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

Junfeng (Jim) Zhang, PhD

Presented at the Workshop on
Quantifying Exposure to Engineered Nanomaterials from Manufactured Products
Washington, DC, July 7-8, 2015

Duke NICHOLAS SCHOOL OF THE ENVIRONMENT
DUKE GLOBAL HEALTH INSTITUTE
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Risk Assessment for Manufactured Nanoparticles Used in Consumer Products

Risk Assessment for Manufactured Nanoparticles Used in Consumer Products

J. Zhang, F. Chung, Y. Nazarenko, L. Calderon, P. Subramaniam, K. Lee, E. Garfunkel, P.J. Lioy, S. Sarkar, S. Schwander, W. Baker, J. Seiffert, R. Smith, A.J. Thorley, T.D. Tetley, H. Kipen, S. Chen, M. Ryan, A. Porter, M. Duarte, J. Gong, G. Mainelis, X. Cui, J. Osterberg, R. Di Giulio, Z. Mi, T. Cai, P. Georgopoulos, etc

Imperial College London

RUTGERS THE STATE UNIVERSITY OF NEW JERSEY

Duke UNIVERSITY

RAMNUC Project Meeting, New Jersey, January 2012

Acknowledgements

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ENVIRONMENT
RESEARCH COUNCIL

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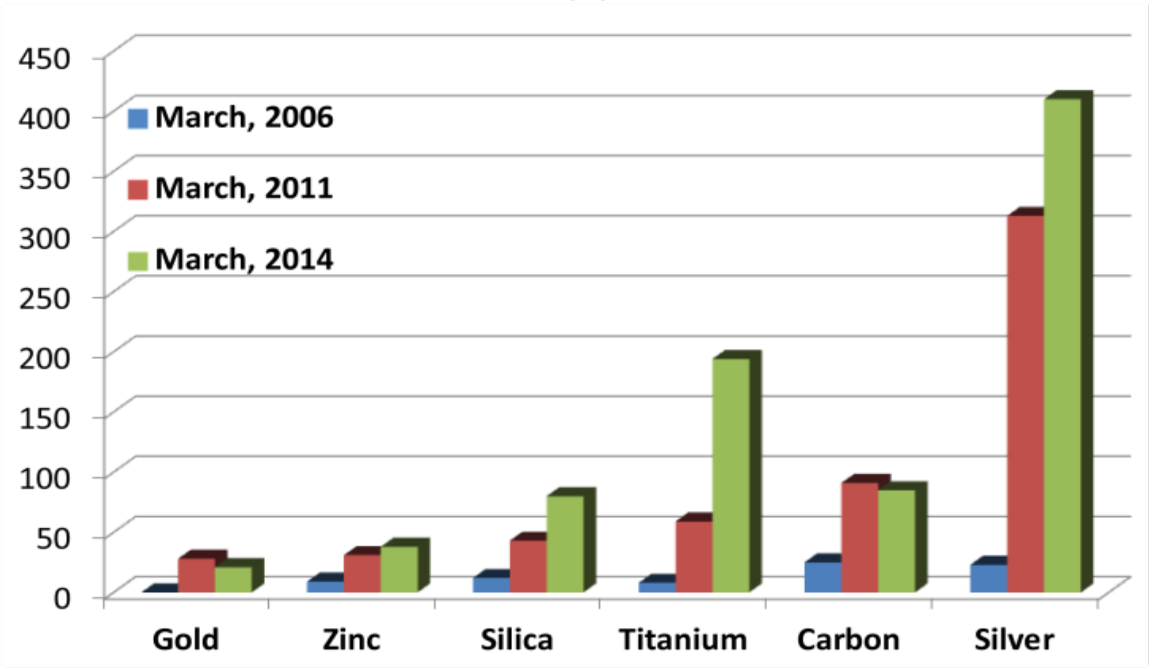
Risk Assessment for Manufactured Nanoparticles Used in Consumer Products

J Nanopart Res (2014) 16:2724
DOI 10.1007/s11051-014-2724-4



Number of MNP-containing products in the US as of March, 2014

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)

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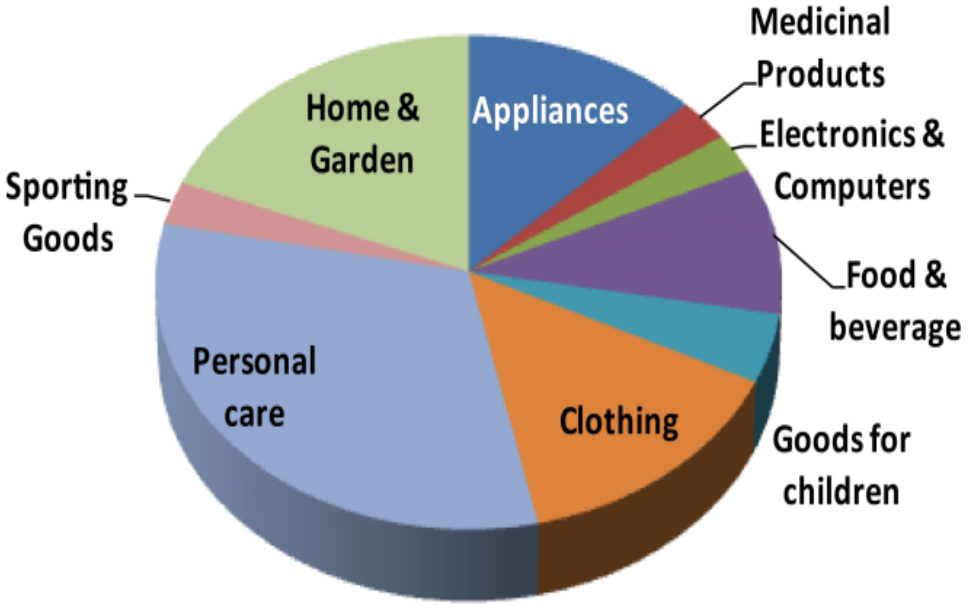
Consumer Products Use and Exposure Routes



Distribution of number of products in the US containing AgNP as of March, 2014

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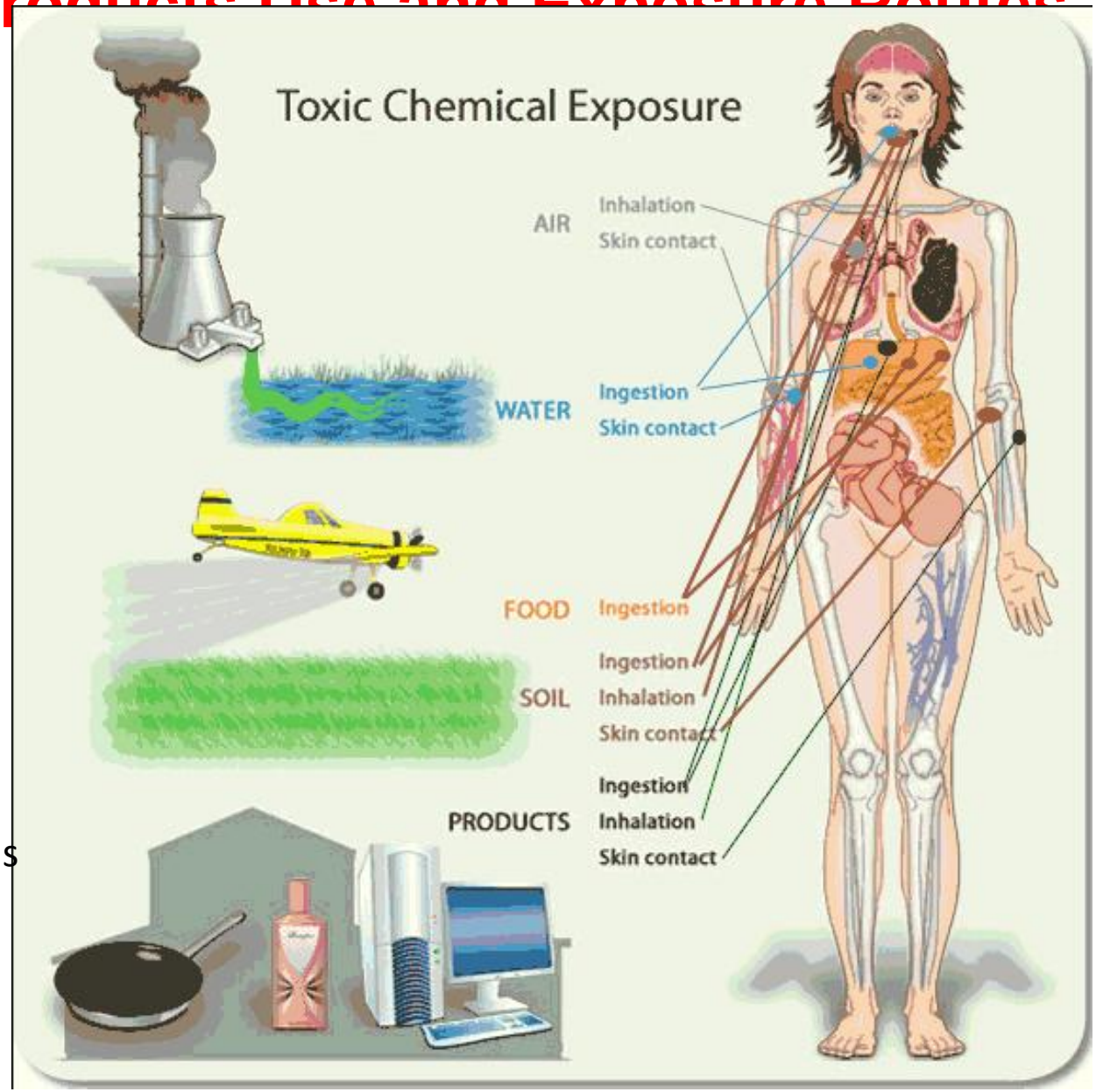
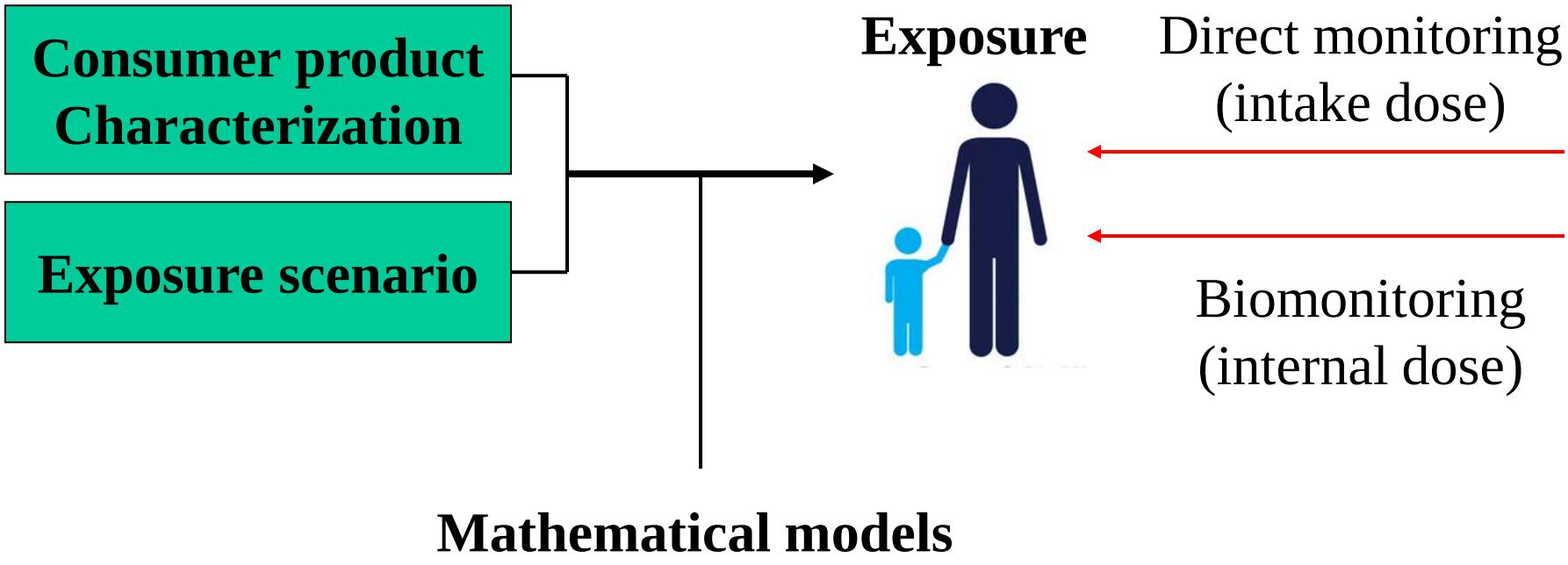
Consumer Products Use and Exposure Routes



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

Exposure Assessment Approaches



Product Characterization for Manufactured Nanomaterials / Nanoparticles (MNMs / MNPs)

International Journal of Hygiene and Environmental Health 218 (2015) 345–357

Characterization of silver nanoparticles in selected consumer products and its relevance for predicting children's potential exposures

Nicolle S. Tulve[a,*], Aleksandr B. Stefaniak[b], Marina E. Vance[c], Kim Rogers[a], Samuel Mwilu[d], Ryan F. LeBouf[b], Diane Schwegler-Berry[b], Robert Willis[a], Treye A. Thomas[e], Linsey C. Marr[f]

"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…"

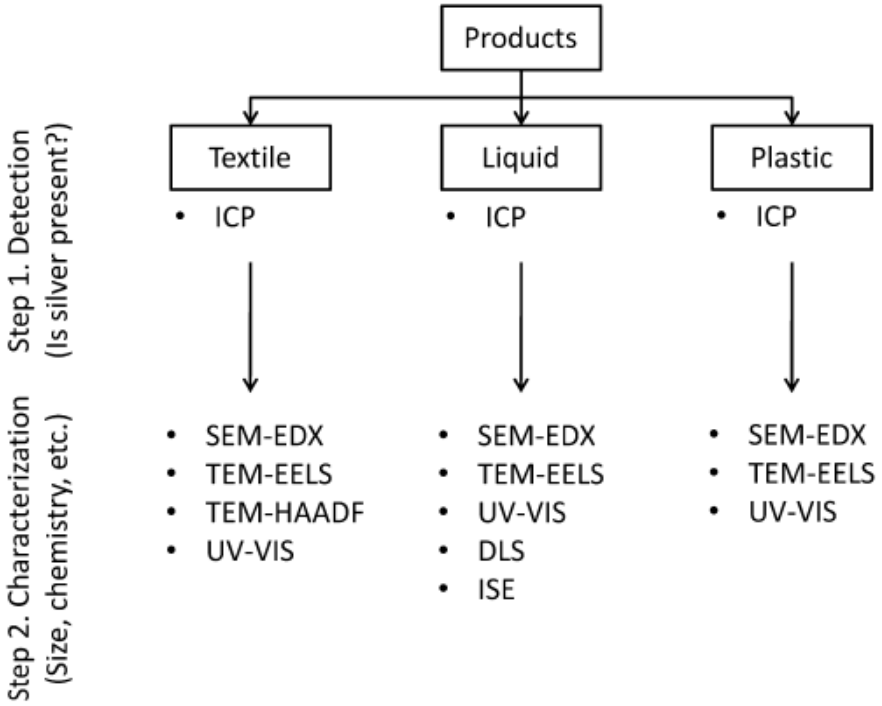
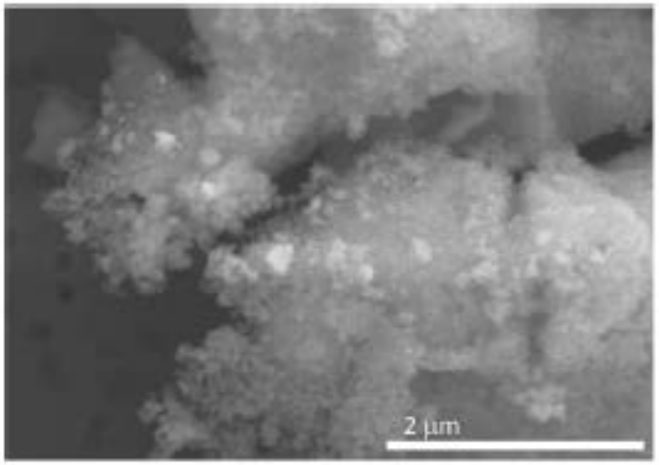


Fig. 1. Tiered approach for the analysis of consumer products for AgNPs.



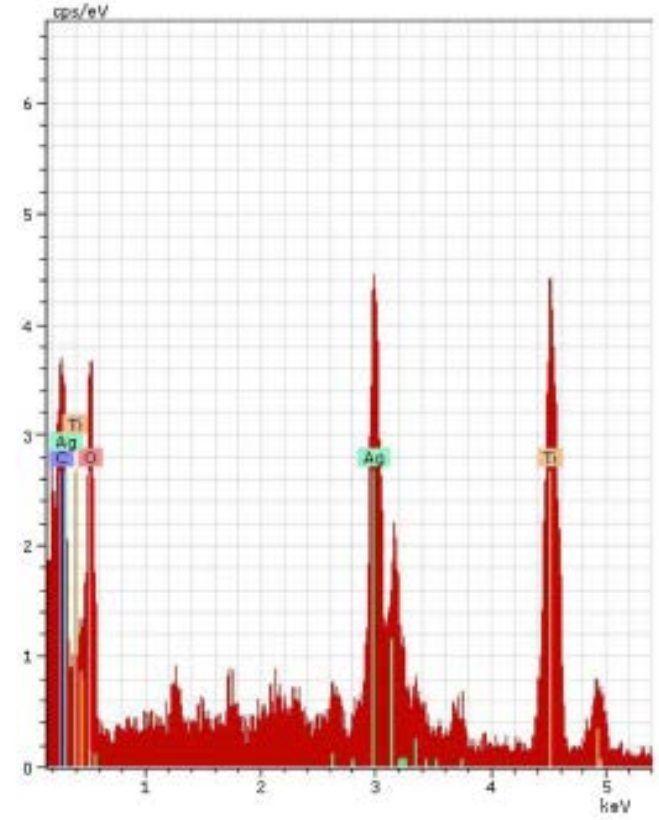


Fig. 3. SEM micrograph and EDX spectrum of ashed glove palm fabric. Particles were composed of silver and titanium, which was probably used as an inert carrier material for the silver metal particles.

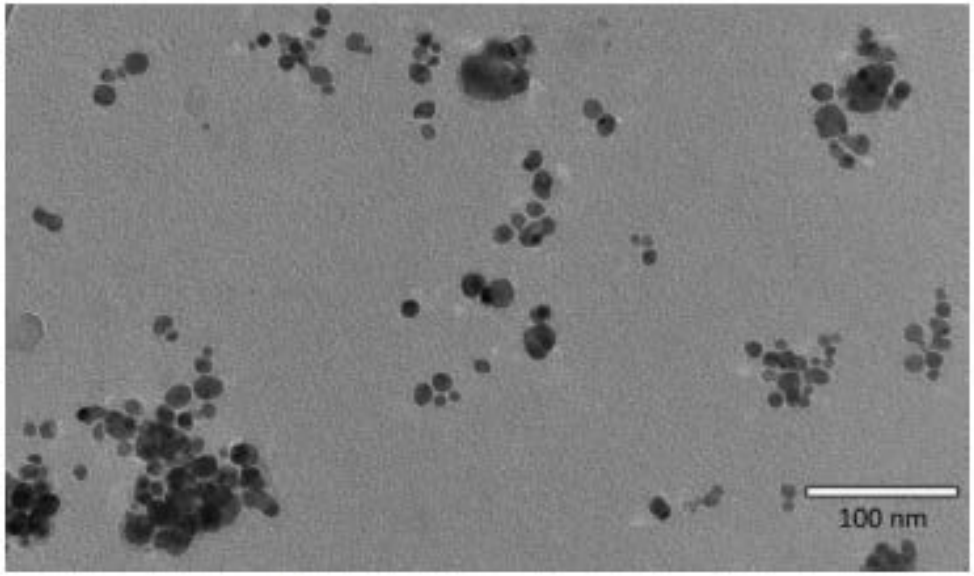


Fig. 5. TEM micrograph of the disinfecting spray.

ENVIRONMENTAL Science & Technology

DOI: 10.1021/acs.est.5b00370
Environ. Sci. Technol. 2015, 49, 4317−4324

Analysis of Silver Nanoparticles in Antimicrobial Products Using Surface-Enhanced Raman Spectroscopy (SERS)

Huiyuan Guo,[†] Zhiyun Zhang,[‡] Baoshan Xing,*[,†] Arnab Mukherjee,[§] Craig Musante,[§] Jason C. White,[§] and Lili He*[,‡]

[†]Stockbridge School of Agriculture, University of Massachusetts, Amherst, Massachusetts 01003, United States

[‡]Department of Food Science, University of Massachusetts, Amherst, Massachusetts 01003, United States

[§]Department of Analytical Chemistry, The Connecticut Agricultural Experiment Station, New Haven, Connecticut 06511, United States

" 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."

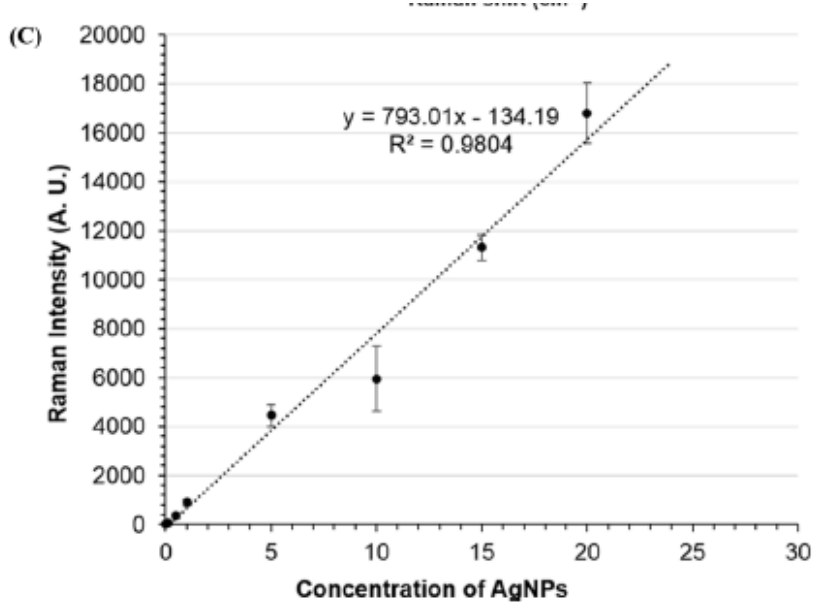


Figure 3. Concentration-dependent SERS spectra of AgNPs (citrate, 60 nm) with ferbam (10 mg/L) as an indicator. (A) Common scale. (B) Full scale. (C) The linear relationship between Raman intensity and AgNPs concentration. The error bars represent the standard errors of five parallel SERS measurements.

Environmental Science & Technology

Critical Review

pubs.acs.org/est

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[†]

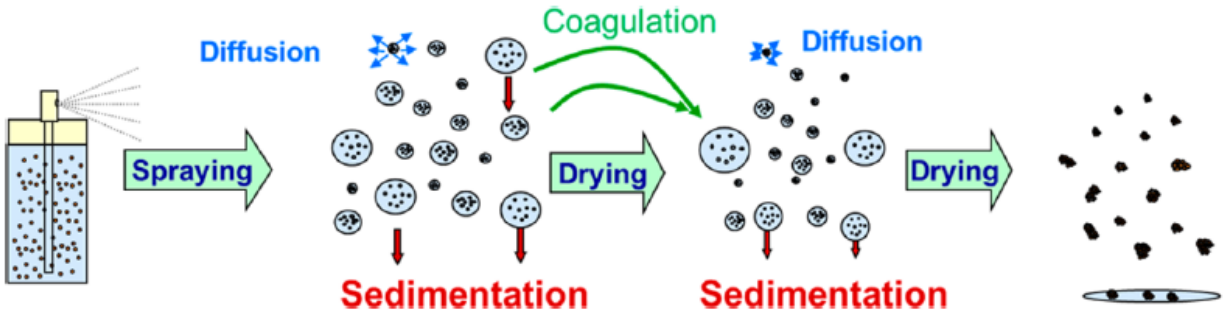


Figure 1. Processes influencing nanoparticle size and aggregation status during and after spraying.

dx.doi.org/10.1021/es5001819 | *Environ. Sci. Technol.* 2014, 48, 5366−5378

ENVIRONMENTAL Science & Technology

dx.doi.org/10.1021/es202770m | Environ. Sci. Technol. 2011, 45, 10713–10719

ARTICLE

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

Marina E. Quadros and Linsey C. Marr*

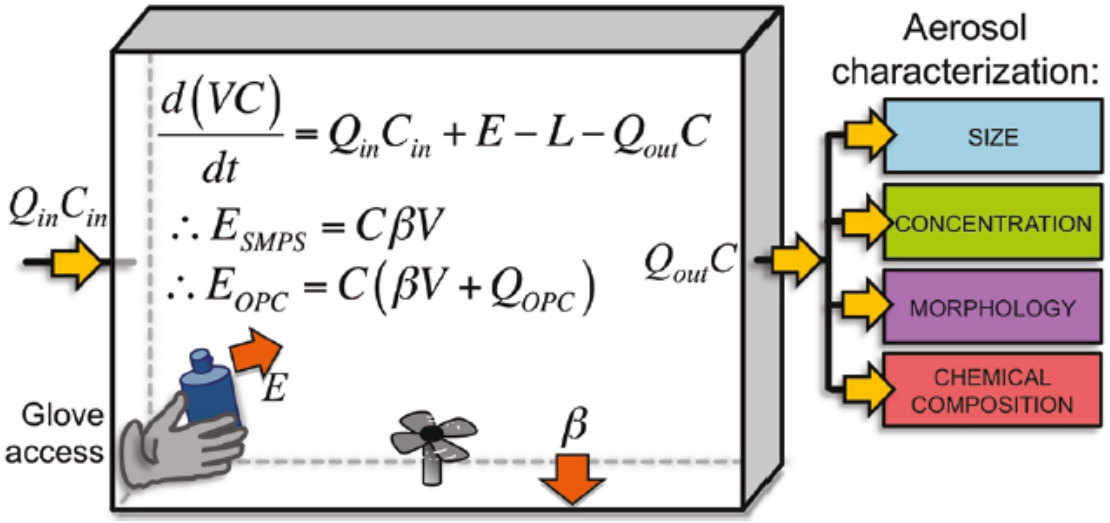

Figure 1. Experimental setup and mass balance equations used to determine aerosol emission rates (further described in the Supporting Information).

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Environmental Health Perspectives • VOLUME 120 | NUMBER 6 | June 2012

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 Mainelis[1,3]

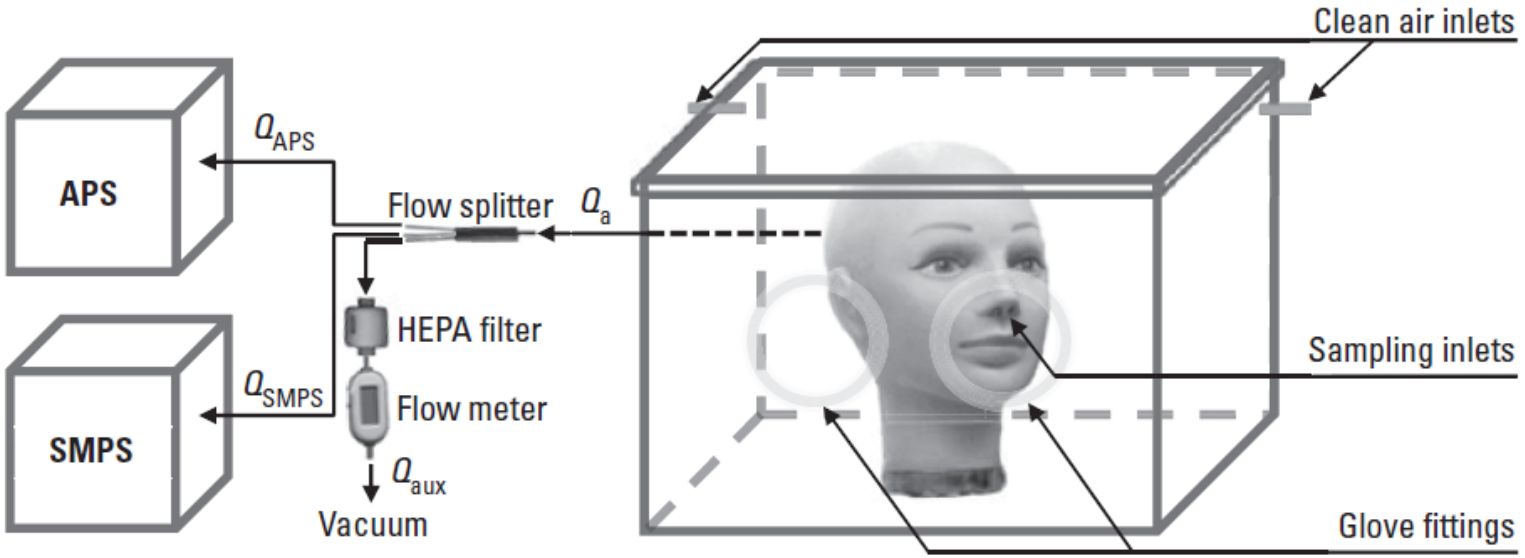

Figure 1. Experimental setup for simulated cosmetic powder application and measurement of resulting aerosol. Q_a, total sampling flow rate; Q_{APS}, aspiration rate of the APS; Q_{aux}, auxiliary aspiration rate; Q_{SMPS}, aspiration rate of the SMPS.

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Environmental Health Perspectives • VOLUME 120 | NUMBER 6 | June 2012

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

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

ENVIRONMENTAL Science & Technology

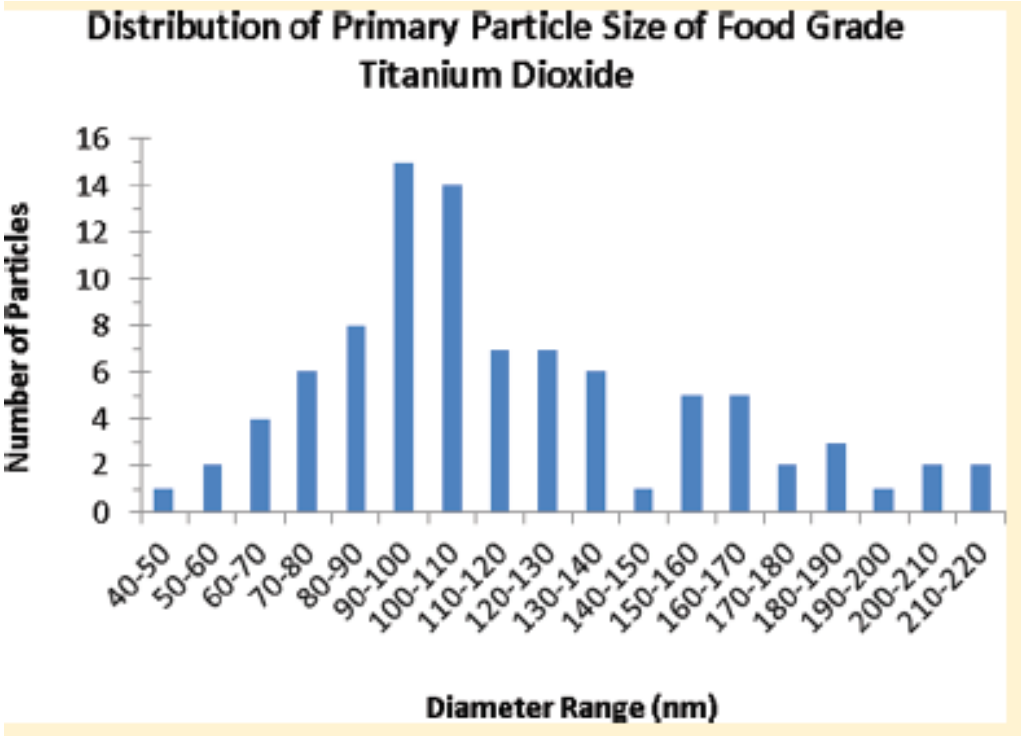
dx.doi.org/10.1021/es204168d | *Environ. Sci. Technol.* 2012, 46, 2242–2250

Article

pubs.acs.org/est

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

dx.doi.org/10.1021/es204168d | *Environ. Sci. Technol.* 2012, 46, 2242–2250

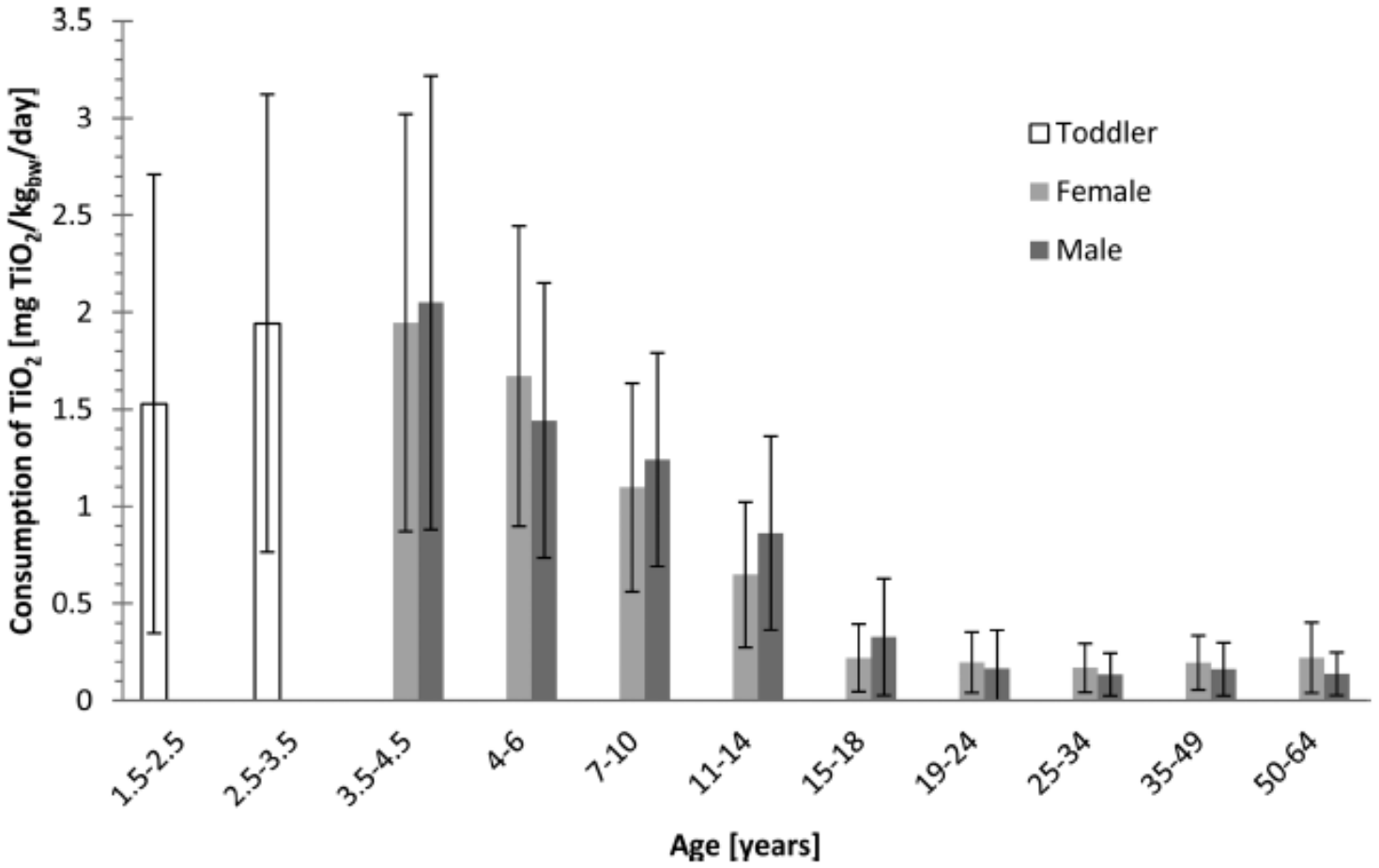


Figure 3. Histogram of the average daily exposure to TiO2 for the US population (Monte Carlo simulation). Error bars represent the upper and lower boundary scenarios

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J Nanopart Res (2014) 16:2724
DOI 10.1007/s11051-014-2724-4

RESEARCH PAPER

Modeling population exposures to silver nanoparticles present in consumer products

Steven G. Royce · Dwaipayan 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

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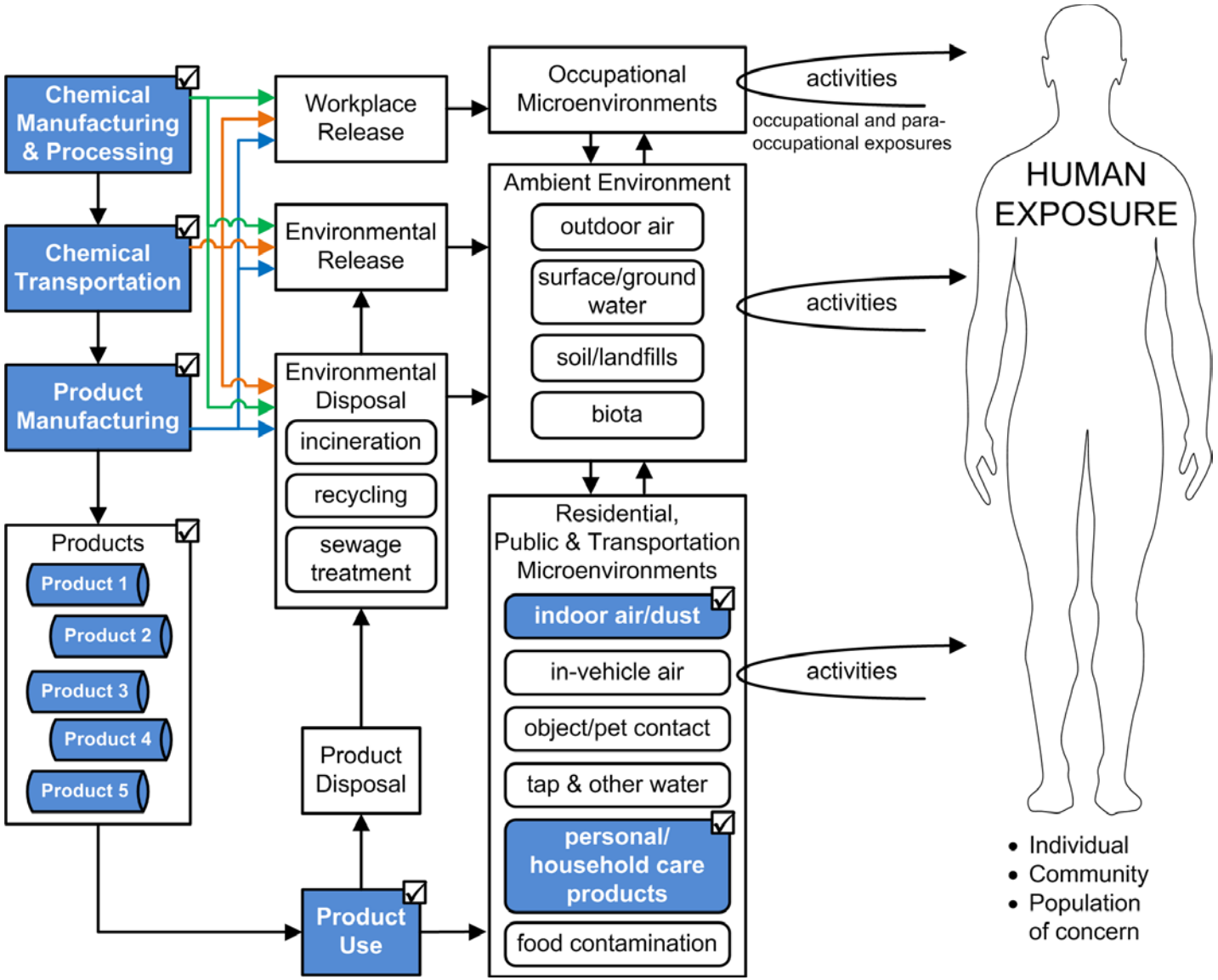
The Prioritization/Ranking of Toxic Exposures with GIS Extension (PRoTEGE) framework for tiered exposure modeling



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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

Environmental Science & Technology

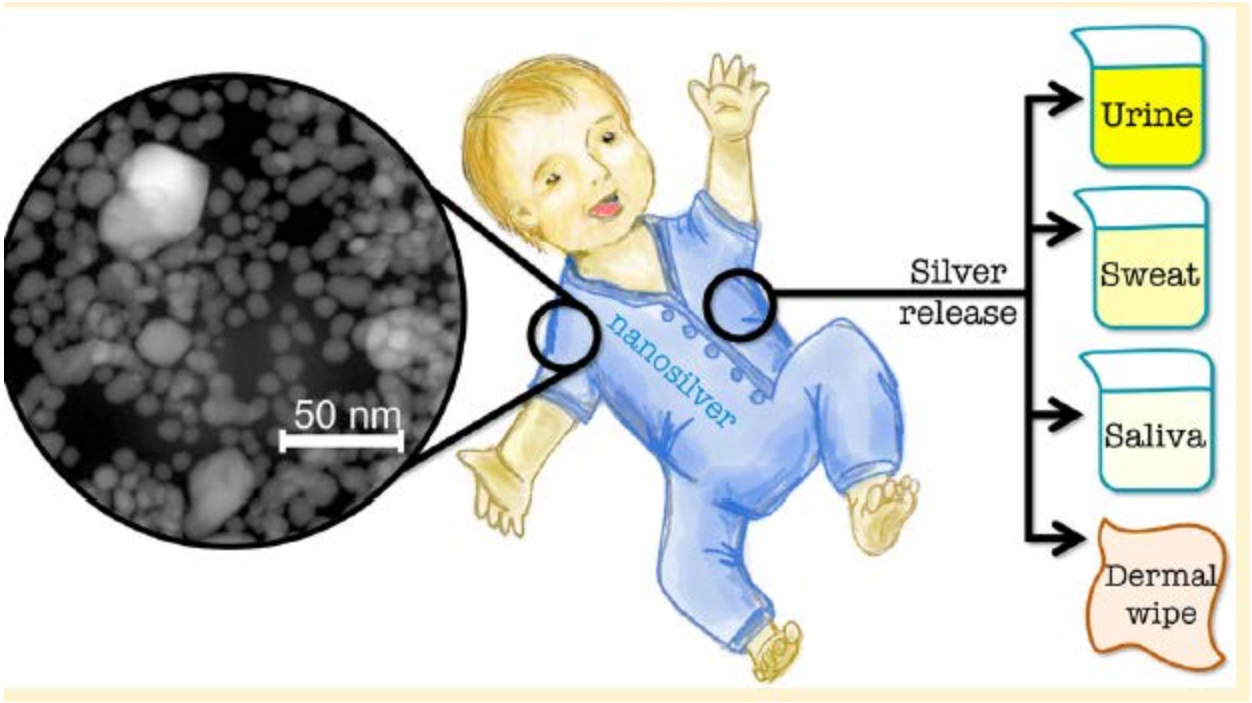
dx.doi.org/10.1021/es4015844 | Environ. Sci. Technol. 2013, 47, 8894–8901

Article

pubs.acs.org/est

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[†]



ENVIRONMENTAL Science & Technology

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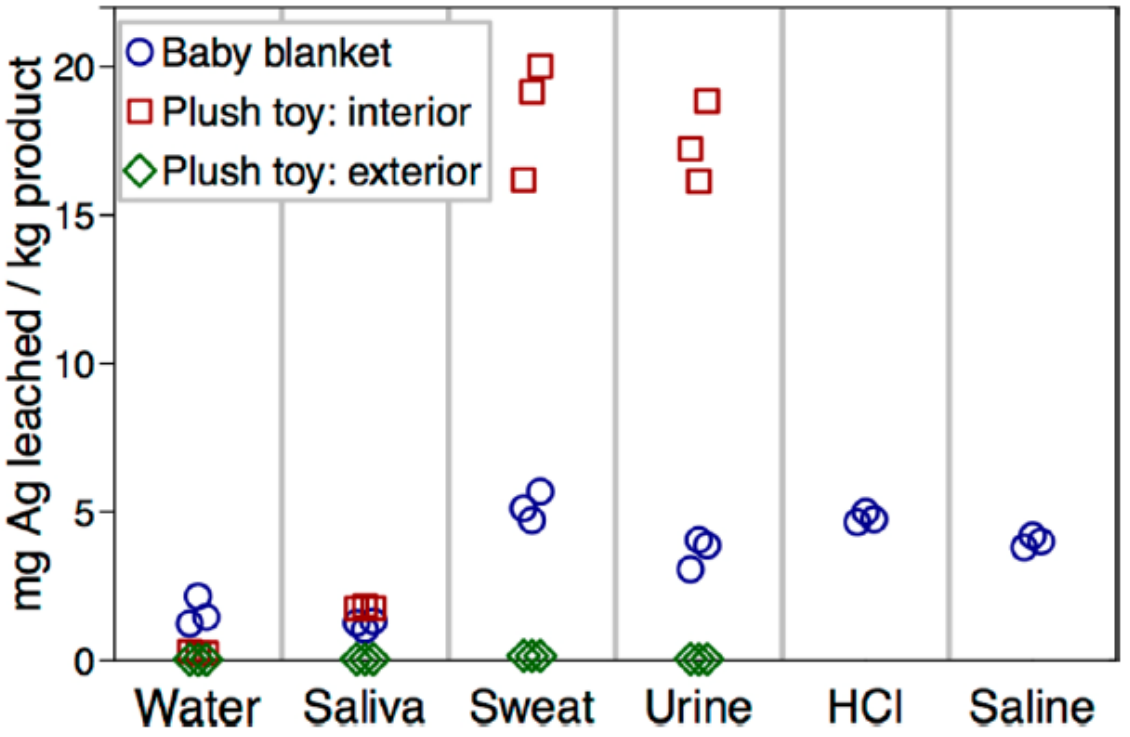

Figure 1. Amount of silver released into different leaching media (all data points shown). Data points are slightly offset to improve legibility.

ENVIRONMENTAL Science & Technology

dx.doi.org/10.1021/es4015844 | *Environ. Sci. Technol.* 2013, 47, 8894–8901

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"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."

Talanta 136 (2015) 23–28

Pilot study on the identification of silver in skin layers and urine after dermal exposure to a functionalized textile

Carlotta Bianco [a,b], Sanja Kezic [a], Maaike J. Visser [a], Olivier Pluut [a], Gianpiero Adami [b], Petra Krystek [c,*]

- 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

Talanta 136 (2015) 23–28

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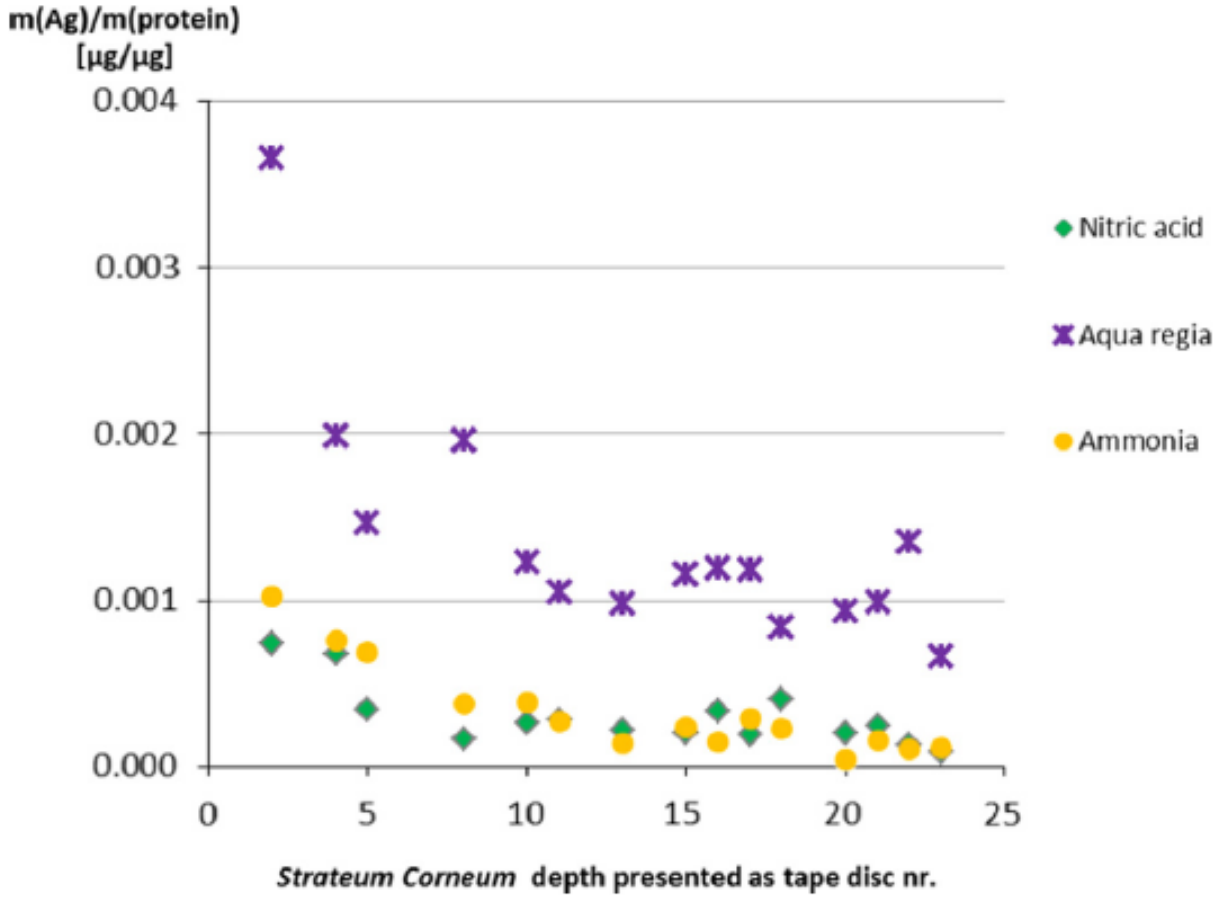


Fig. 4. Silver concentrations normalized for protein amount in the *Stratum Corneum* layers after leaching with different media.

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

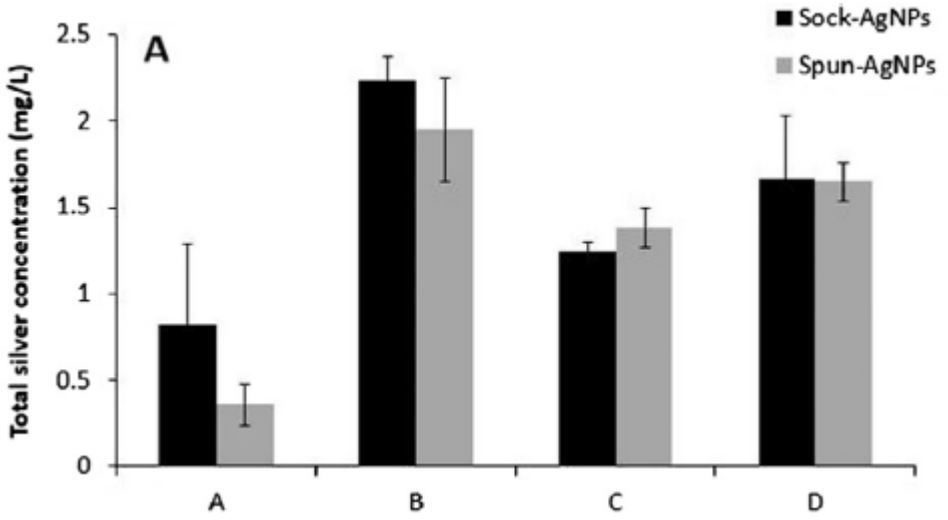
Are we measuring health-relevant exposures?

Chemosphere 119 (2015) 948–952

Short Communication

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

Jiejun Gao [a], Maria S. Sepúlveda [a], Christopher Klinkhamer [a], Alexander Wei [b], Yu Gao [a], Cecon T. Mahapatra [a,*]



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"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."

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Consumer Products Tested

MesoSilver

- 15.86µg/ml Colloidal silver
- Deionized water

Nanofix

- 1.21µg/ml silver
- Citric Acid
- Alcohol
- Nitrilotriacetic acid
- Quaternary alkyl methyl amine ethoxylate methyl chloride

DermaZinc

- 505.4ug/ml Pyrithione Zinc
- SDA-40 Alcohol
- Isopropyl Myristate
- SLS needles
- Undecy lenic acid

Therazinc

- 5115µg/ml Zinc
- Vegetable Glycerine
- Peppermint Oil
- Clovebud oil
- Echinacea extract
- Menthol

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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.**

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Containing ~2% CeO2 nanoparticles

Whether and how does the addition of *Envirox* affect physicochemical and toxicological properties of diesel exhaust?

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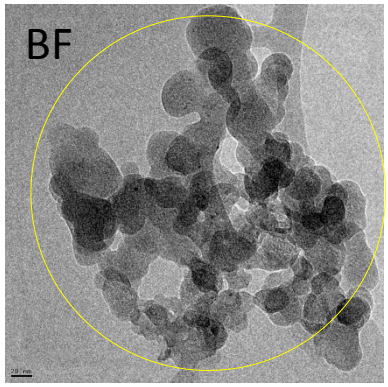
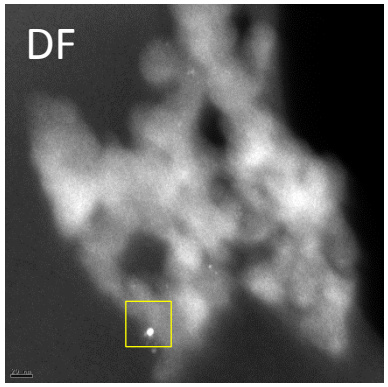
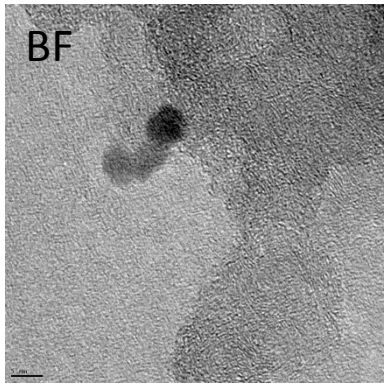
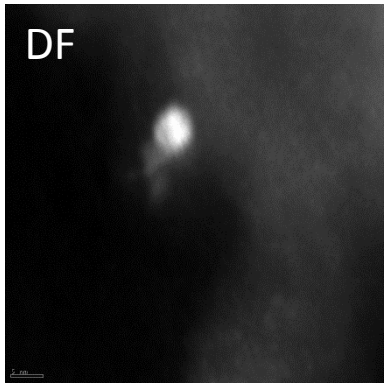
DEP released after Envirox addition

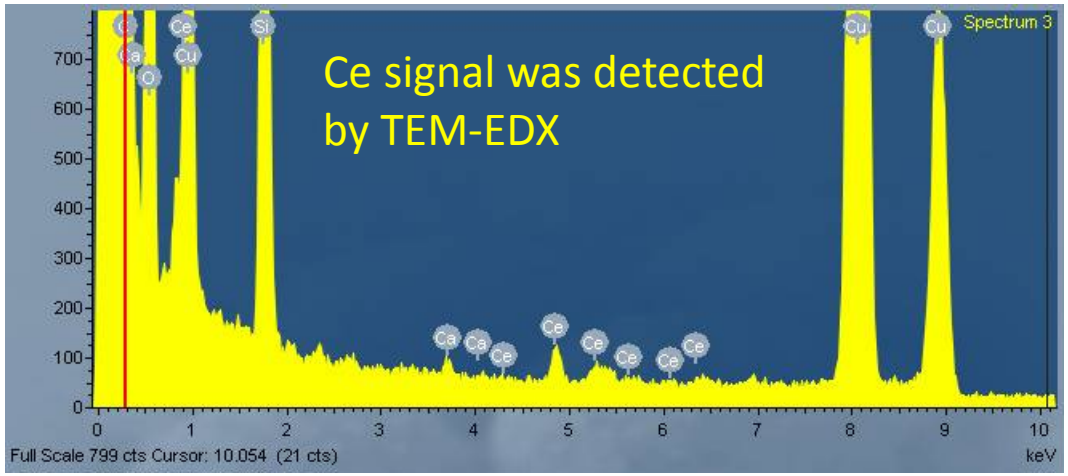


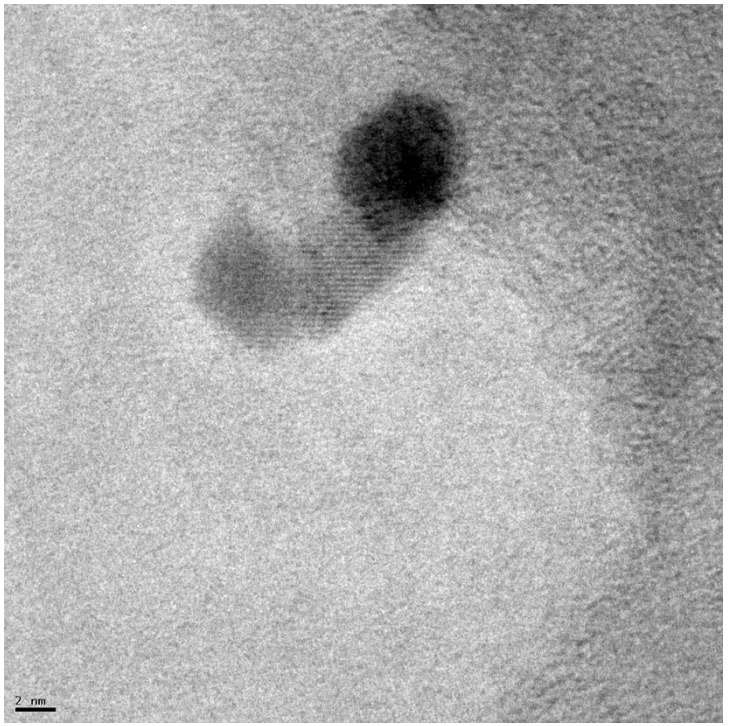






BF: bright field, DF: dark field





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

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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 CeO2!!

The RAMNUC Approach: