Release of nanomaterials from consumer products and implications for consumer exposure assessment - DTU Orbit (20/02/2019)

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During the past decade the number of consumer products that contain nanomaterials (NMs) has been rapidly increasing. Materials manufactured at the nanoscale exhibit unique physiochemical properties and have greater reactivity in comparison to the bulk material. Because of this, NMs are being utilized in a wide variety of products, ranging from food and personal care products to electronics and large appliances.

Over the course of the last four years, the number of products claiming to contain NMs has increased from 1,200 in 2012 to more than 2,300 in 2016. The increasing use of nanoproducts and the uncertainties associated with the risks they may pose is raising concerns about consumer safety. During the use of nano-enabled products there is a potential for NM release, which can consequently lead to consumer and/or environmental exposure. Consumer exposure testing has only recently started to receive some attention, and the data currently available in the literature is scarce. Most studies are addressing only a narrow range of product categories and a few NM types, having experimental setups that are rarely comparable from study to study. Moreover, the analytical techniques applied for release testing are rarely suitable for reporting NM release with particle number concentration, size distribution or surface area concentration, which are known to be of toxicological importance.

The work presented in this thesis addresses the lack of data on consumer exposure to NMs from various consumer products. First, data from literature and online databases was used to obtain an overview of what nanoproducts are available on the EU market, and which nanoproducts have been experimentally tested for their potential NM release. Specific focus was placed on evaluating suitable analytical methods for NM quantification and characterization. The findings showed that single particle inductively coupled plasma mass spectrometry (spICP-MS) in combination with other methods is a well suited analytical technique that can provide extensive NM characterization, such as mass and number concentration, and size distribution of NMs. Then, several nano-enabled products were selected for experimental testing of NM release, namely four types of food contact materials (Ag) and two types of toothbrushes (Ag) for potential dermal exposure, as well as five types of textiles (TiO2) and five different surface coatings (Ag and CuO) for potential dermal exposure. The NM release was characterized by using spICP-MS and transmission electron microscopy (TEM), together providing data for NM mass and number concentration, size distribution, and morphology. In most cases, it was found that NM release from the consumer products was in the ng/g (or ng/cm2 where applicable) range. Ag release from food contact materials and toothbrushes was tested in food simulants (deionized (DI) water, ethanol, acetic acid) and tap water, respectively. The results showed that there is a potential for Ag exposure both in dissolved and nano-particulate form (up to around 6 µg/L and 40,000 particles/mL), but the amounts were magnitudes below the permitted Ag exposure limits set by European Food Safety Authority (EFSA) and World Health Organization (WHO). The TiO2 release was tested for five types of textiles that did not openly disclose TiO2 content. The fabrics were immersed in DI water, and the resulting amounts of potential Ti exposure were found to be up to around 8,000 particles/cm2 corresponding to around 24 ng/cm2. These amounts may be considered negligible compared to the reported Ti amounts in a wide range of products available on the market that claim to contain nano-TiO2 as an additive, especially when it comes to food products. Dermal exposure testing for Ag and CuO surface coatings was done by wiping tests and revealed particle release very close to background levels, unless the surface was subjected to abrasion before executing the wiping tests. In general, all the products that were tested released very low amounts of the initial NM content present in the product, indicating that throughout long-term use of the products there might be continuous NM release, or most of the NMs would end up in solid waste. The NM release data obtained both from the literature and from the experimental studies presented in this thesis were subsequently used for consumer exposure estimation. Several consumer exposure assessment tools were identified and their applicability for NM exposure assessment is discussed in this thesis. It was concluded that current consumer exposure assessment models have not been designed for estimating NM-relevant exposures, as they are mainly dealing with mass as a dose metric, without taking NM properties into consideration. This highlights the need of developing tools that are specifically designed for NM exposure assessment, taking into account not only potential exposure in terms of total NM mass, but also number concentration and size distribution.

All in all, the work presented in this thesis underlined various important issues that need to be considered and addressed when completing nanoproduct release testing, NM quantification and characterization, data reporting, and consumer exposure assessment. Firstly, there is an urgent need to apply a combination of characterization methods to gain a better understanding about the potential NM exposure. Secondly, standardization of NM release testing and data reporting is of key relevance, to ensure that the data generated is comparable among studies and can be extrapolated to other nanoproducts with similar properties. Finally, standardized data reporting and exposure assessment is of utmost importance to move towards harmonization of NM exposure and hazard characterization that could further aid NM-relevant risk assessment.

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