CHALMERS
UNIVERSITY OF TECHNOLOGY

Risk Assessments Show Engineered Nanomaterials To Be of Low Environmental Concern

Citation for the original published paper (version of record):
Arvidsson, R. (2018)
Risk Assessments Show Engineered Nanomaterials To Be of Low Environmental Concern
Environmental Science & Technology, 52: 2436-2437
http://dx.doi.org/10.1021/acs.est.8b00754

VIEWPOINT IN PREPARATION FOR

ENVIRONMENTAL SCIENCE & TECHNOLOGY

Risk assessments show engineered nanomaterials to be of low environmental concern

RICKARD ARVIDSSON[1,*]

[1] Environmental Systems Analysis, Chalmers University of Technology, Vera Sandbergs Allé 8, SE 412 96 Gothenburg, Sweden.

* Corresponding author. Phone: +46 (0) 31 772 2161. E mail: rickard.arvidsson@chalmers.se

Concerns about environmental risks related to engineered nanomaterials (ENMs) have spurred research into these risks that has been ongoing since the early 2000s. A valid question at this point is what the results indicate so far – do ENMs seem to be an environmental concern or not? The final answer to this question can arguably not be answered yet. There still remain a number of data gaps and challenges related to the production of ENMs, the release of ENMs from products, the measurement of ENMs in environmental media, the assessment of ENMs exposure to different organisms and the ecotoxicity testing of ENMs. However, an early indication might be obtained by considering the environmental risk assessments of ENMs conducted so far. In particular, a parameter called the risk characterization ratio (RCR, sometimes called risk quotient) might offer guidance. RCR is calculated by dividing the estimated exposure of an ENM (often quantified as a predicted environmental concentration, PEC) by a presumed safe concentration below which no adverse effects are believed to occur for that ENM (often quantified as a predicted no-effect concentration, PNEC). The RCR thus tells whether the presumed safe concentration is exceeded by the exposure concentration by taking values above 1 in such cases. Although RCRs are generally derived from quantitative risk modeling rather than measurements, they might provide some guidance while experimental methods are still under development.

Most ENM modeling studies provide estimates of release and/or concentrations in the environment. Only seven studies presenting RCRs for ENMs have been identified. From these studies, best estimates of RCRs for commonly studied ENMs were obtained for fresh/surface water, freshwater sediment, sewage treatment plant (STP) effluent and soil. Blaser et al. [1] calculated RQs for silver nanomaterials (nano-Ag) in the Rhine river, although they used ecotoxicological data for other forms of silver than nano-sized. 'Realistic scenario' RCRs calculated for nano-Ag, titanium dioxide nanomaterials (nano-TiO_2) and carbon nanotubes (CNT) in Switzerland were obtained from the study by Mueller and Nowack [2]. RCRs for the same ENMs plus zinc oxide nanomaterials (nano-ZnO) and fullerenes were obtained from Gottschalk et al. [3], representative for Switzerland, the United States (US) and the European Union (EU). RCRs for nano-TiO_2 and nano-Ag representative for Johannesburg City were obtained from Musee [4]. His scenario with no dilution of STP effluent was assumed to represent STP effluent and his scenario with the highest (ten-fold) dilution of the STP effluent was assumed to represent freshwater. RCRs for silicon dioxide nanomaterials (nano-SiO_2) were obtained from Wang et al. [5], representing Switzerland and the EU. Coll et al. [6] provided EU-wide RCRs for nano-TiO_2, nano-Ag, nano-ZnO, CNT and fullerenes. Finally, Kjølholt et al. [7] presented RCRs for several ENMs in Denmark. Those for nano-TiO_2, nano-Ag, nano-ZnO and CNT were obtained. For studies providing RCRs in the form of probability distributions, most likely (i.e. mode) values were considered to represent best estimates.

Figure 1 shows the results of this mini review for different compartments. Freshwater and STP effluent are the most considered compartments in these studies, while a few RCRs exist for freshwater sediment and soil as well. Clearly, the most common result is that RCR<1. For the freshwater compartment, only one in one case was RCR>1 obtained, namely for nano-Ag in the EU according to Gottschalk et al. [3] (RQ=1.1). However, several other studies obtained RCR<<1 for nano-Ag, including the more recent EU-wide study by Coll et al. [6] (RCR=0.038). For STP effluent, Gottschalk et al. [3] again obtained RCR>1 for nano-Ag, but also for nano-ZnO and nano-TiO_2. Their RCR=61 for nano-Ag in STP effluents in the EU is the highest RCR found in the review. However, it must be remembered that the STP effluent is not in itself a habitat for organisms, and becomes diluted when reaching environmental media.

Figure 1 shows best estimates of RCRs, which means that higher RCRs have been obtained in worst-case scenarios in the reviewed studies. It is still notable that so few realistic modeling results show RCR>1 and that nano-Ag is the only ENM for which RCR>1 was obtained in an environmental compartment given a realistic scenario. In particular, the ENMs CNT, fullerenes and nano-SiO_2 show very low RCRs, even in STP effluents (≤0.03). Kjølholt et al. [7], who included some additional ENMs to those reviewed here in their Danish study, write in concordance with this review: “With the current scientific knowledge, and current use patterns and volumes, none of the ENMs selected for this study appear to constitute a general environmental risk or to be of significant environmental concern (i.e. they do not at the same time show high toxicity to aquatic organisms and occur at significant levels in the environment).” Current evidence from risk modeling studies thus suggests that many ENMs often included in risk assessments seem to be of minor environmental concern. If these modeling results are accurate, it warrants a shift in the focus of environmental risk research unless production and use of the well-studied ENMs increase drastically. It might be time to ask whether other ENMs would be more interesting to study? The development of new ENMs is ongoing. Examples of more recently developed ENMs include the two-dimensional materials graphene and boron nitride. Another example is the functionalization of ENMs for specific applications, such as the fullerene-based material [6,6]-phenyl-C_{61}-butyric acid methyl ester (PCBM) used as electron acceptor molecule in organic solar cells. Investigations of more novel ENMs might reveal ENMs of higher environmental concern.

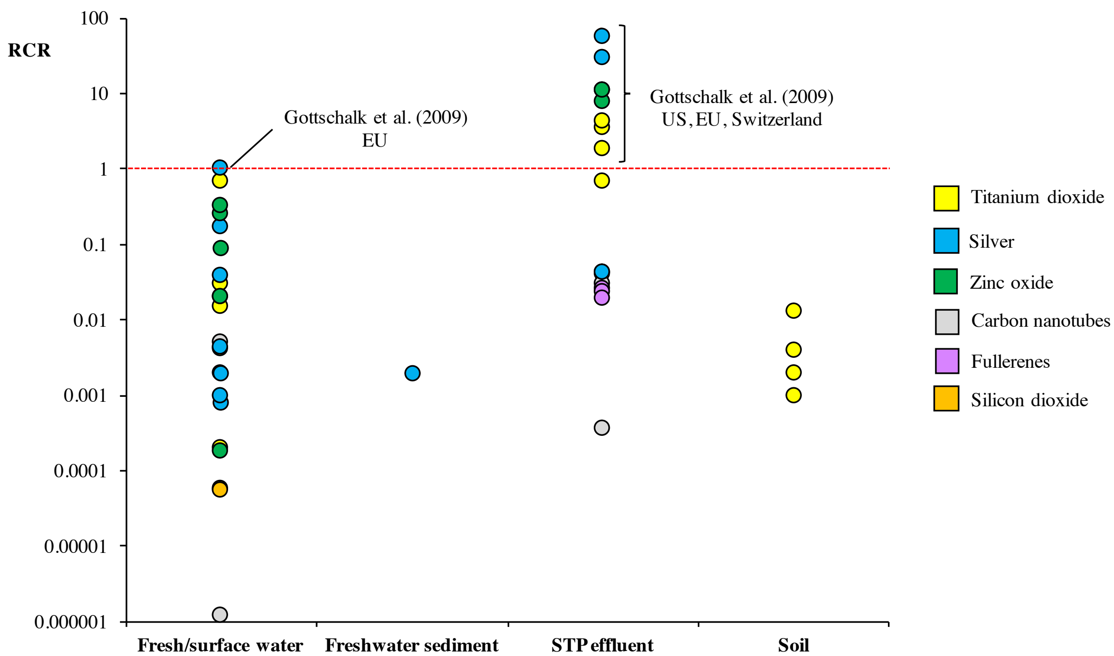

Figure 1. Review of risk characterization ratios for engineered nanomaterials. RCR=risk characterization ratio, EU=European Union, US=United States, STP=sewage treatment plant.

Acknowledgements

The financial support from the Swedish Research Council for Environment, Agricultural Sciences and Spatial Planning (Formas) is gratefully acknowledged.

References

1. Blaser, S. A.; Scheringer, M.; MacLeod, M.; Hungerbühler, K., Estimation of cumulative aquatic exposure and risk due to silver: Contribution of nano-functionalized plastics and textiles. *Science of the Total Environment* **2008,** *390*, (2-3), 396-409.
2. Mueller, N. C.; Nowack, B., Exposure Modeling of Engineered Nanoparticles in the Environment. *Environmental Science & Technology* **2008,** *42*, (12), 4447-4453.
3. Gottschalk, F.; Sonderer, T.; Scholz, R. W.; Nowack, B., Modeled Environmental Concentrations of Engineered Nanomaterials (TiO2, ZnO, Ag, CNT, Fullerenes) for Different Regions. *Environmental Science & Technology* **2009,** *43*, (24), 9216-9222.

4. Musee, N., Simulated environmental risk estimation of engineered nanomaterials: A case of cosmetics in Johannesburg City. *Human and Experimental Toxicology* **2011,** *30*, (9), 1181-1195.
5. Wang, Y.; Kalinina, A.; Sun, T.; Nowack, B., Probabilistic modeling of the flows and environmental risks of nano-silica. *Science of the Total Environment* **2016,** *545–546*, 67-76.
6. Coll, C.; Notter, D.; Gottschalk, F.; Sun, T.; Som, C.; Nowack, B., Probabilistic environmental risk assessment of five nanomaterials (nano-TiO2, nano-Ag, nano-ZnO, CNT, and fullerenes). *Nanotoxicology* **2016,** *10*, (4), 436-444.
7. Kjølholt, J.; Gottschalk, F.; Brinch, A.; Lützhøft, H.-C. H.; Hartmann, N. B.; Nowack, B.; Baun, A. *Environmental assessment of nanomaterial use in Denmark*; The Danish Environmental Protection Agency: Copenhagen, 2015.