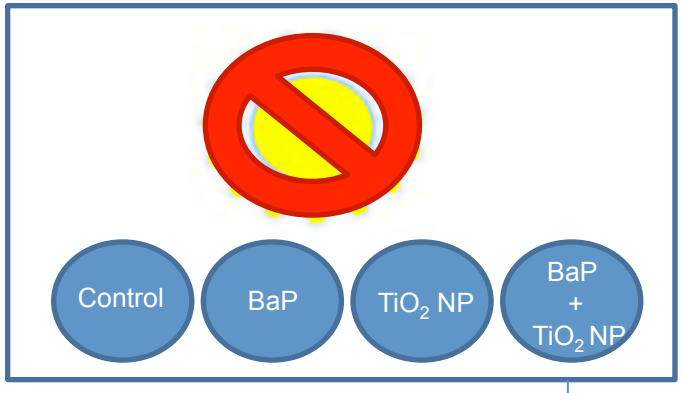
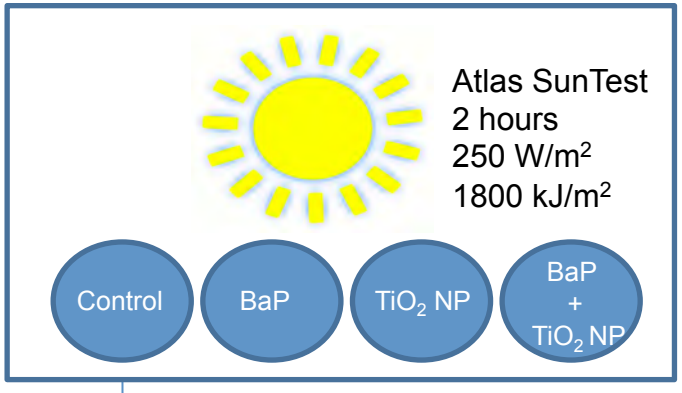
TiO_2 NP Photocatalyzed Degradation of Benzo(a)pyrene Increases Toxicity to Zebrafish

A. Bone[1] and R.T. Di Giulio[1]

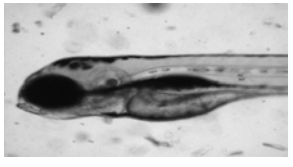
Objective: Determine effect of photocatalytically degrading benzo(a)pyrene using TiO_2 NP on larval zebrafish.

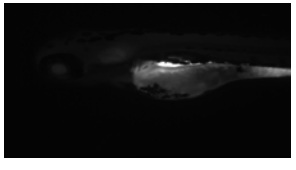




Expose 5 dpf zebrafish larvae to resultant solutions

Assess toxicity at 48 hpf
CYP activity (EROD assay)
Mortality





A Solutions of BaP photocatalytically degraded with TiO_2 NP (1ppm) induced more PAH-related toxicity and exposure than solutions of BaP exposed to UV alone, or unilluminated BaP.

B At higher levels of TiO_2 NP (>2 ppm), mortality is seen only in these solutions. No mortality occurs in any other treatments (B). Mortality is dose-responsive to both BaP and TiO_2 NP concentrations.

C Increased toxicity is likely due to production of a more toxic BaP daughter product. Chemical analysis of degradation products is underway.

[1] Nicholas School of the Environment, Duke University

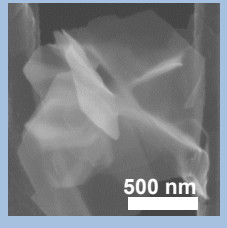
NSF EF-0830093 CEINT

Environmental Transport & Transformations: Nano Examples from Natural and Engineered Highly Complex (Real) Environments

Carol Johnson[1], Bojeong Kim[1], and Michael F. Hochella, Jr.[1]

Nano Iron Oxide Redox Transformations in Minewater Outflow

Observations | Proposed Mechanism



U mine groundwater outflow (anoxic)

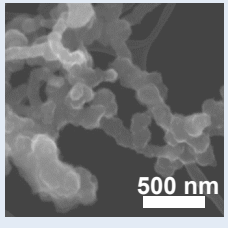
Green Rust nano-platelets
$Fe^{2+}_6Fe^{3+}_2(OH)_{18}\cdot 4(H_2O)$

redox boundary

$Fe^{2+}_{(aq)}$

$Fe^{3+}_{(aq)}$

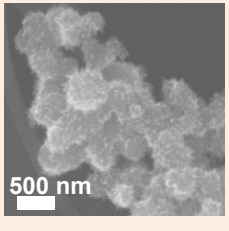
dissolution, precipitation



Outflow stream water (oxic)

Amorphous iron (oxyhydr)oxides coated with amorphous silica

sedimentation, aging



Underlying sediment (oxic)

Particles grow, goethite nanoneedles form from surface

Amorphous silica | Iron (oxyhydr)oxides

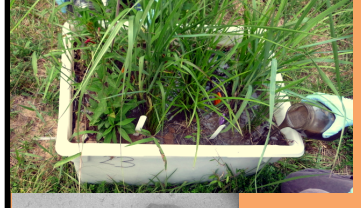
Nano Titanium Dioxide (TiO_2) in Sewage Sludge and Sewage-Amended Soils

TiO_2 Nanoparticles (NPs) Production & Use

Sewage Treatment Plant Sewage Sludge Products

TiO_2 NPs were repeatedly identified across the sewage sludge types tested.

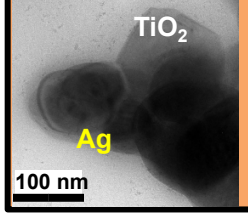
They have faceted shapes with the rutile crystal structure, and typically form small, loosely packed aggregates.



Terrestrial Environment Agricultural Soils

8 weeks incubation in the field after soils amended with Ag NPs-spiked sewage sludge materials.

TiO_2 NPs from sewage sludge products interact with Ag and then enter the environment as a soil amendment.

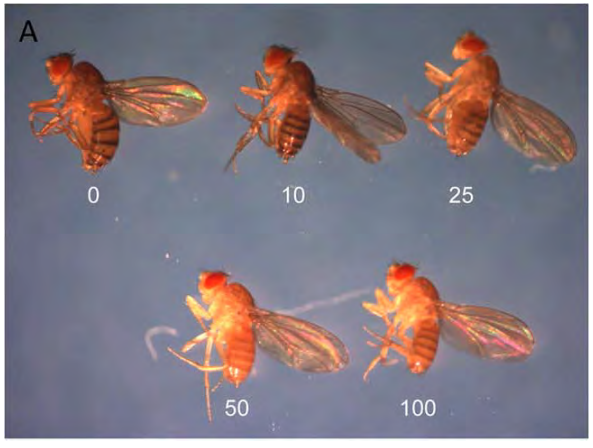


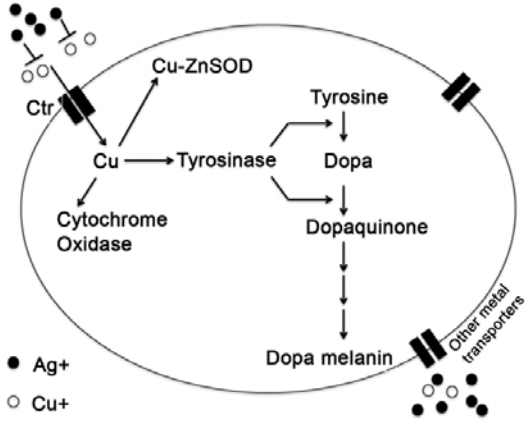
[1]Department of Geosciences, Virginia Tech University

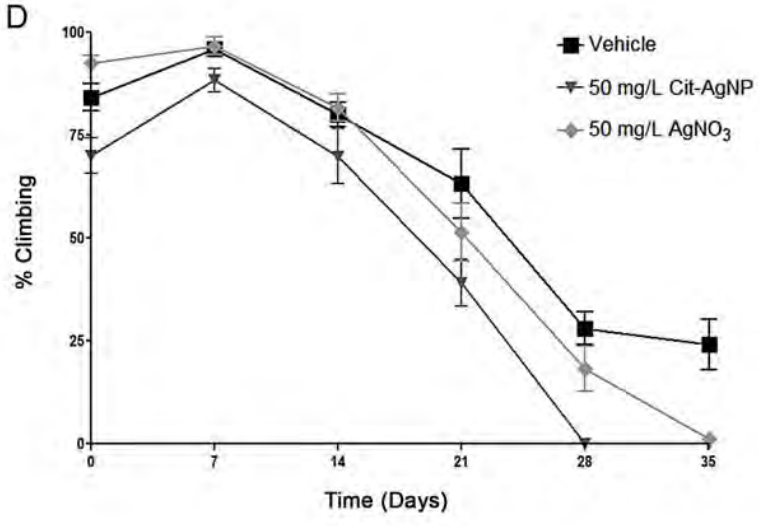
NSF EF-0830093 CENT

Silver Nanoparticles affect *Drosophilia*

Najealicka Armstrong, Malai Ramamoorthy, Delina Lyon, Kimberly Jones, Atanu Duttaroy
Department of Civil and Environmental Engineering, Howard University







AgNPs interfere with Cu-dependent enzymes, affecting biological processes in the fruit flies.

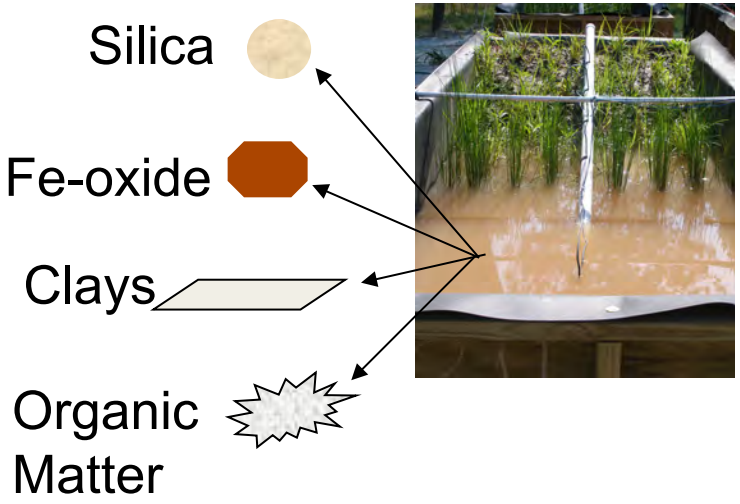
Armstrong N, et al,(2013) PLoS ONE 8(1): e53186. doi: 10.1371/journal.pone.0053186

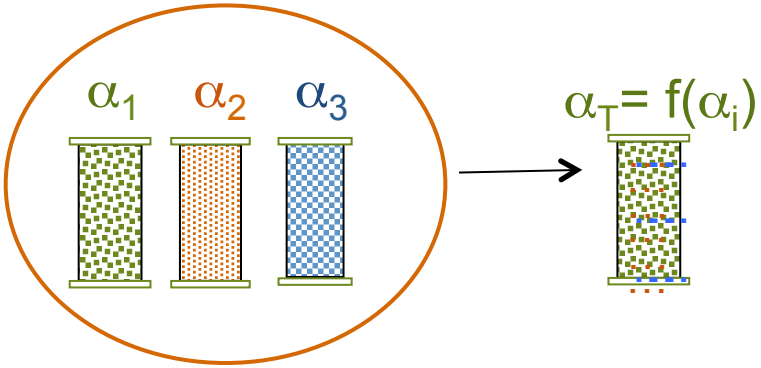
NSF EF-0830093 CEINT

Attachment Efficiency:

Predicting ENM transport and attachment

Delina Lyon[1], Shihong Lin[2], Stacey Louie[3], Ricardo Charles[1], Greg Lowry[3], Mark Wiesner[2], Kimberly Jones[1]





- Attachment efficiency, α, can be used to predict NP transport in the environment by using compositional weighted averaged α values.
- Models/theories can be developed to predict α for ENMs and coated ENMs.

[1] Department of Civil and Environmental Engineering, Howard University
[2] Department of Civil and Environmental Engineering, Duke University
[3] Department of Civil and Environmental Engineering, Carnegie Mellon University

NSF EF-0830093 CEINT

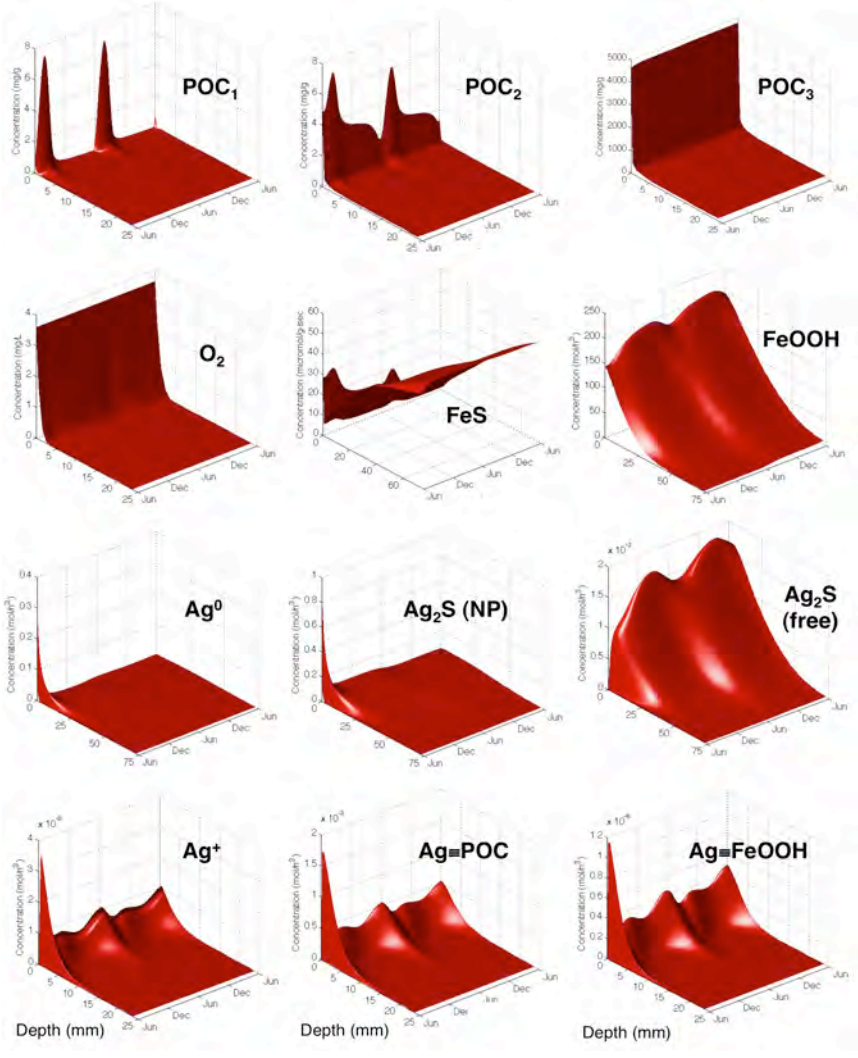
Modeling Nanosilver Transformations in Freshwater Sediments

Amy Dale[1], Greg Lowry[2], and Elizabeth Casman[1]

[1] Department of Engineering and Public Policy, Carnegie Mellon University

[2] Department of Civil and Environmental Engineering, Carnegie Mellon University

- Due to their tendency to aggregate, nanomaterials are expected to accumulate in the sediments of aquatic systems, where they will undergo chemical transformations that will affect their toxicity as well as their mobility.
- We have developed a 1-dimensional diagenetic model for nano-silver speciation and distribution in freshwater sediments and calibrated it to CEINT mesocosm data.
- This model will be part of an integrated fate and transport model for nanomaterials to be used in environmental risk assessment and will enable the formulation of science-based policy for the regulation of nanomaterials.



Amy L. Dale, Gregory V. Lowry, Elizabeth A. Casman (in preparation) "Modeling Nanosilver Transformations in Freshwater Sediments."

NSF EF-0830093 CEINT

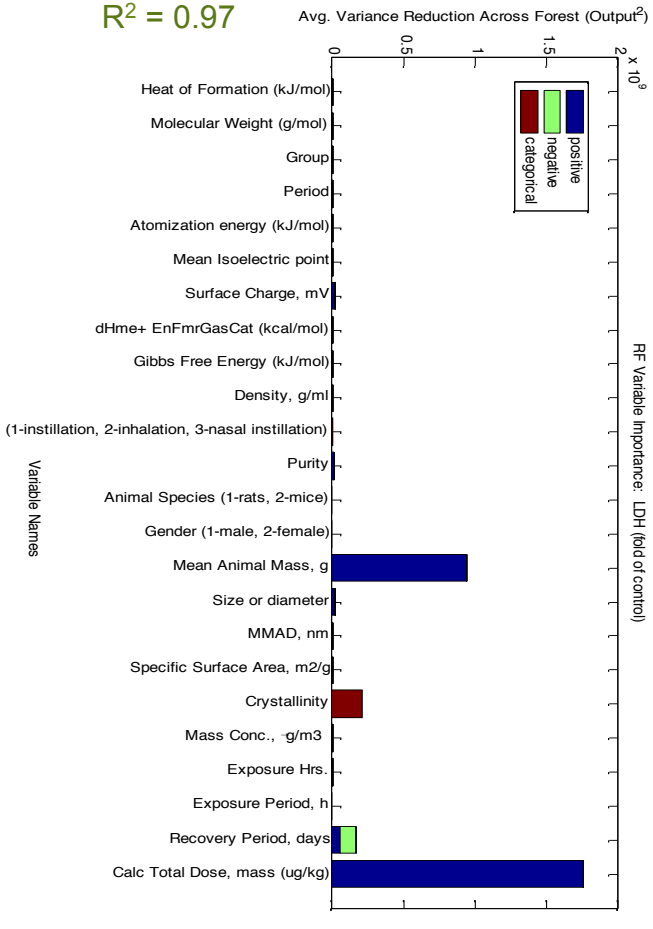
Meta-Analysis of *in vivo* pulmonary toxicity studies

Jeremy Gernand and Elizabeth Casman

Department of Engineering and Public Policy, Carnegie Mellon University

BAL-LDH Response to Metal Oxide* NPs

$R^2 = 0.97$



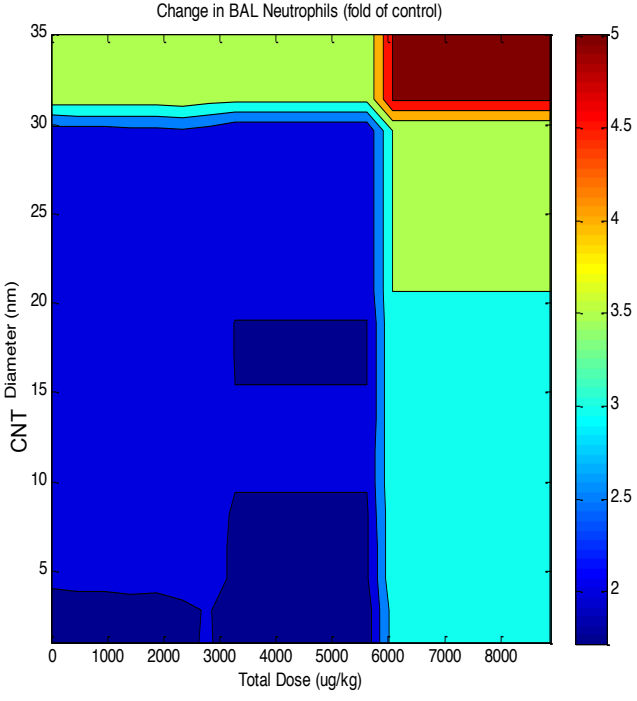
* TiO_2, CeO_2, Fe_2O_3, MgO, NiO, SiO_2, ZnO

Machine learning techniques produce models relating nanoparticle properties and experimental conditions to indicators of pulmonary toxicity.

Results facilitate the quantitative comparison of factors contributing to toxicity across studies and elucidate the interactions between such factors.

Insights gained from these models test hypotheses relating to nano-particle-specific causes of pulmonary toxicity.

Interaction of CNT diameter and CNT dose

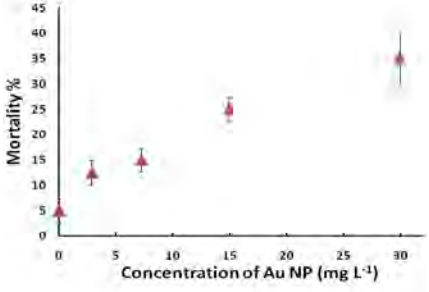


Jeremy Gernand and Elizabeth Casman (in review) "A meta-analysis of carbon nanotube pulmonary toxicity studies – how physical dimensions and impurities affect the toxicity of carbon nanotubes. *Risk Analysis*

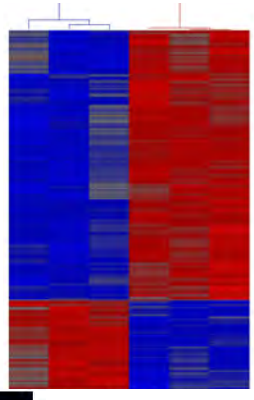
NSF EF-0830093 CEINT

Toxicogenomic Effects of Au-NPs on *C. elegans*

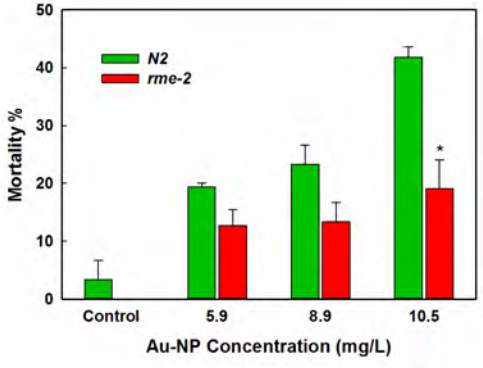
O. Tsyusko, J. Unrine, D. Spurgeon, E. Blalock, M. Tseng, D. Starnes, and P. Bertsch
Department of Plant and Soil Sciences, University of Kentucky

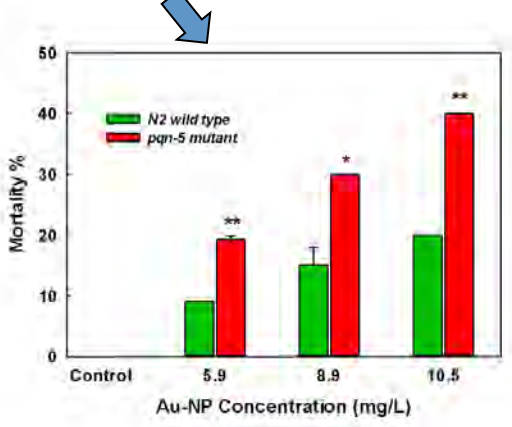


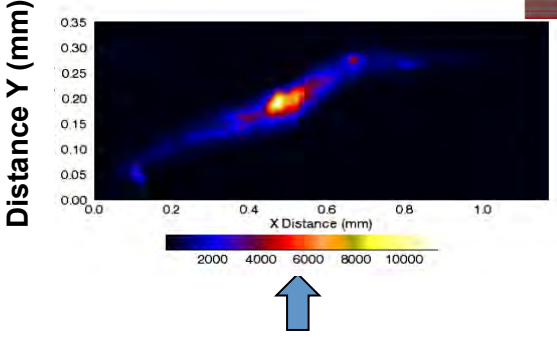
Control Au-NPs

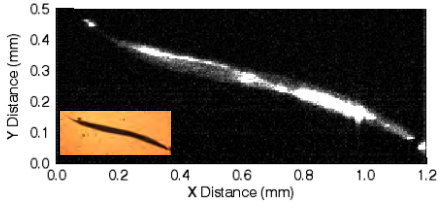


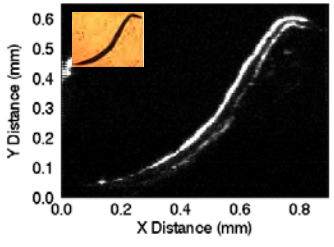
Endocytosis and Unfolded Protein Response (UPR)

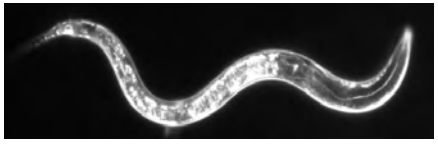












- Demonstrated that *rme-2* from the endocytosis pathway is involved in Au-NP uptake
- Genes from a *C. elegans* –specific UPR pathway, such as pqn-5, plays a role in detoxification of Au-NPs

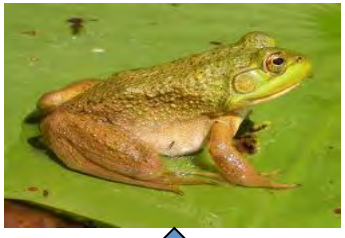
Tsyusko et al. *ES&T 2012 46: 4115*

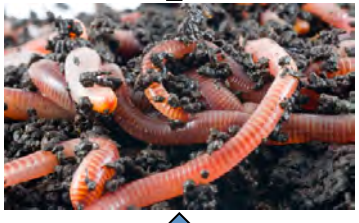
NSF EF-0830093 CEINT

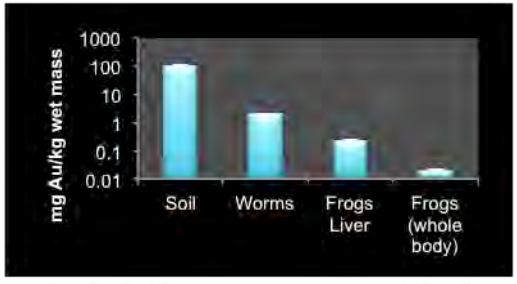
Trophic Transfer Enhances Bioavailability of Au Nanoparticles

J. Unrine, O. Zhurbich, A. Shoults-Wilson, O. Tsyusko and P. Bertsch

Department of Plant and Soil Sciences, University of Kentucky





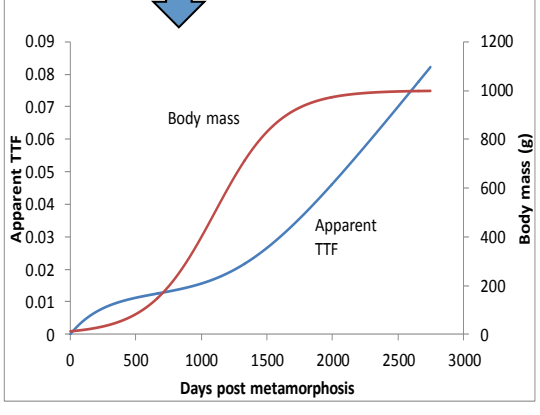


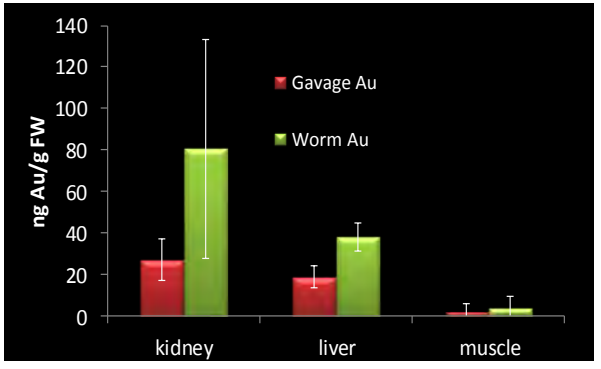
$$TTF(t) = C_{frog}(t)/C_{worm}(t) \quad (1)$$

$$C_{frog}(t) = A_{frog}(t)/M_{frog}(t) \quad (2)$$

$$M_{frog}(t) = M_a/(1 + be^{-kt}) \quad (3)$$

$$A_{frog}(t) = (C_{worm}(t) \times AE \times IR \times M_{frog}(t)) + A_{frog(t-1)} \quad (4)$$





- Demonstrated trophic transfer of Au nanoparticles.
- Showed that trophic transfer enhances bioavailability of nanoparticles.
- Modeled concentrations over lifespan of predator using a biodynamic model.

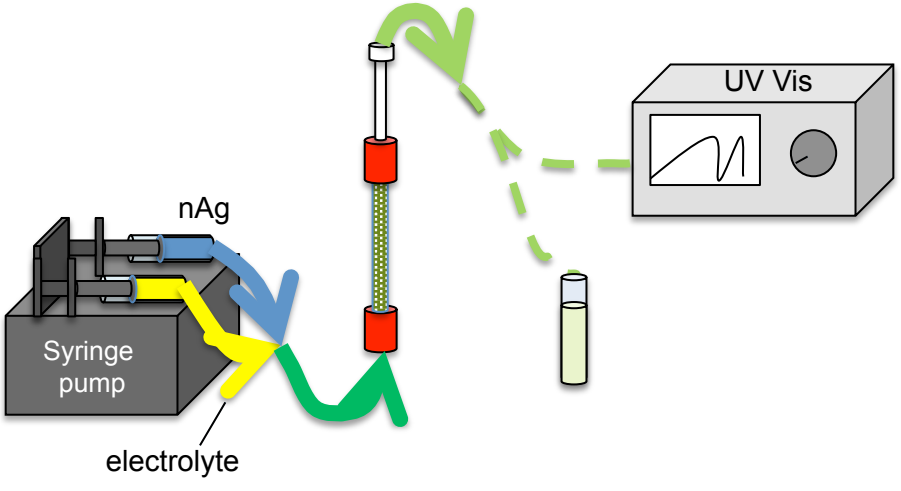
Unrine et al. *ES&T 2012 46: 9753*

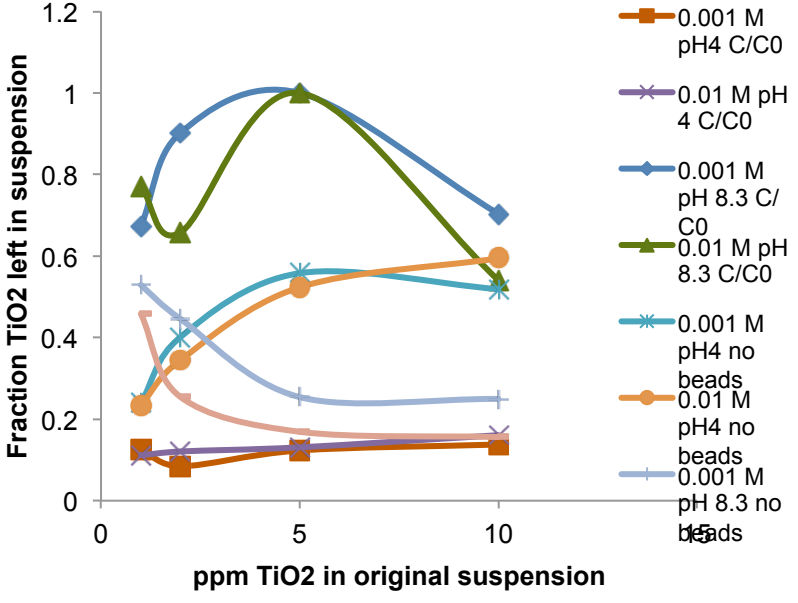
NSF EF-0830093 CENT

Fate and Transport of Nano TiO_2 at Expected Environmental Concentrations

Ricardo Charles, Delina Lyon, Kimberly Jones

Department of Civil and Environmental Engineering, Howard University





Batch and column studies allow investigation of TiO_2 attachment at low concentrations (~100 ppb).

NSF EF-0830093 CEINT

CEINT-NISE Net Partnership- Highlighted as Model

NISE Net invites CEINT Associate Director to highlight museum-university partnerships

CEINT Partnered with NISE Net since 2009- 3 national museum partners

Over 17,000 visitors to CEINT partner museums: NanoDays 2009-13

NanoDays➔ NanoNights➔ Nano Camps➔ Science Cafes➔ Educational Video

Field trips for museum educators to CEINT➔Partner on new Museum grants

Why are medaka used in CEINT research?

Benefits of Museum Partnerships to University Research Center

Interested audiences -broad engagement- network facilitates national expansion

NISE Net templates help students pitch level for science translation

CEINT students value learning science translation

Activities demo CEINT research for broad, continuing use

Allows more depth face-to-face public engagement:

What roles do microbes play in the environment?
How could nanoparticles influence those roles?

Do coatings change where nanoparticles go?

CEINT Video on NISE Net Website
Does Every Silver Lining Have a Cloud?

NSF EF-0830093

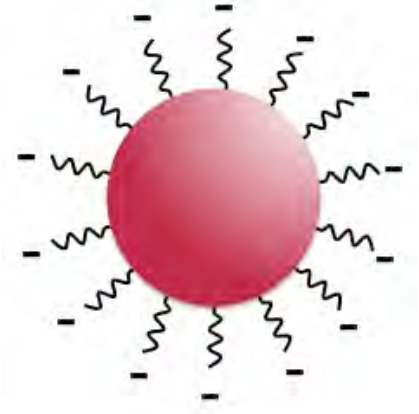
CEINT

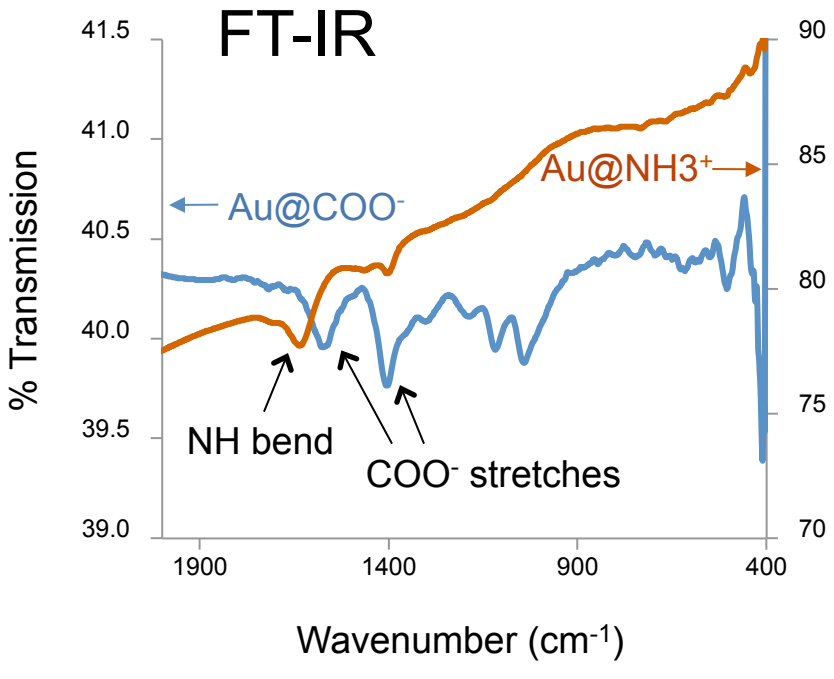
Gold NPs with Positive or Negative Charge

Synthesized to explore the effect of surface charges on transport, transformations, biouptake and toxicity

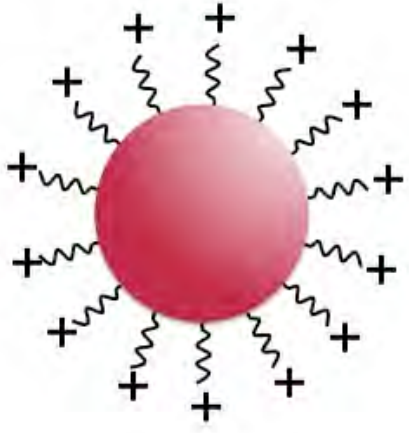
Stella Marinakos and Jie Liu
Department of Chemistry, Duke University

zeta potential: -42 mV





zeta potential: +43 mV



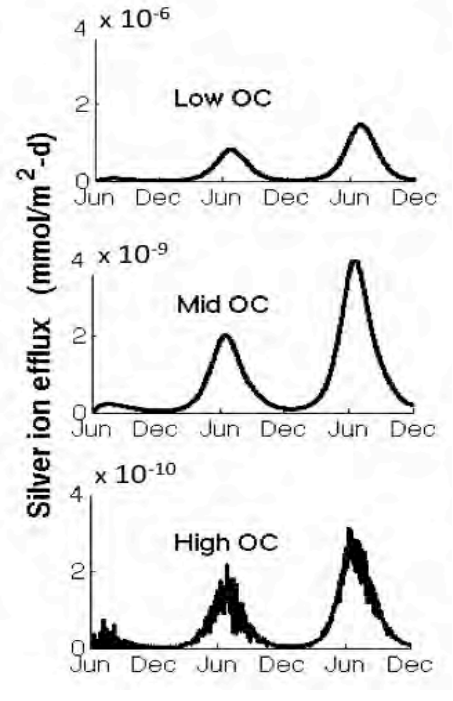
NSF EF-0830093

Environmental properties are at least as important as nanomaterial properties in assessing behavior and effects

Ben P. Colman[1], Emily Bernhardt[1], Jason M. Unrine[2], Audrey J. Bone[1], Rich Di Giulio[1], Paul Bertsch[2], Cole W. Matson[3], Mark R. Wiesner[1], and Gregory V. Lowry[4]

[1]Duke University, [2]University of Kentucky, [3]Baylor University, [4]Carnegie Mellon University

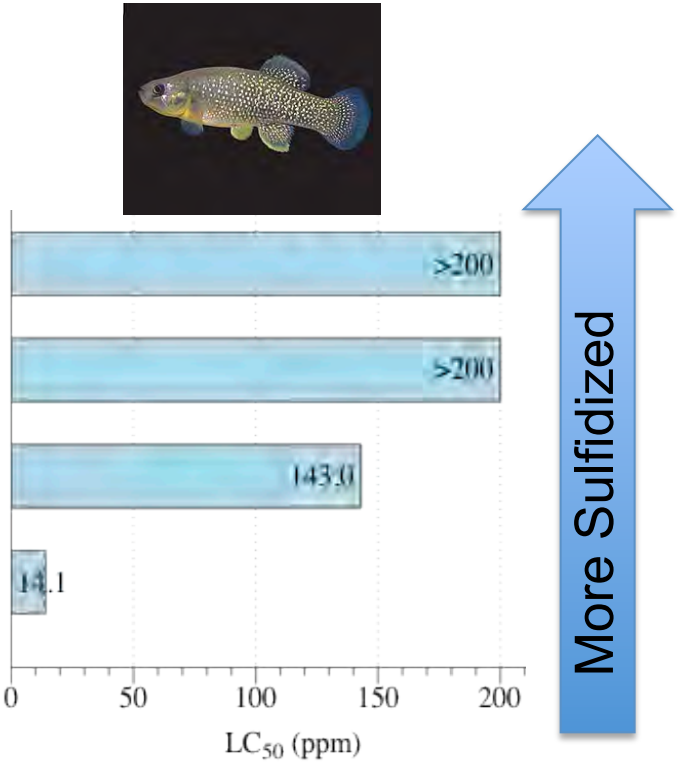
Research must identify macroscopic behavior of nanomaterials in representative environments (e.g. transformations), and the impacts of those behaviors on observed effects.



Organic carbon level in sediment controls Ag NP sulfidation and Ag^+ efflux

AND

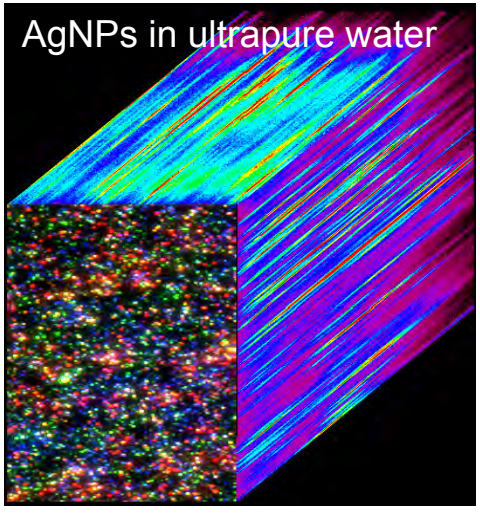
Resulting sulfidation of AgNPs dramatically decreases toxicity

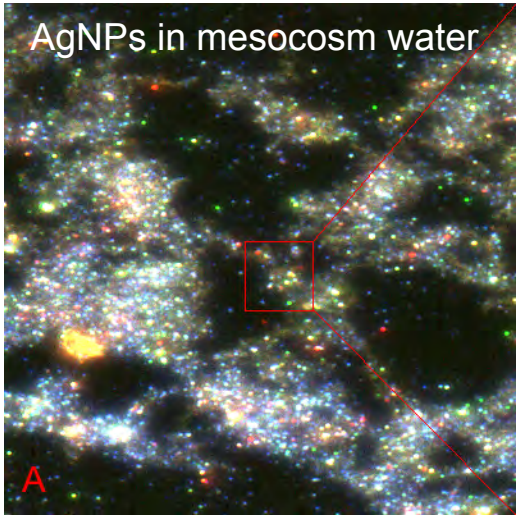


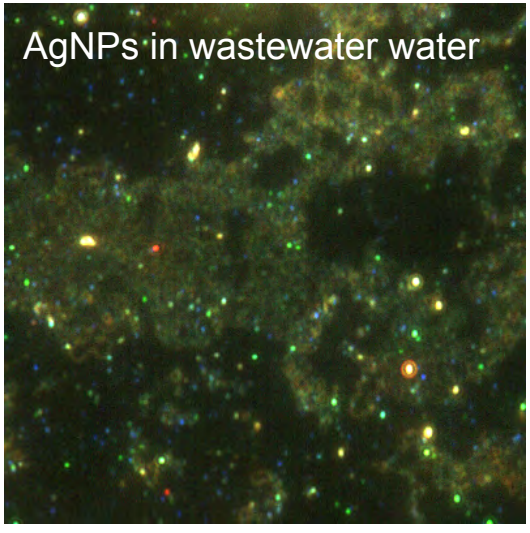
NSF EF-0830093 CEINT

Darkfield Hyperspectral Imaging Microscopy:
Nanoparticle Characterization and Analysis in Complex (Real) Environments

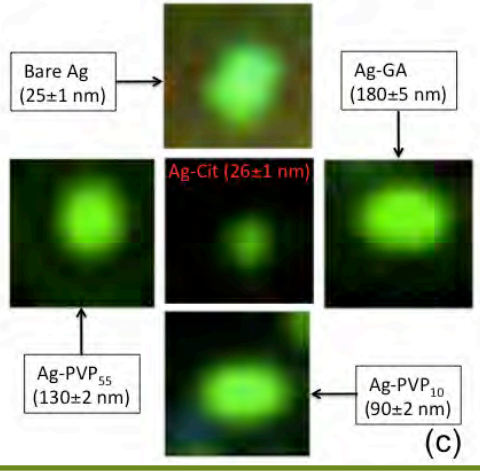
Appala Raju Badireddy[1], Jie Liu[2] and Mark R. Wiesner[1]

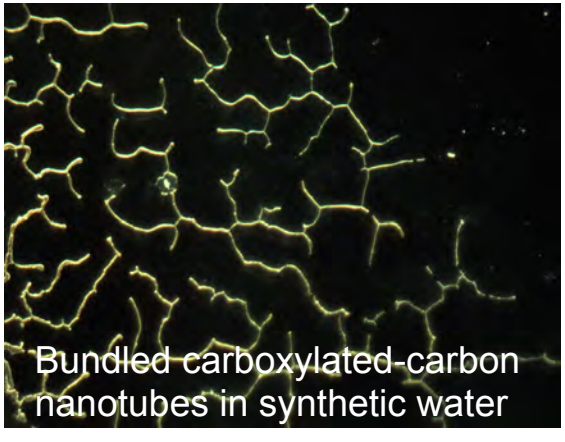


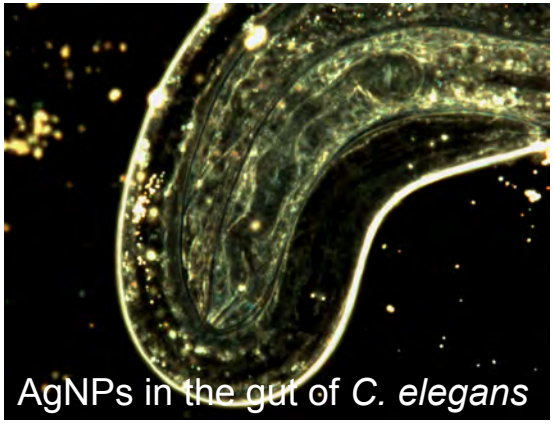




Type of coating affects the hydrodynamic size of AgNPs







Duke UNIVERSITY

[1] Department of Civil and Environmental Engineering, Duke University
[2] Department of Chemistry, Duke University

NSF EF-0830093 CEINT

Modeling the Environmental Release, Transport, Transformation and Biouptake of Nanomaterials: An Integrated Center-wide Initiative

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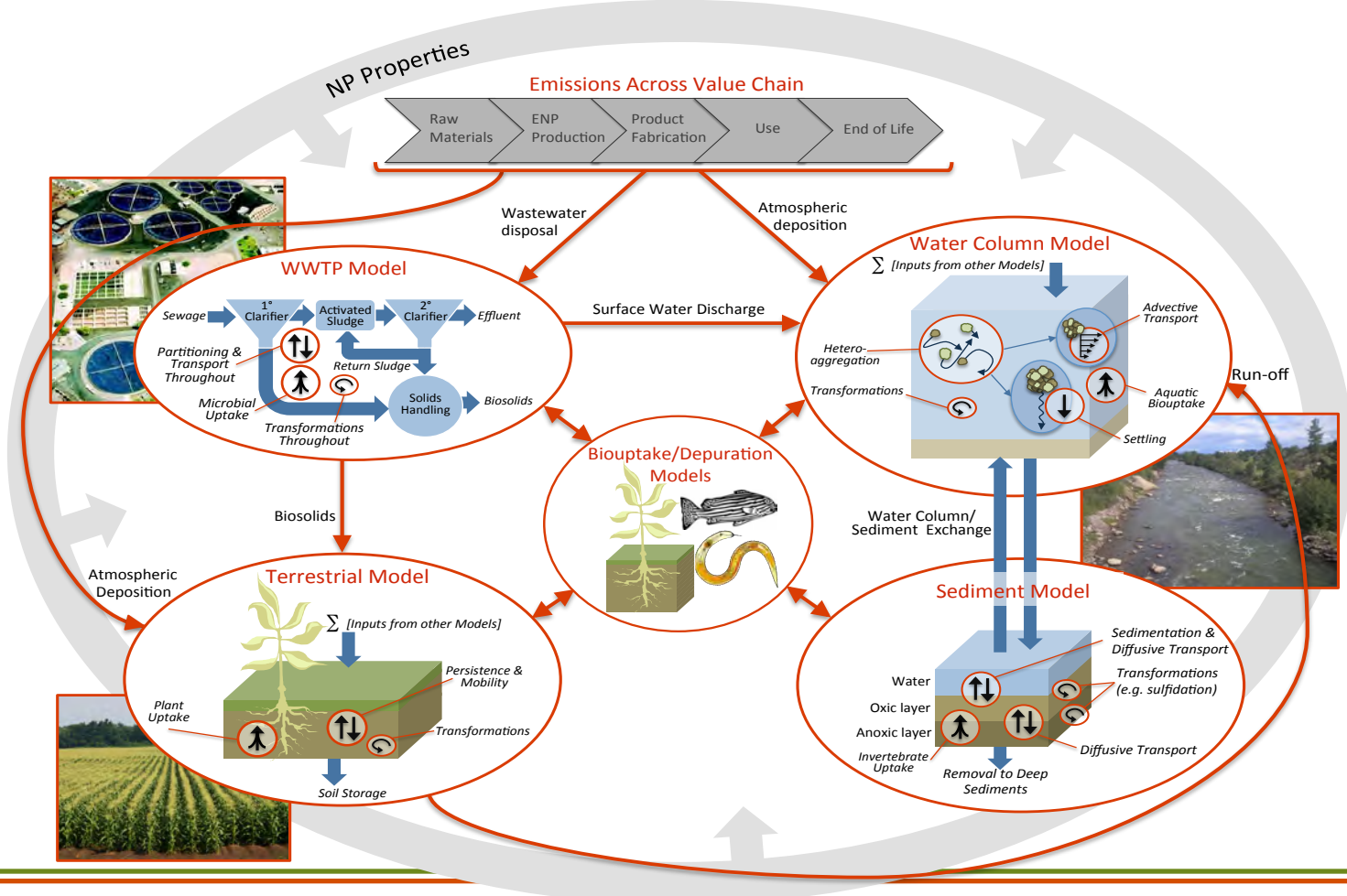

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