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Grouping of nanomaterials released into benthic systems: Development of an Integrated Approach to Testing and Assessment within the EU project GRACIOUS

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Introduction

Benthic systems (the lowest ecological zones in water bodies) are integral to the functioning of aquatic systems due to their rich biodiversity and roles in nutrient cycling and sediment aeration.

These systems are predicted to be the ultimate sink for an ever increasing array of nanomaterials (NMs)/ nanoforms (NFs) that are released into the environment throughout their lifecycle. Performing a risk assessment for NFs in benthic systems is crucial; however consideration of each on an individual basis is unrealistic.

GRACIOUS is developing a Framework to logically group NFs. The framework will allow use of (existing) data from similar NMs/NFs to extrapolate between (read-across) NFs, materials and substances, thereby reducing the need to assess exposure and toxicity on a case-by- case basis.

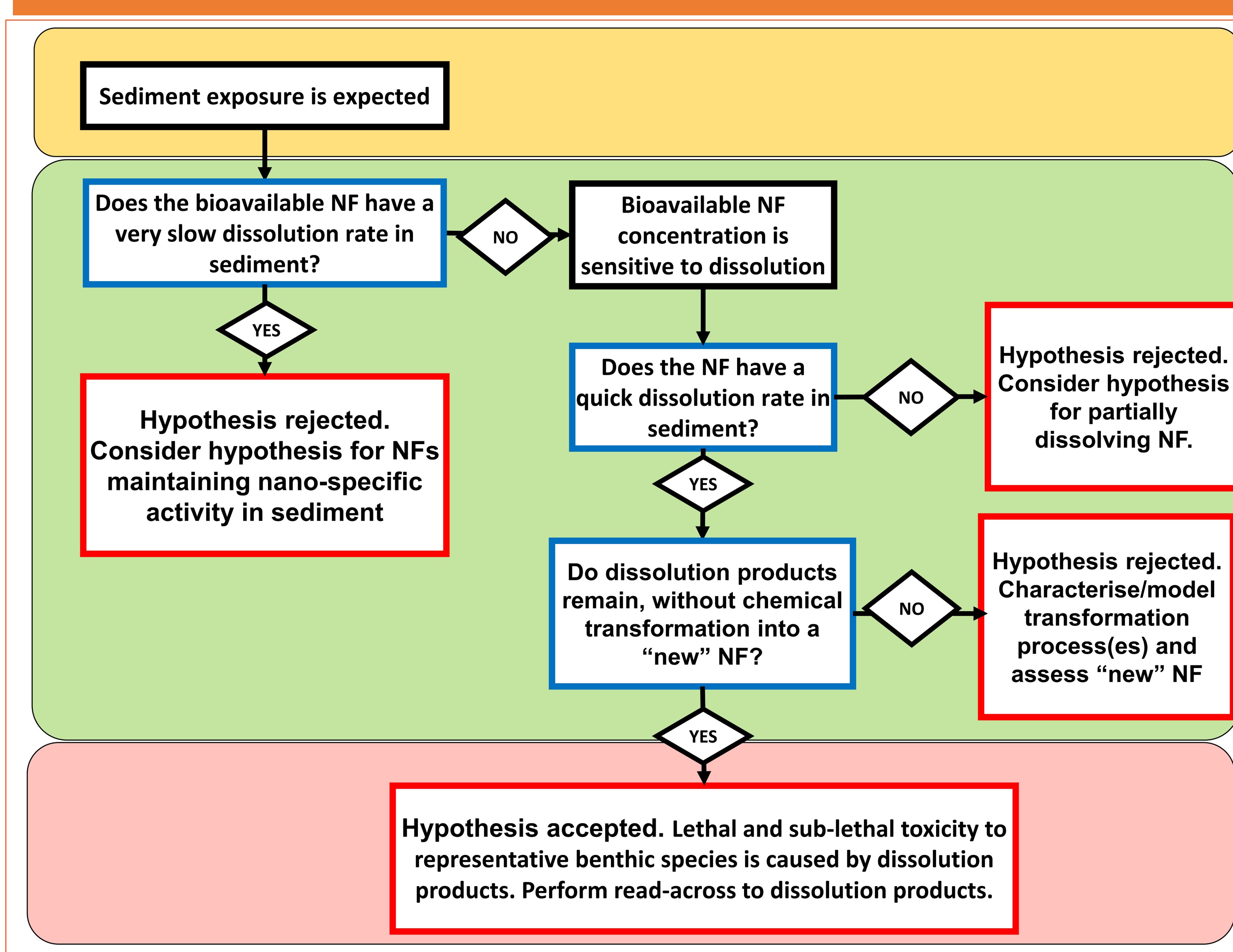
Grouping hypotheses within the GRACIOUS Framework are underpinned by scientific evidence and identify key NF descriptors related to 'what they are', 'where they go' and 'what they do'.

The broad sediment hypothesis (right) is used to identify and explain how shared NF attributes can be used to facilitate risk assessment and decision making. A number of sediment sub-hypotheses exist, each with their own implication upon acceptance.

NF in an unstable dispersion in environmentally relevant aquatic media: NFs in this group will settle to benthic systems where lethal and sub-lethal toxicity to representative benthic species is driven by their dissolution rate

Purpose: Targeted testing, regulatory **Context:** Aquatic environments	
Input from life cycle Release to aquatic environment	**What they are?** NFs with a slow/partial dissolution rate that have a high affinity for natural colloids in aquatic compartments. **Where they go?** Removed from the aquatic compartment and deposited to sediment compartments (via sedimentation). **What they do?** Persist in sediment compartments resulting in lethal and sub-lethal toxicity to representative sediment species.

IATA Overview



- Generation of data required to assess the similarity between NFs as postulated by the sediment hypotheses is guided via an Integrated Approach to Testing and Assessment (IATA).
- Where aquatic exposure is anticipated, IATA are triggered to identify the environmental compartment of concern, based on sensitivity analysis of the NF exposure model, SimpleBox4Nano (SB4N).
- NFs that do not quickly dissolve and meet a critical heteroaggregation attachment value ($1.1 \cdot 10^{-4}$) in water are anticipated to result in sediment exposure (Meesters *et al.,* 2019), triggering sediment-specific IATA.
- Decision nodes in sediment IATA (e.g. left) concern the dissolution rate of bioavailable NFs in sediment based on SB4N modelling.
- Where very slow or quick dissolution is evident, toxicity to representative benthic species is dominated by dissolution products or NF, respectively.
- For partially dissolving NFs, toxicity will be determined by dissolution rate constants and dissolution products:NF toxicity ratios.

Testing and Implications

- Each decision node in the IATA is accompanied by a tiered testing strategy, recommending tests with increasing in complexity from 1-3 to account for the different purposes for grouping (e.g. sae(r) by design, regulatory decision making).
- Different implications occur for NFs following their inclusion or exclusion from a sediment group.
- E.g. where very quick dissolution is predicted, waiving of lengthy, whole sediment NF toxicity testing may be justified and instead, read-across to dissolution product hazard data may be used to streamline risk assessment
- By modifying physicochemical properties which contribute to sediment exposure and/or hazard, safe(r) by design may reduce the risk associated with NFs from an early stage in the innovation process.

About the GRACIOUS Project

GRACIOUS develops a highly innovative science-based Framework to enable practical application of grouping, leading to read-across and classification of nanomaterials and nanoforms

References

Meesters, J. A. J., Peijnenburg, W. J. G. M., Hendriks, A. J., Van de Meent, D., & Quik, J. T. K. (2019). A model sensitivity analysis to determine the most important physicochemical properties driving environmental fate and exposure of engineered nanoparticles. Environmental Science: Nano, 6(7), 2049-2060.

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