Health Risk Driven Exposure Assessment for Consumers during the Life Cycle of Nanomaterial–containing Products

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Risk Assessment for Manufactured Nanoparticles Used in Consumer Products

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Consumer products containing MNPs have shown 5-10 fold increase over the last 5 years with Titanium, Carbon, and Silver being the predominant materials.

(Source: The Project on Emerging Nanotechnologies - nanotechproject.org)
Consumer Products Use and Exposure Routes

Distribution of number of products in the US containing AgNP as of March, 2014
Consumer Products Use and Exposure Routes

Source: Green Kidz R Us
http://www.completesense.com/gkconcerns.html
Exposure Assessment Approaches

- Consumer product characterization
- Exposure scenario

Exposure

- Direct monitoring (intake dose)
- Biomonitoring (internal dose)

Mathematical models
Product Characterization for Manufactured Nanomaterials/Nanoparticles (MNMs/MNPs)
"We identified 165 consumer products... We selected 19 products for further analysis. These products were classified as a children’s toy, personal care product, textiles, storage containers, household cleaning products, dietary supplement..."
Fig. 3. SEM micrograph and EDX spectrum of ashed glove palm fabric. Particles were composed of silver and titanium, which was probably used as an inert carrier material for the silver metal particles.

Fig. 5. TEM micrograph of the disinfecting spray.
“The SERS-based method developed in this study not only shows high potential for differentiating AgNPs from other silver species, but also has applicability for detecting AgNPs of different coatings, sizes, and concentrations.”
Human Exposure to Conventional and Nanoparticle-Containing Sprays—A Critical Review

Sabrina Losert, Natalie von Goetz, Cindy Bekker, Wouter Fransman, Susan W. P. Wijnhoven, Christiaan Delmaar, Konrad Hungerbuhler, and Andrea Ulrich

Figure 1. Processes influencing nanoparticle size and aggregation status during and after spraying.

Silver Nanoparticles and Total Aerosols Emitted by Nanotechnology-Related Consumer Spray Products

Marina E. Quadros and Linsey C. Marr*

Figure 1. Experimental setup and mass balance equations used to determine aerosol emission rates (further described in the Supporting Information).
Potential for Inhalation Exposure to Engineered Nanoparticles from Nanotechnology-Based Cosmetic Powders

Yevgen Nazarenko,¹ Huajun Zhen,¹ Taewon Han,¹ Paul J. Lioy,²,³ and Gediminas Mainelis¹,³

Figure 1. Experimental setup for simulated cosmetic powder application and measurement of resulting aerosol. \( Q_a \), total sampling flow rate; \( Q_{APS} \), aspiration rate of the APS; \( Q_{aux} \), auxiliary aspiration rate; \( Q_{SMPS} \), aspiration rate of the SMPS.
RESULTS: We found that a user would be exposed to nanomaterial predominantly through nanoparticle-containing agglomerates larger than the 1–100-nm aerosol fraction.

CONCLUSIONS: Predominant deposition of nanomaterial(s) will occur in the tracheobronchial and head airways—not in the alveolar region as would be expected based on the size of primary nanoparticles. This could potentially lead to different health effects than expected based on the current understanding of nanoparticle behavior and toxicology studies for the alveolar region.
Estimating Population Exposures to MNPs
Titanium Dioxide Nanoparticles in Food and Personal Care Products

Alex Weir,† Paul Westerhoff,*† Lars Fabricius,*‡§ Kiril Hristovski,‖ and Natalie von Goetz‡

TiO$_2$ content in various foods

Food Consumption data
Figure 3. Histogram of the average daily exposure to TiO2 for the US population (Monte Carlo simulation). Error bars represent the upper and lower boundary scenarios.
Modeling population exposures to silver nanoparticles present in consumer products

Steven G. Royce · Dwipayan Mukherjee · Ting Cai · Shu S. Xu ·
Jocelyn A. Alexander · Zhongyuan Mi · Leonardo Calderon ·
Gediminas Mainelis · KiBum Lee · Paul J. Lioy · Teresa D. Tetley ·
Kian Fan Chung · Junfeng Zhang · Panos G. Georgopoulos
The Prioritization/Ranking of Toxic Exposures with GIS Extension (PRoTEGE) framework for tiered exposure modeling
Findings and Needs

• Applications of PRoTEGE with available data demonstrate that nAg exposures from “near field sources” are order of magnitudes greater than exposures from “far field sources,” at least for certain population segments.

• Databases exist that can provide fundamental information on input variables needed to complete range finding and planning type estimates of potential exposures.

• Datasets are needed on actual human exposures and on controlled human exposures to refine and test the performance of Tier 1 and Tier 2 nanomaterial applications of PRoTEGE.
Assessment of Bioavailability of MNPs
Release of Silver from Nanotechnology-Based Consumer Products for Children

Marina E. Quadros,Ⅷ,Ⅸ,Ⅹ Raymond Pierson, IV,† Nicolle S. Tulve,‡ Robert Willis,‡ Kim Rogers,‡ Treye A. Thomas,§ and Linsey C. Marr†
Release of Silver from Nanotechnology-Based Consumer Products for Children

Marina E. Quadros, Ray Pierson, IV, Nicolle S. Tulve, Robert Willis, Kim Rogers, Treye A. Thomas, and Lin

Figure 1. Amount of silver released into different leaching media (all data points shown). Data points are slightly offset to improve legibility.
Release of Silver from Nanotechnology-Based Consumer Products for Children
Marina E. Quadros, Raymond Pierson, IV, Nicolle S. Tulve, Robert Willis, Kim Rogers, Treye A. Thomas, and Linsey C. Marr

“Of the liquid media, sweat and urine yielded the highest amount of silver release, up to 38% of the silver mass in products; tap water yielded the lowest amount, ≤1.5%. Leaching from a blanket into sweat plateaued within 5 min, with less silver released after washing. ... bioavailable silver is expected to be in ionic rather than particulate form.”
• The “silver sleeves” are a prototype of a Ag coated medical garment intended for use in the treatment of Atopic Dermatitis.
• The garment contains 79% modal, 11% polyamide, 7% elastane and 3% silver.
• After 5 days x 8 hr/day wearing of the product, adhesive tape discs were used to sample Ag in Stratum Corneum layers
Pilot study on the identification of silver in skin layers and urine after dermal exposure to a functionalized textile

Carlotta Bianco\textsuperscript{a,b}, Sanja Kezic\textsuperscript{a}, Maaike J. Visser\textsuperscript{a}, Olivier Pluut\textsuperscript{a}, Gianpiero Adami\textsuperscript{b}, Petra Krystek\textsuperscript{c,*}

Ag was detected in the urine; no statistical tests performed.

Fig. 4. Silver concentrations normalized for protein amount in the \textit{Stratum Corneum} layers after leaching with different media.
Are we measuring health-relevant exposures?
Short Communication

Nanosilver-coated socks and their toxicity to zebrafish (Danio rerio) embryos

Jiejun Gao\textsuperscript{a}, Maria S. Sepúlveda\textsuperscript{a}, Christopher Klinkhamer\textsuperscript{a}, Alexander Wei\textsuperscript{b}, Yu Gao\textsuperscript{a}, Cecon T. Mahapatra\textsuperscript{a,\textsuperscript{*}}
“Results suggest that sock-AgNP and spun-AgNP solutions were more toxic relative to AgNO3. These results are in disagreement with previous studies in zebrafish and other organisms that have consistently shown that AgNPs are less toxic compared to Ag+.

It is worth noting that in these earlier studies investigators tested pure AgNPs, whereas our source of AgNPs was derived from a commercial textile product. These results suggest toxicity is being elicited by other elements or compounds added during the manufacturing process, rather than AgNPs.”
### Consumer Products Tested

<table>
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<tr>
<th>Product</th>
<th>Ingredients</th>
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<tr>
<td>MesoSilver</td>
<td>• 15.86 µg/ml Colloidal silver&lt;br&gt;• Deionized water</td>
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<tr>
<td>Nanofix</td>
<td>• 1.21 µg/ml silver&lt;br&gt;• Citric Acid&lt;br&gt;• Alcohol&lt;br&gt;• Nitrilotriacetic acid&lt;br&gt;• Quaternary alkyl methyl amine ethoxylate methyl chloride</td>
</tr>
<tr>
<td>DermaZinc</td>
<td>• 505.4 µg/ml Pyrithione Zinc&lt;br&gt;• SDA-40 Alcohol&lt;br&gt;• Isopropyl Myristate&lt;br&gt;• SLS needles&lt;br&gt;• Undecylenic acid</td>
</tr>
<tr>
<td>Therazinc</td>
<td>• 5115 µg/ml Zinc&lt;br&gt;• Vegetable Glycerine&lt;br&gt;• Peppermint Oil&lt;br&gt;• Clovebud oil&lt;br&gt;• Echinacea extract&lt;br&gt;• Menthol</td>
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Findings from in vitro pulmonary cell studies

- Therazinc – medium (particle-free portion) was much more toxic on viability and IL-6 and ROS than particles (filtered on filters).
- Dermazinc – particles were more toxic than medium.
- Nanofix – particles were very toxic.
- Mesosilver – not at all toxic.
- Some spray products which contain nanoparticulate zinc or silver may affect respiratory system.
Whether and how does the addition of *Envirox* affect physicochemical and toxicological properties of diesel exhaust?
DEP released after Envirox addition

Ce signal was detected by TEM-EDX

DF-TEM reveal the presence of highly crystallized Ce which was confirmed by STEM-EDX on 10 X Ce sample.
Findings

• The nano-ceria diesel additive reduced emissions of CO$_2$, DEP mass, CO, per kWh generated.
• The additive increased emissions of ultrafine particle number conc and decreased UFP sizes.
• The additive modified DEP chemical compositions (OC, TC, PAHs, Ce) and surface characteristics.
• The additive produced DEPs that generally showed lower bio-reactivity (oxidative stress and inflammation) in model cells, zebra fish, and mice.
• Experimental methods to assess toxicity/bio-reactivity of the whole exhaust are highly desirable. Does not make sense to just chasing the nano CeO$_2$!!