describe the materials. Such uncertainty is further driven by the substantial variations in the properties of the original material due to variable manufacturing processes employed in nanomaterial production. To guide scientists and engineers in nanomaterial research and application as well as to promote the safe handling and use of these materials, we propose a decision support system for classifying nanomaterials into different risk categories. The classification system is based on a set of performance metrics that measure both the toxicity and physico-chemical characteristics of the original materials, as well as the expected environmental impacts through the product life cycle. Stochastic multicriteria acceptability analysis (SMAA-TRI), a formal decision analysis method, was used as the foundation for this task. This method allowed us to cluster various nanomaterials in different ecological

Hazard input information	Available for plastic?
Agglomeration and aggregation	**Yes**, depended on salinity, temperature, protein, electrolytes, pH and humic acid e.g. NP PS, Polyspherex™ 50-nm carboxylated poly(methyl methacrylate) (PMMA-COOH) nanospheres, Polyspherex 50-nm plain PMMA nanospheres, Visiblex™ 50-nm red-dyed polystyrene nanospheres, and Visiblex 50-nm blue-dyed poly-styrene nanospheres (Shupe et al. 2021, Lee and Fang 2021, Li et al. 2021, Dong et al. 2021) (see net slide)
Reactivity	**Yes** – NP PS (Bianco et al. 2020)
Critical functional groups	**Yes** - ($-NH_2$) or carboxyl (−COOH)-modified polystyrene (PS) NPs (Zhang et al. 2022, Kim et al. 2017)
Particle size	**Yes**
Contaminant dissociation	**Yes** – PE, PP, PS, PES and PVC + contaminants such as PBDs, PFAS, PCBs, PAHs, phthalates surfactants, personal care products) pharmaceuticals (tetracycline, ciprofloxacin, sertraline, propranolol, and sulfamethoxazole) (Agboola and Benson 2021)
Bioavailable and bioaccumulation potential	Bioavailable **yes** – bioaccumulation **no** (Miller et al. 2020)
Toxic potential	**Yes**, depending of type of plastics (Lithner et al. 2011)

Tervonen et al. 2009. J Nanopart Res (2009) 11:757–766, DOI 10.1007/s11051-008-9546-1

Aggregation and agglomeration



Lee and Fang
http://dx.doi.org/10.1016/j.scitotenv.2021.152562

End results of using a Risk-based classfication system of nanomaterials

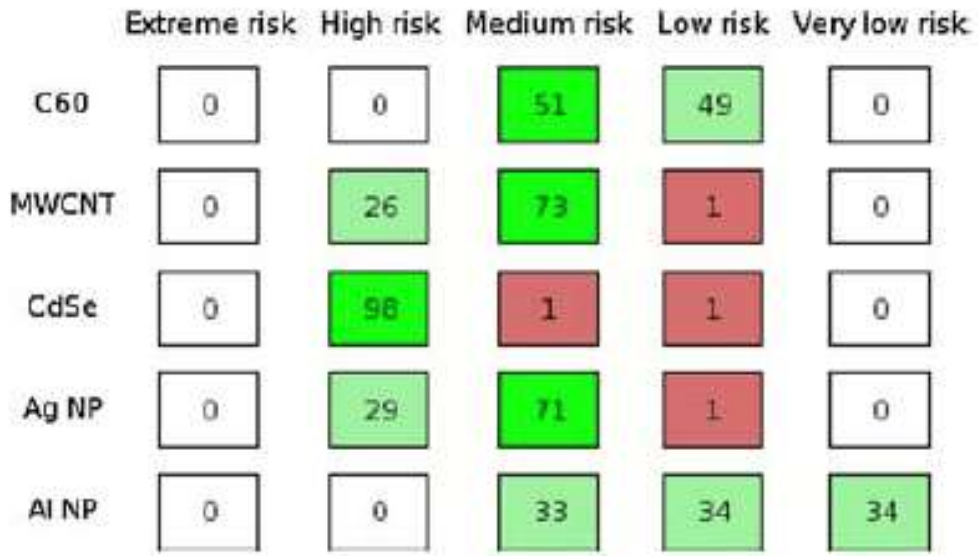
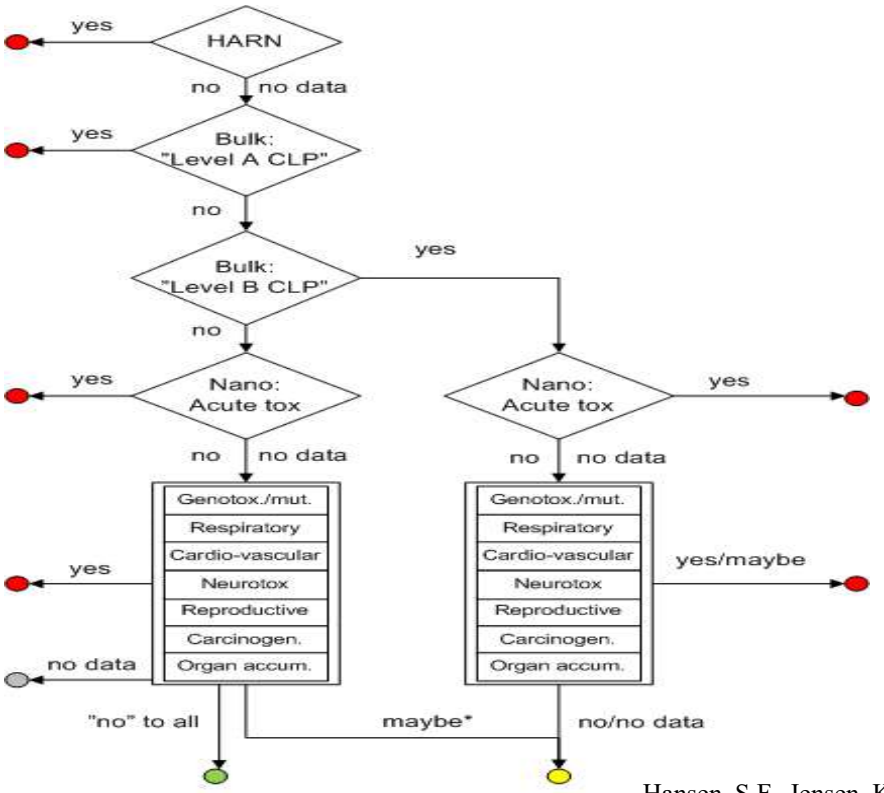


Fig. 2 Category acceptability indices of the example. A high index means that the material is assigned to the corresponding category with a high confidence, as measured by a larger percentage share of possible parameter values corresponding to this category

J Nanopart Res (2009) 11:757–766

NanoRiskCat – Evaluation of Human effects



- NM HARN?
- Bulk CLP?
- NM Acute tox?
- NM associated with:
  - CMR?
  - Respiratory tox?
  - CVD?
  - Neurotox?
  - Organ accumulation?

Hansen, S.F., Jensen, K.A., Baun, A. 2014. NanoRiskCat: A conceptual tool for categorization and communication of exposure potentials and hazards of nanomaterials in consumer products. Journal of Nanoparticle Research 16(1): 2195 DOI 10.1007/s11051-013-2195-z

Final Risk Evaluation – does this make sense for MNPs?

Does this make sense for MNPs?

Name	Swiss Precautionary Matrix	Nanorisk framework	MCM risk-based classification system
Risk evaluation	Total score of the precautionary need V = N * (W * E + S) and classified as "A" (V= 0-20) and "B" (V> 20)	Evaluation of nature, magnitude and probability of risk types	Classification into extreme, high, medium, low, and very low risk categories
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Name	Swiss Precautionary Matrix	Nanorisk framework	MCM risk-based classification system
Reference	2013)	(2009)	
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		n of nature, e and probability of	Classification into extreme, high, medium, low, and very low risk categories
		on minimizing	Unspecified
		f product info posure and risk ith stakeholders is nded	Uses an outranking model termed Stochastic multicriteria acceptability analysis (SMAA-TRI)
	considers workers, consumers, environment taking a life-cycle perspective	de on how to document, and communicate information	High level of transparency in selection of criteria which enables the users to define their own criteria
Weaknesses	Dubious use of default values for redox activity or catalytic activity; Unclear why unknown parameters are assigned 100% of the high-risk score; Questionable quantitative derivation of whether there is a precautionary need for action; Overall classification scores seems arbitrary	High data requirements often not available; unclear how to evaluate nature, magnitude and probability of risk types, as independent validation by stakeholders is hard to obtain	Low level of transparency in the qualitative assignment of scores between 1 and 5 to various nanomaterials. Unclear how specific weight bonds were assigned

Total score of the Swiss Precautionary Matrix

- Total score of the precautionary need:

  V = N * (W * E +S)

  N: Nano-relevance

  W: Potential effect

  E: Potential human exposure

  I: Available informatin on the life cycle

  - If V = 0-20 then classified as A
  - If V > 20 then classified as B

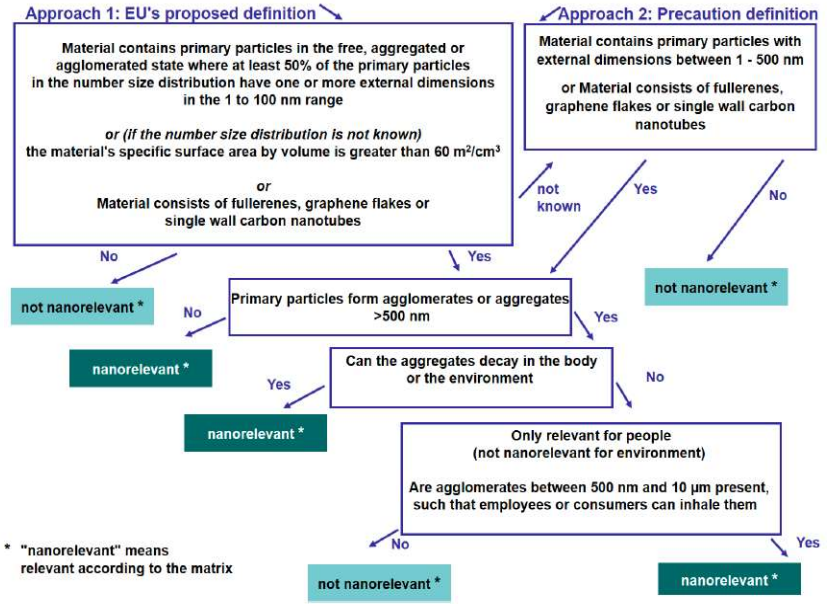

Figure 4: Process for establishing nano-relevance

Conclusion

- Several tools and frameworks that could be used to assess risks of MNPs
- Information is available for many of the input parameters needed to use these
- Information is not always available for all MNPs and their additives
- Not clear whether the final end results of the tools and framework captures the essence of MNPs risks

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Thank you
for your attention!

Sfha@env.dtu.dk

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 965196

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