A Risk Forecasting Framework for Nanomaterials

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US-EU Collaborations in NanoEHS
10-11 March 2011

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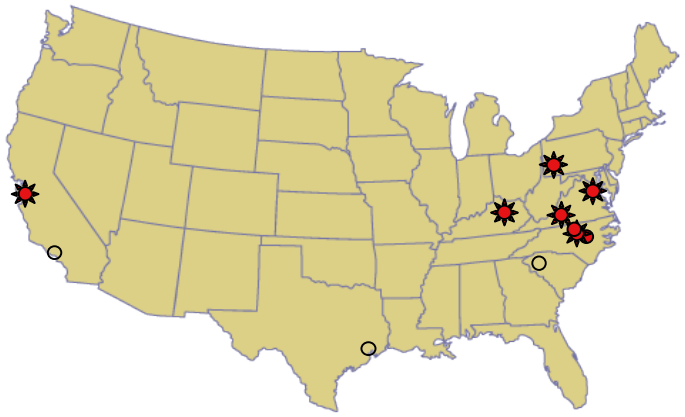
Center for the Environmental Implications of NanoTechnology (CEINT)

1. *Elucidate general principles that determine environmental behavior of nanomaterials*
2. *Provide guidance in assessing existing and future concerns*
3. *Educate students and the general public regarding nanotechnology, nanoscale science, and the environment*

- *Core Institutions: Duke (headquarters), CMU, Howard, Virginia Tech, U Kentucky, Stanford*
- *36 faculty, 76 undergraduate and graduate students*
- *Collaborating US universities & government entities*
- *ICEINT- International partners (France) supported by CNRS and CEA*
- *TINE (UK- Rothamsted, Cranfield, Lancaster, NERC CEH), ENPRA (IOM)*



CEINT
International Consortium for the Environmental Implications of Nano Technology

ENPRA
Risk Assessment of Engineered NanoParticles
SEVENTH FRAMEWORK PROGRAMME

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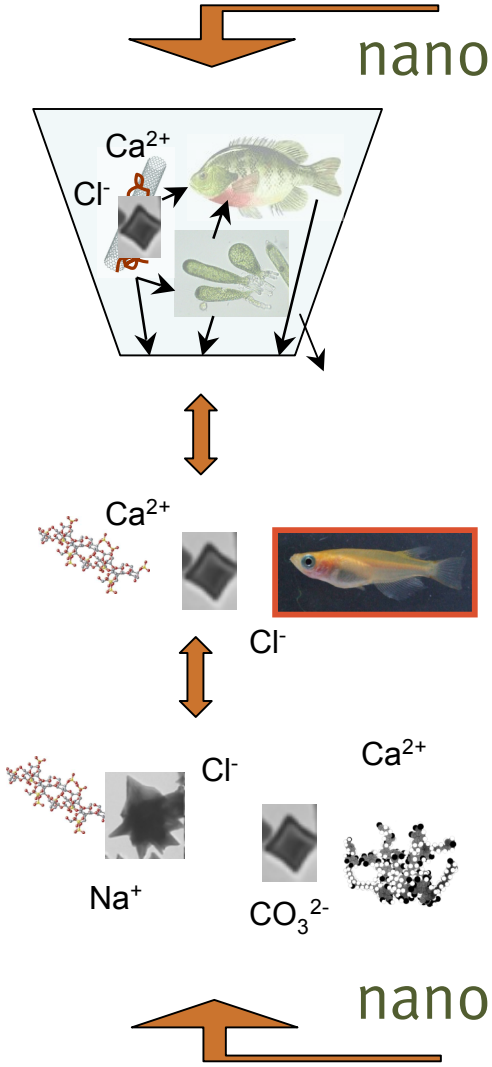
Research Themes



exposure

hazard

exposure

Modeling,
Risk assessment,
Tools for risk management

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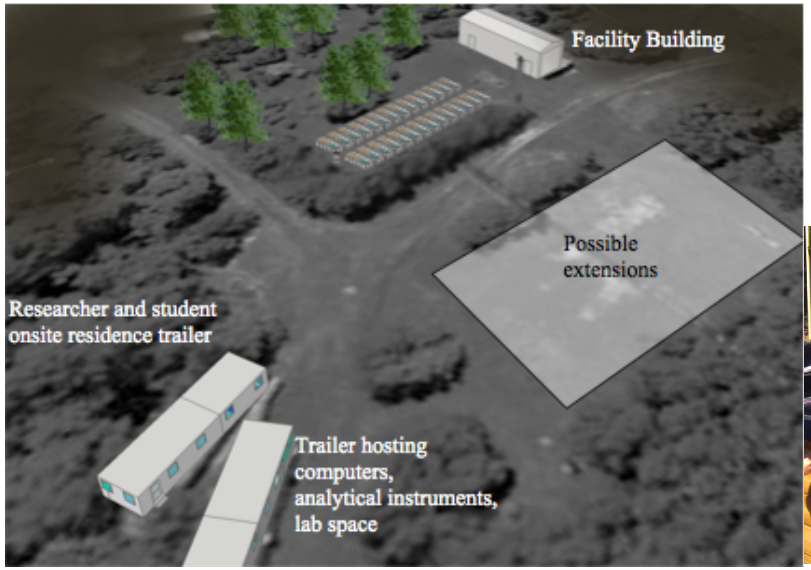
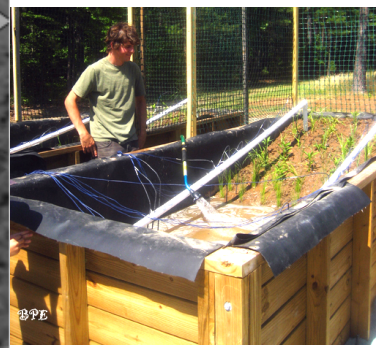
Mesocosms

- 26 mesocosms constructed, planted
- Probes, data acquisition, and web-based data monitorin
- Webcam
- Preliminary experiment started Oct '09
- First duplicated experiment with Ag NPs to begin May- June 2010
- CeO2, SWCNTs, TiO2 (single mc)





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Example: TiO2 exposure via wastewater discharge

exposure
*organismal impacts
*ecosystem impacts

vector describing nanoparticle characteristics

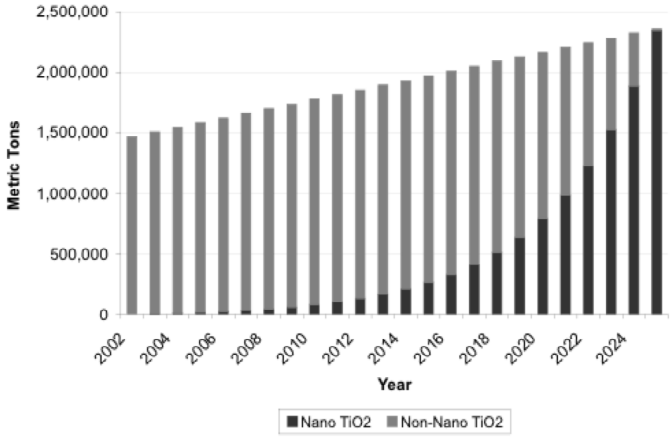
vector describing system (wastewater treatment plant, mesocosm)

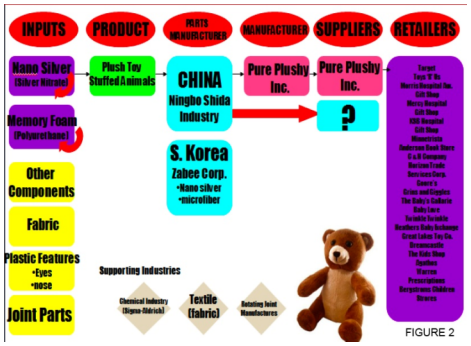
$$C_{TiO2,sludge} = (S_{TiO2}) f_{TiO2,ww} \cdot P_{sludge}\left(\vec{\lambda}_{TiO2}, \overrightarrow{\gamma_{ww}}\right) / [Q_{ww} r]$$

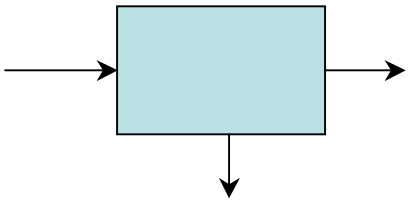
Source inventory (per time)
commercialization trends

usage profile
*social science
*engineering

Partitioning transfer function
*physical chemical properties
*transport
*microbiology







•Simulation
•Bayesian networks

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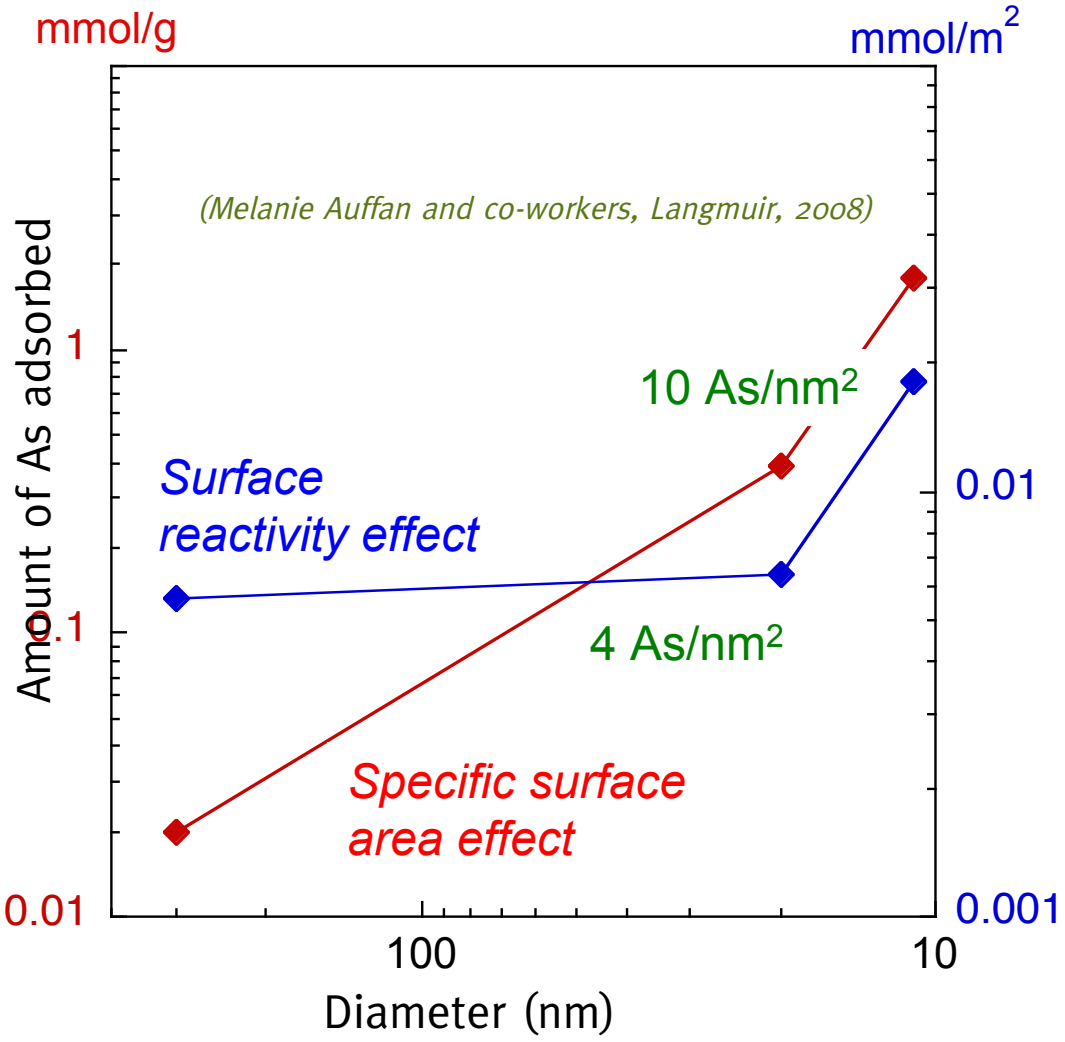
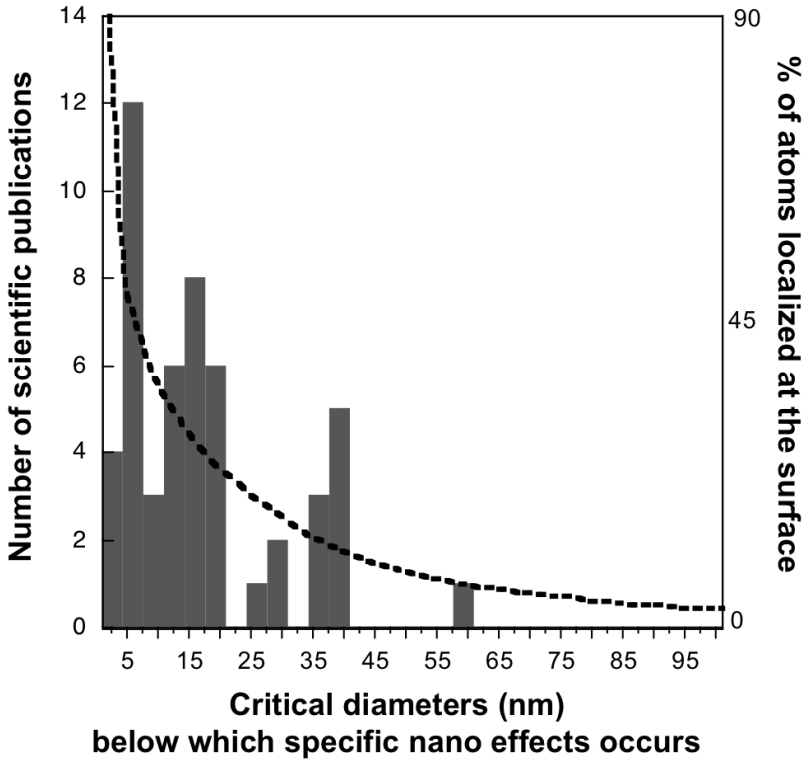
A NANOPARTICLE IS:
1) SMALL 2) HAS NOVEL PROPERTIES





Nature Nanotechnology 2009

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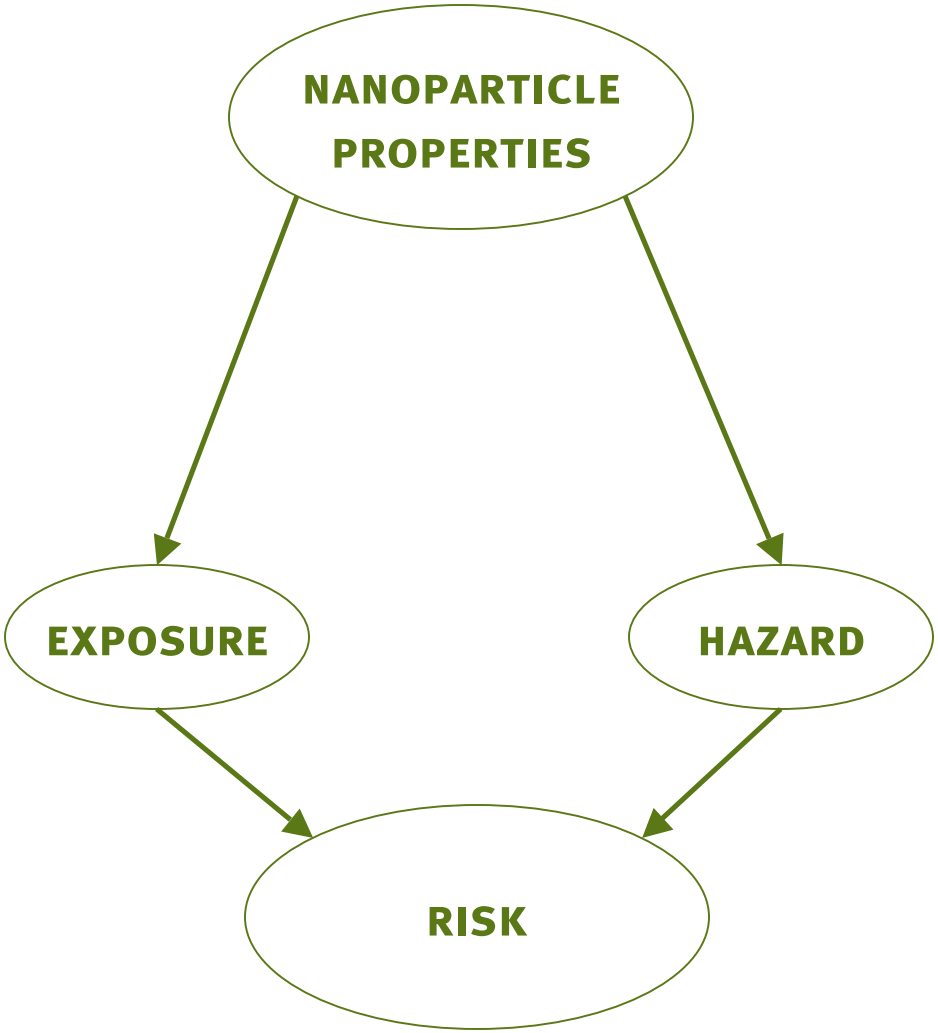
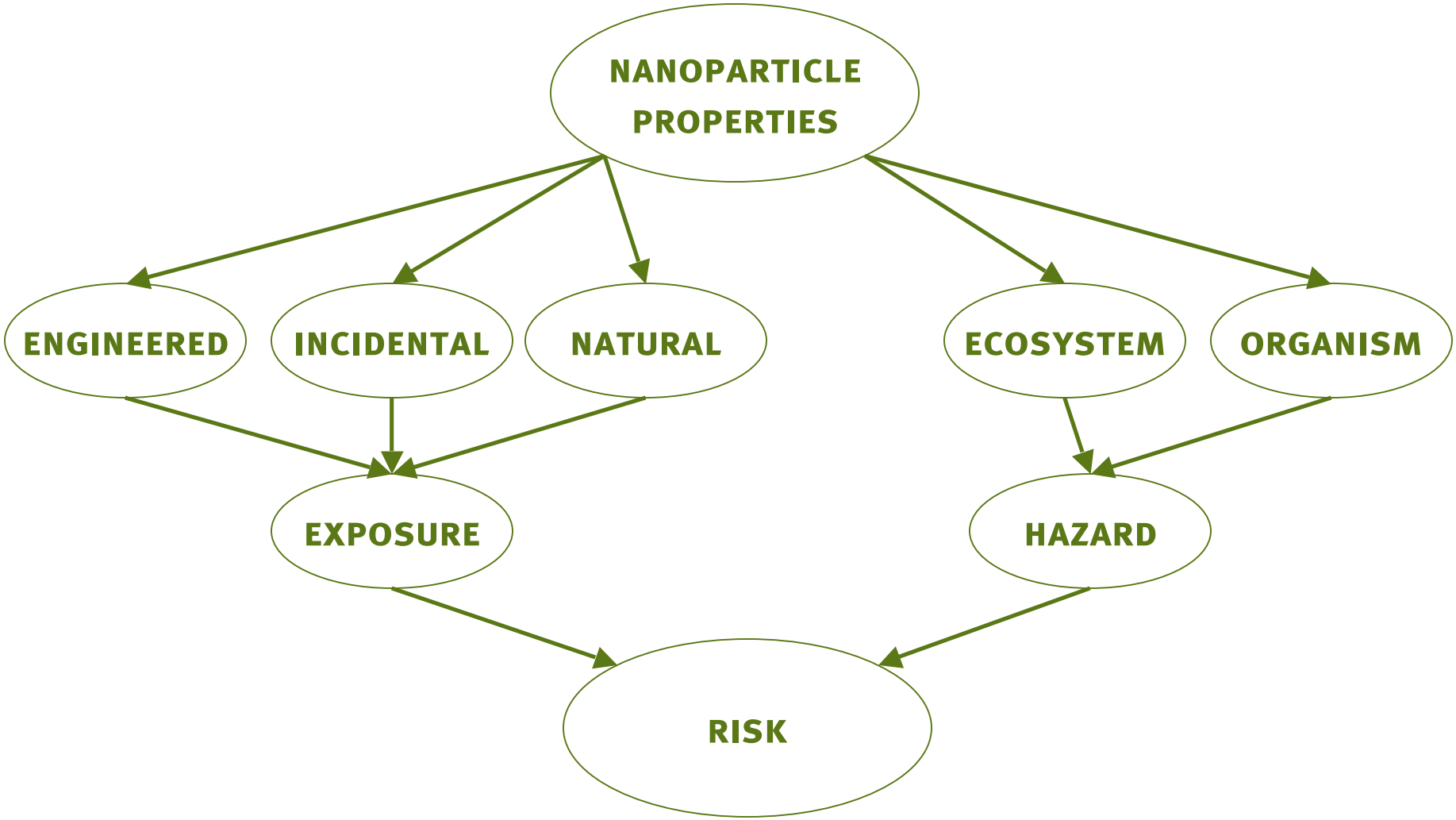
Desirable Elements of a risk forecasting framework

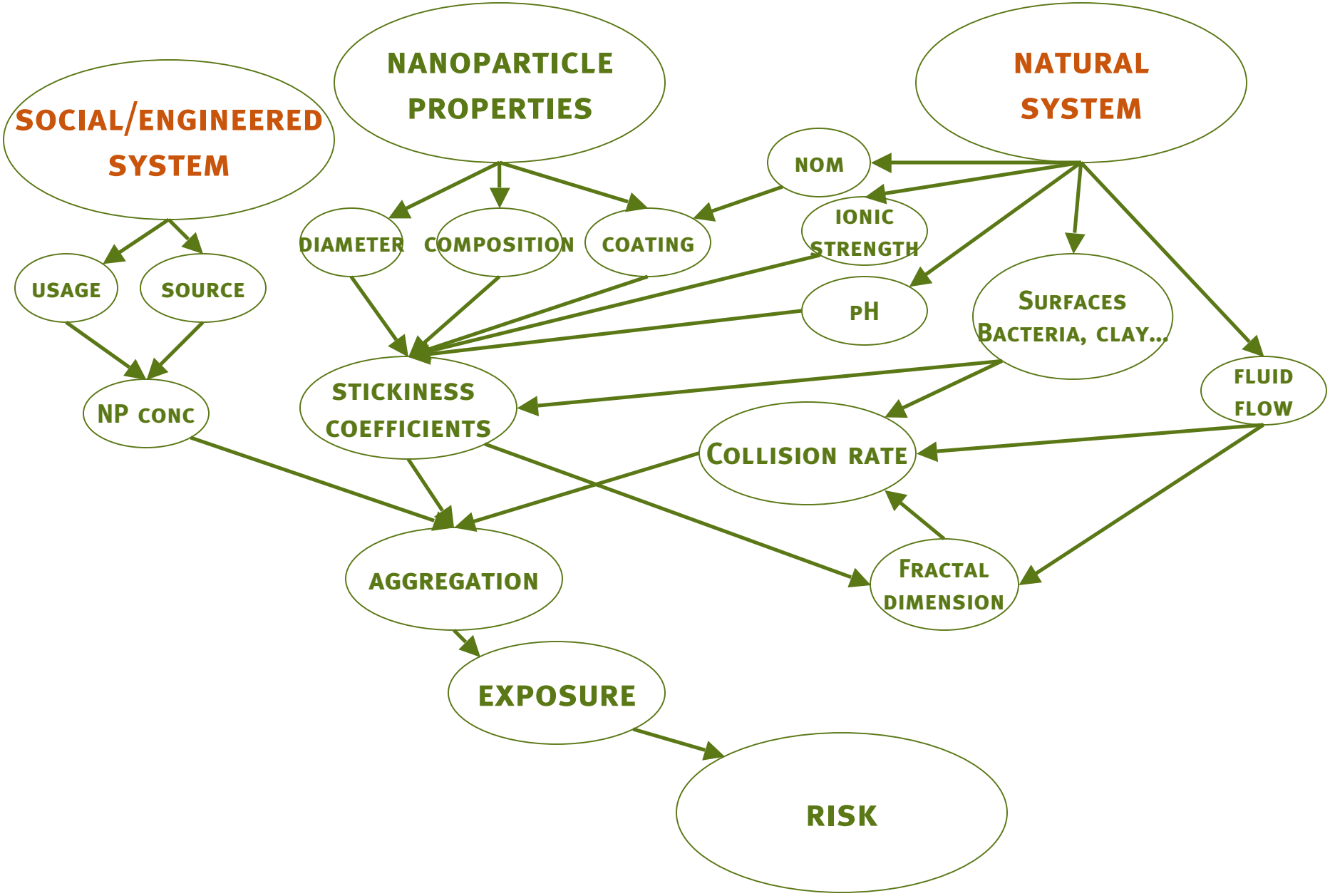
1) generates forecasts and associated levels of uncertainty for questions of immediate concern
2) Incorporates fundamental properties of nanomaterials with goal of forecasting risk for new materials
3) Considers all pertinent sources of nanomaterials
4) Includes life-cycle and ecosystem-level impacts
5) Ability to adapt and update risk forecasts as new information becomes available
6) feedback to improve information gathering
7) feedback to improve nanomaterial design

Risk Assessment Framework

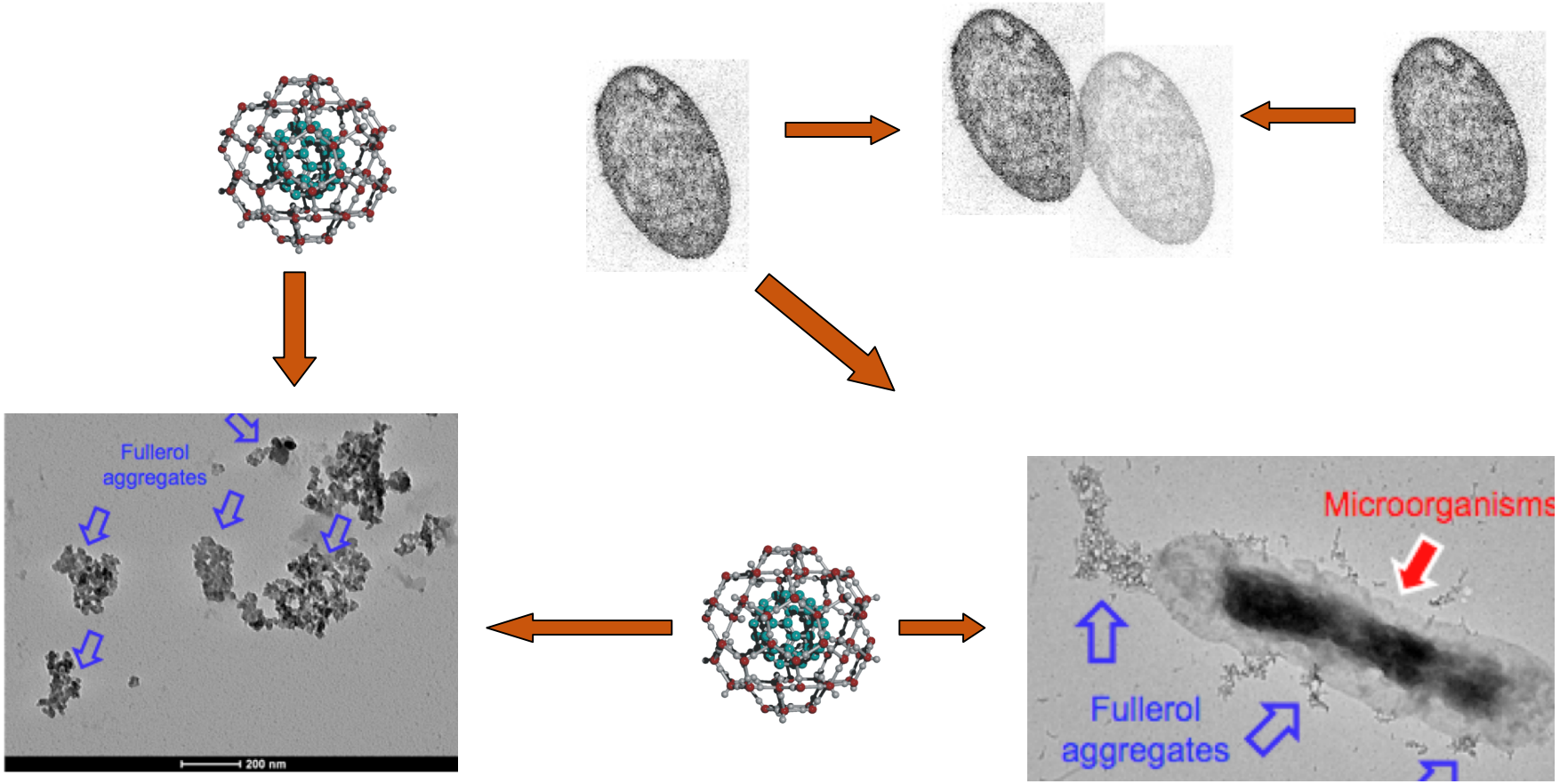


Multiple sources, multi-scale impacts

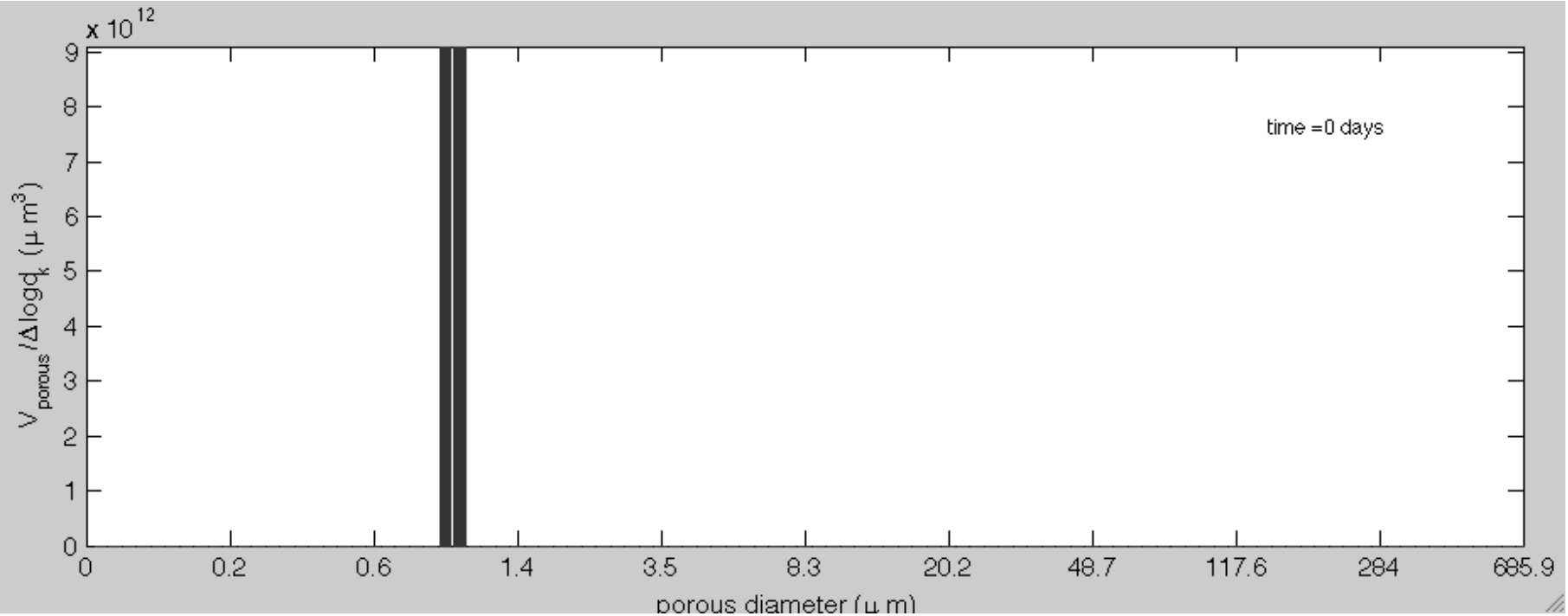



SOCIAL/ENGINEERED SYSTEM
NANOPARTICLE PROPERTIES
NATURAL SYSTEM
USAGE
SOURCE
DIAMETER
COMPOSITION
COATING
NOM
IONIC STRENGTH
pH
SURFACES BACTERIA, CLAY...
NP CONC
STICKINESS COEFFICIENTS
COLLISION RATE
FLUID FLOW
AGGREGATION
FRACTAL DIMENSION
EXPOSURE
RISK

Aggregation may occur between many components



Transfer function



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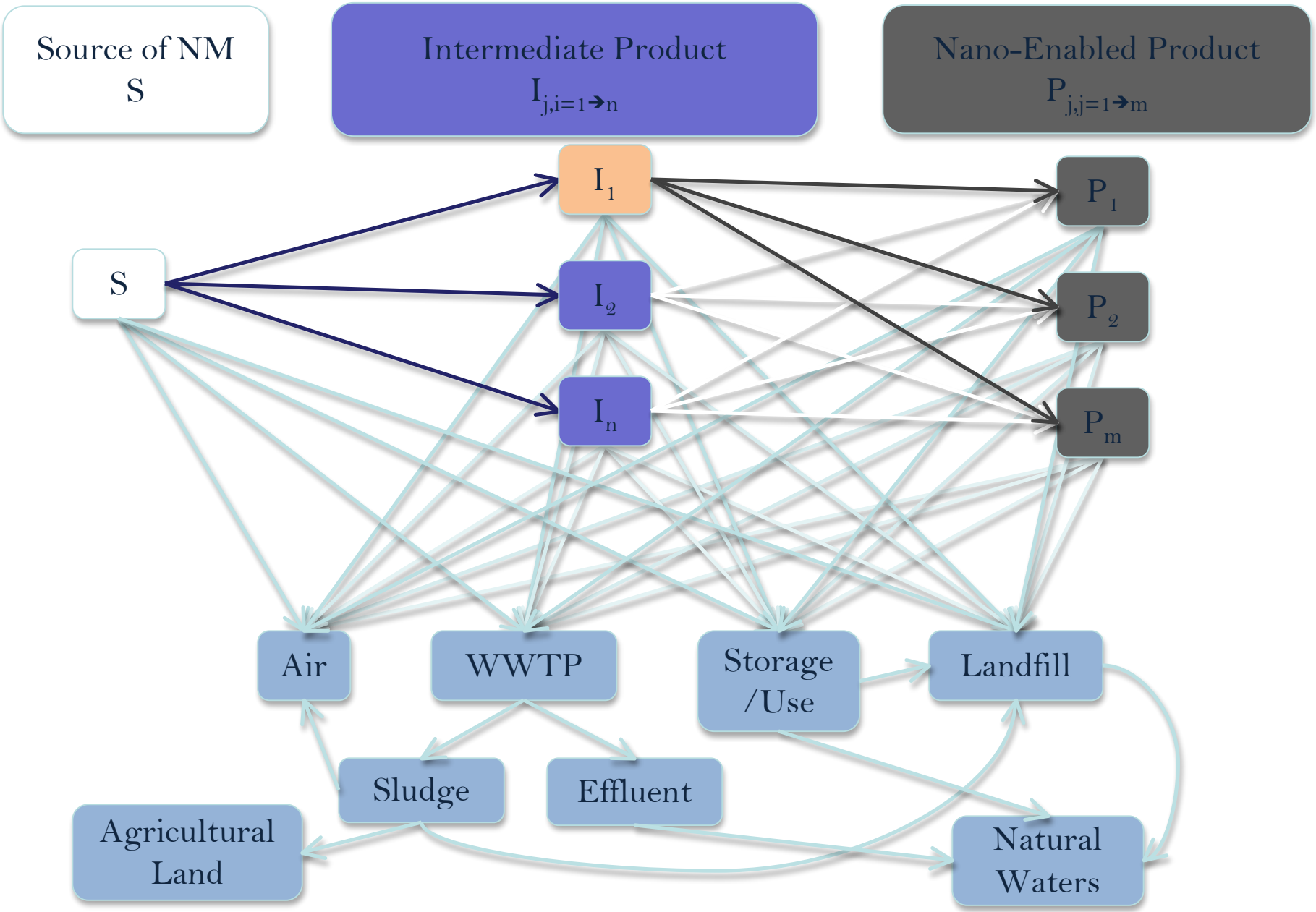
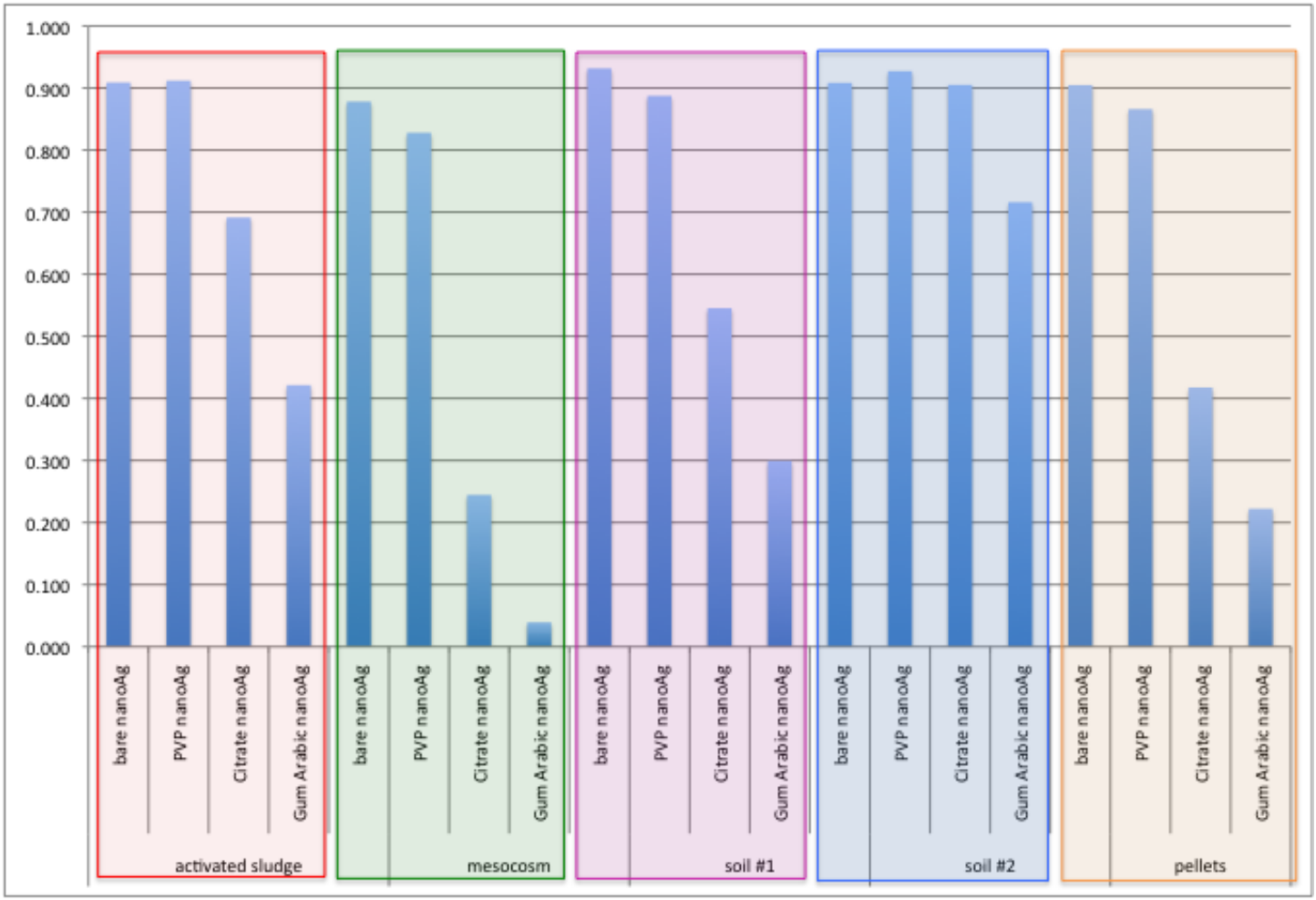

Source of NM
S
Intermediate Product
$I_{j,i=1\rightarrow n}$
Nano-Enabled Product
$P_{j,j=1\rightarrow m}$
S
I_1
I_2
I_n
P_1
P_2
P_m
Air
WWTP
Storage /Use
Landfill
Sludge
Effluent
Agricultural Land
Natural Waters

Nanomaterial fabrication estimates

Product	Lower bound (tpy)	Upper bound (tpy)
nano-TiO_2	7,800	38,000
nano-Ag	2.8	20
nano-CeO_2	35	700
CNT	55	1101
Fullerenes	2	80

C. Hendren, Wiesner and co-workers, in review

Partitioning experiments



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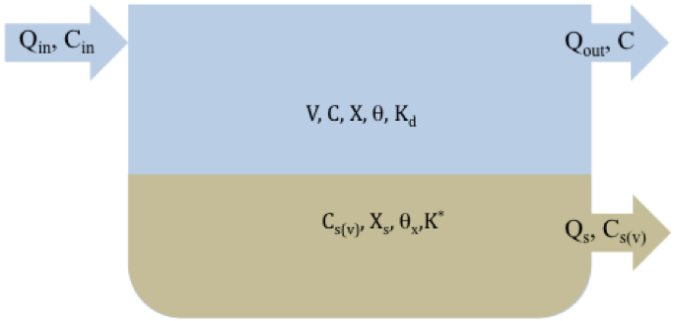
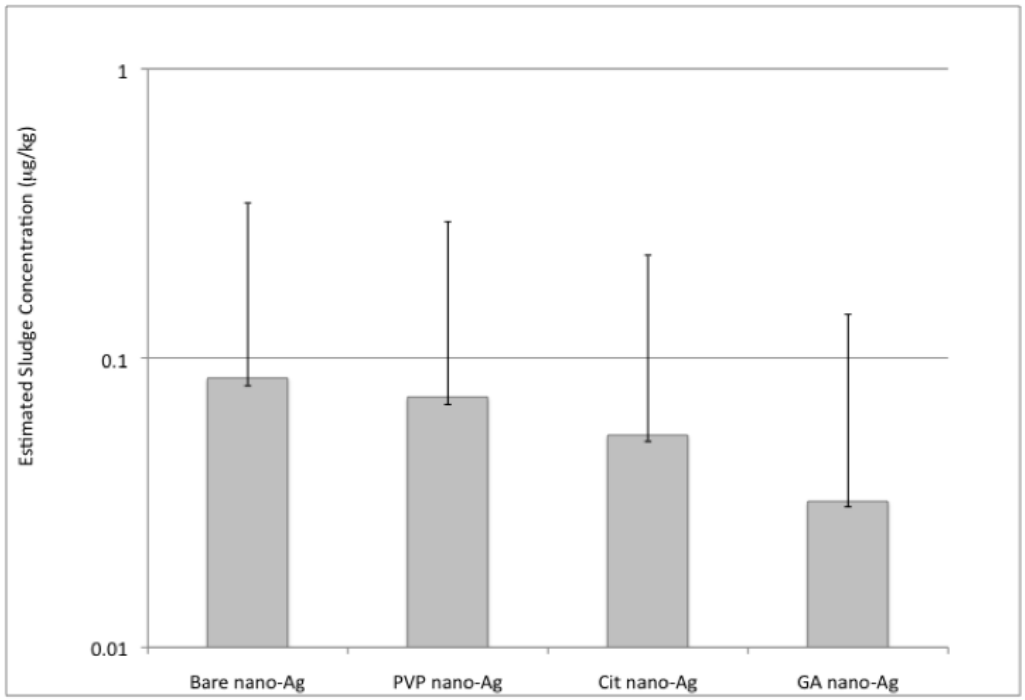
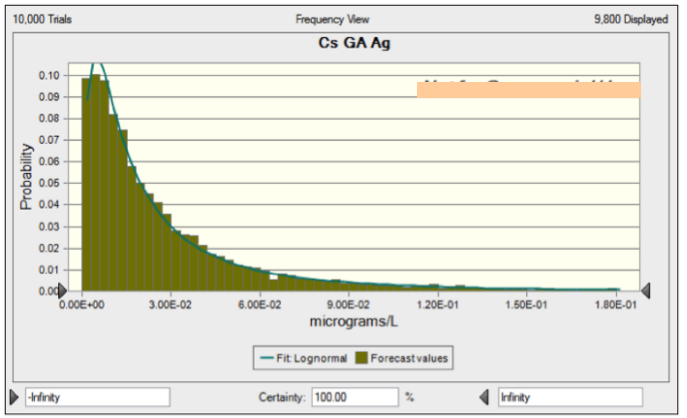
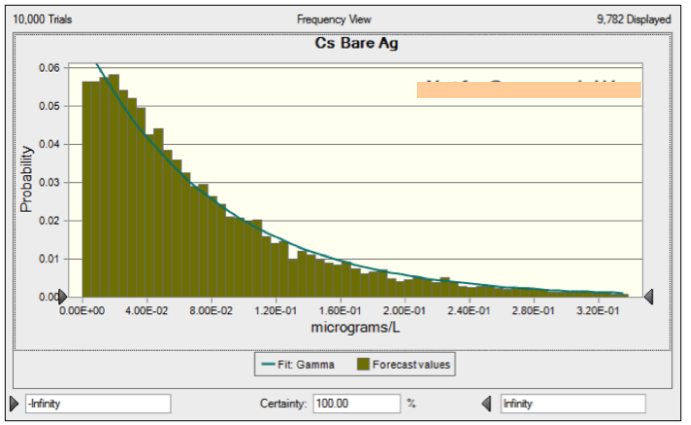
Monte Carlo calculations of sludge concentrations









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Thank You

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