Use of modeling to predict environmental concentrations of nanomaterials

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Background

- ENM are used in numerous applications and products
- ENM release during production, use and disposal is likely
- First results about release of ENM published, e.g. from paints and textiles
- Currently no quantitative trace analytical method available: Therefore no information on environmental exposure available
- Modeling can provide these data
Material flow to the environment

Product life cycle

Wastewater treatment

Landfill

Waste incineration

Environment

Manufacturing

Production

uses

uses

uses

uses
Environmental fate: Multi-compartment modeling
Release of ENM from products

- Some products are used up (e.g. sunscreen): (almost) complete release
- Most products release only part of the ENM
- Only few data available on release
  - Paints
  - Textiles
  - Coatings
- Estimations required
Material-flow model for nano-TiO$_2$ for the EU (mode values in tons/year)

Modeled environmental concentrations in waters of the EU (mode and 15 and 85% quantiles in ng/L)

<table>
<thead>
<tr>
<th></th>
<th>TiO$_2$</th>
<th>Ag</th>
<th>ZnO</th>
<th>CNT</th>
<th>fullerenes</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Surface water</strong></td>
<td>15 (12-57)</td>
<td>0.8 (0.6-2.2)</td>
<td>10 (8-55)</td>
<td>0.004 (0.004-0.021)</td>
<td>0.02 (0.01-0.12)</td>
</tr>
<tr>
<td><strong>Treated wastewater</strong></td>
<td>3'470 (2'500-10'800)</td>
<td>43 (33-111)</td>
<td>432 (136-1'420)</td>
<td>15 (11-32)</td>
<td>5 (4-26)</td>
</tr>
</tbody>
</table>

Release of Ag from textiles during washing

Characterization of released ENM

ZnO from a steel panel (Vorbau, 2009)

TiO$_2$ from paint (Kaegi 2008)

Ag from paint (Kaegi 2010)

Ag from a medical mask (Benn 2010)
Open issues in current models

- All modifications of one ENM are lumped together (e.g. coated-uncoated, different mineralogical forms)
- Form of released materials is not considered
  - Free particles?
  - Matrix-bound?
  - Nanoparticulate?
In what form are ENM present in the environment? Silver as example
Conclusions

- All release paths need to be covered to estimate environmental concentrations
- Very few data on environmental release from products available
- Very little information on form of released ENM available
- Bulk form and dissolved metals need to be considered, too