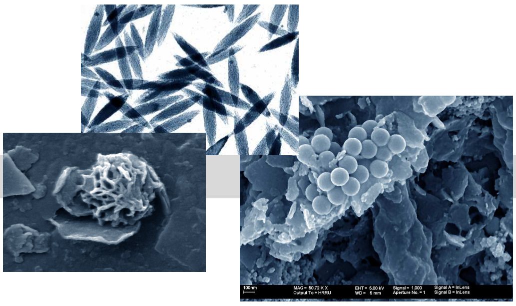
Engineered Nanoparticles in the Environment



FRANK VON DER KAMMER & THILO HOFMANN

DEPARTMENT OF ENVIRONMENTAL GEOSCIENCES

UNIVERSITY OF VIENNA

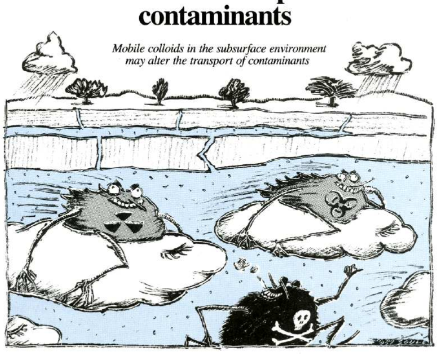
---

colloids & nanoparticles attract attention

ES&T FEATURES

Subsurface transport of contaminants

Mobile colloids in the subsurface environment may alter the transport of contaminants



John F. McCarthy
Oak Ridge National Laboratory
Oak Ridge, TN 37831-6036

John M. Zachara
Battelle Pacific Northwest Laboratory
Richland, WA 99352

1989

Research | Article

Manufactured Nanomaterials (Fullerenes, C_{60}) Induce Oxidative Stress in the Brain of Juvenile Largemouth Bass

Eva Oberdörster

Duke University Marine Laboratory, Beaufort, North Carolina, USA; Department of Biology, Southern Methodist University, Dallas, Texas, USA

Although nanotechnology has vast potential in uses such as fuel cells, microreactors, drug delivery devices, and personal care products, it is prudent to determine possible toxicity of nanotechnology-derived products before widespread use. It is likely that nanomaterials can affect wildlife if they are accidentally released into the environment. The fullerenes are one type of manufactured nanoparticle that is being produced by tons each year, and initially uncoated fullerenes can be modified with biocompatible coatings. Fullerenes are lipophilic and localize into lipid-rich regions such as cell membranes *in vitro*, and they are redox active. Other nano-sized particles and soluble metals have been shown to selectively translocate into the brain via the olfactory bulb in mammals and fish. Fullerenes (C_{60}) can form aqueous suspended colloids (nC_{60}); the question arises of whether a redox-active, lipophilic molecule could cause oxidative damage in an aquatic species. The goal of this study was to investigate oxyradical-induced lipid and protein damage, as well as impacts on total glutathione (GSH) levels, in largemouth bass exposed to nC_{60}. Significant lipid peroxidation was found in brains of largemouth bass after 48 hr of exposure to 0.5 ppm uncoated

bulb (Bodian and Howe 1941; DeLorenzo 1970; Howe and Bodian 1941; Oberdörster et al. 2004). This pathway also exists in rodents and fish for soluble metals (Tjälve and Henriksson 1999; Tjälve et al. 1995).

I hypothesized that this neuronal translocation pathway could also exist in fish for redox-active, lipophilic fullerenes, causing oxidative damage in the brain. I show here that juvenile largemouth bass exposed to 0.5-ppm aqueous uncoated fullerenes (nC_{60}) for 48 hr had a significant increase in lipid peroxidation of the brain, and glutathione (GSH) depletion in the gill.

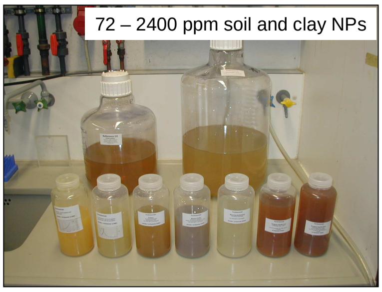
2004

- Engineered nanoparticles <u>will</u> be emitted to the environment
  (lessons learned from chemicals)

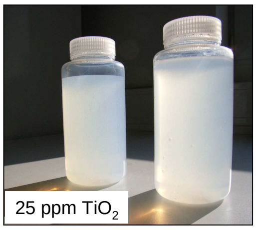
- Engineered nanoparticles <u>are</u> emitted to the environment

  - Titanium dioxide
  - Cerium dioxide
  - Silver
  - Iron
  - ???

- Relevant barriers ?
- Natural background issues
- Distribution ?
- Final destination ?


72 – 2400 ppm soil and clay NPs


121 ppm soil NPs

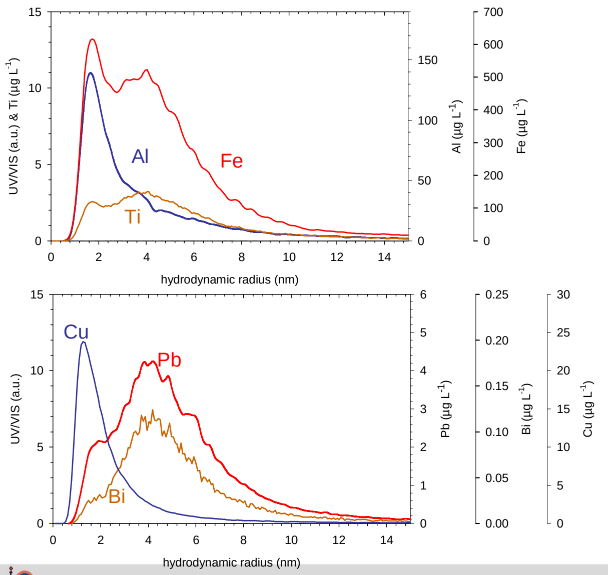

25 ppm TiO_2


650 ppm in surface runoff

@ 17.7 g/L NaCl

element distributions of natural nanoparticles (1 – 20 nm)

INTRODUCTION | METHOD | EXPERIMENTS | RESULTS | CONCLUSION

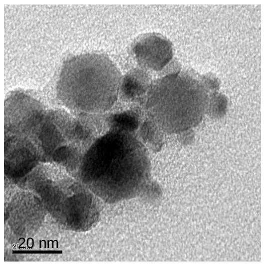


Analysis of soil NP with

Field-Flow Fractionation

coupled to

HR-ICP-MS

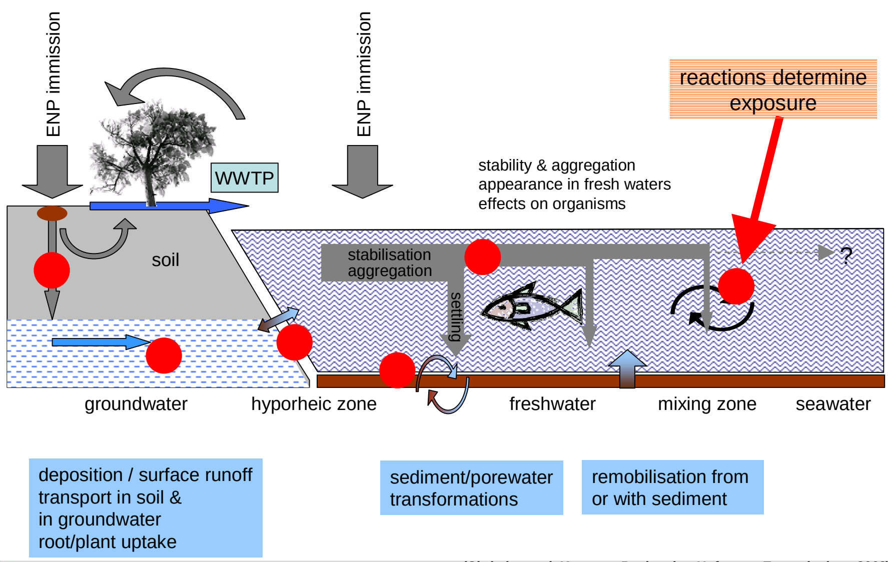


v.d.Kammer & Hassellov 2009 in prep.

center for earth sciences

distribution pathways in terrestrial and aquatic environment

INTRODUCTION | METHOD | EXPERIMENTS | RESULTS | CONCLUSION



(Christian; v.d. Kammer; Baalousha; Hofmann: Ecotoxicology 2008)

center for earth sciences

behaviour → fate → final sink → exposure

INTRODUCTION | METHOD | EXPERIMENTS | RESULTS | CONCLUSION

TABLE 3. Predicted Environmental Concentration (PEC) of Nano-Ag, Nano-TiO_2 and CNT in Air, Water, and Soil[a]

	unit	nano-Ag RE	nano-Ag HE	nano-TiO_2 RE	nano-TiO_2 HE	CNT RE	CNT HE
air	$\mu g\ m^{-3}$	1.7×10^{-3}	4.4×10^{-3}	1.5×10^{-3}	4.2×10^{-2}	1.5×10^{-3}	2.3×10^{-3}
water	$\mu g\ L^{-1}$	0.03	0.08	0.7	16	0.0005	0.0008
soil	$\mu g\ kg^{-1}$	0.02	0.1	0.4	4.8	0.01	0.02

[a] RE: realistic scenario; HE: high emission scenario.

(Mueller & Nowack: ES&T 2008)

aquatic organisms / export to ocean:

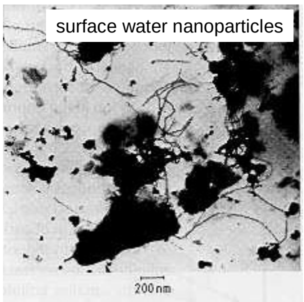
0.7 – 16 µg/L n-TiO_2

heteroaggregation with 25 - 50 mg/l SPM:

14 – 640 mg/kg n-TiO_2 in SPM

sediment concentration:

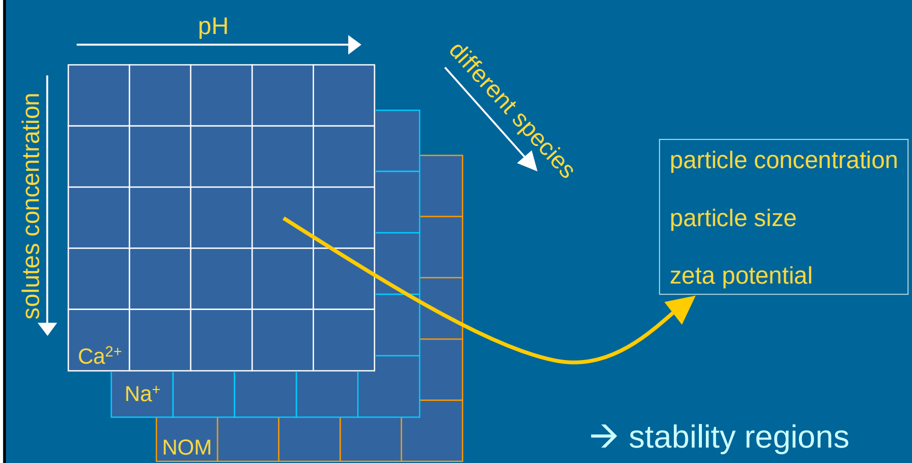
~ 20 – 800 mg/kg n-TiO_2



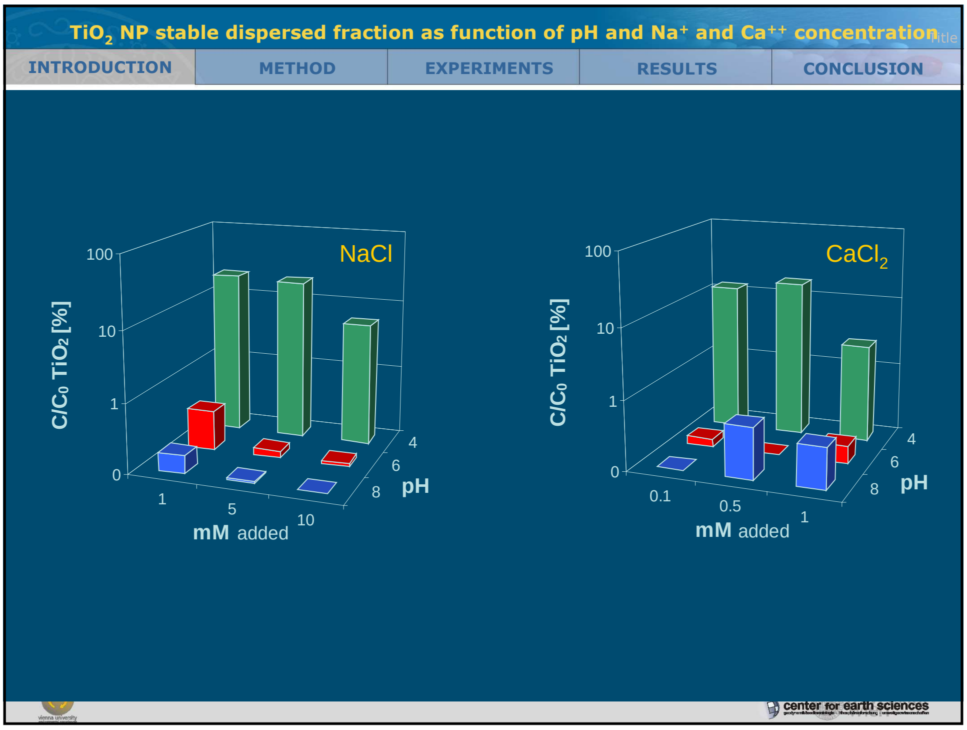
Buffle & Leppard (1995)

Simplified test matrix for dispersion stability in natural waters

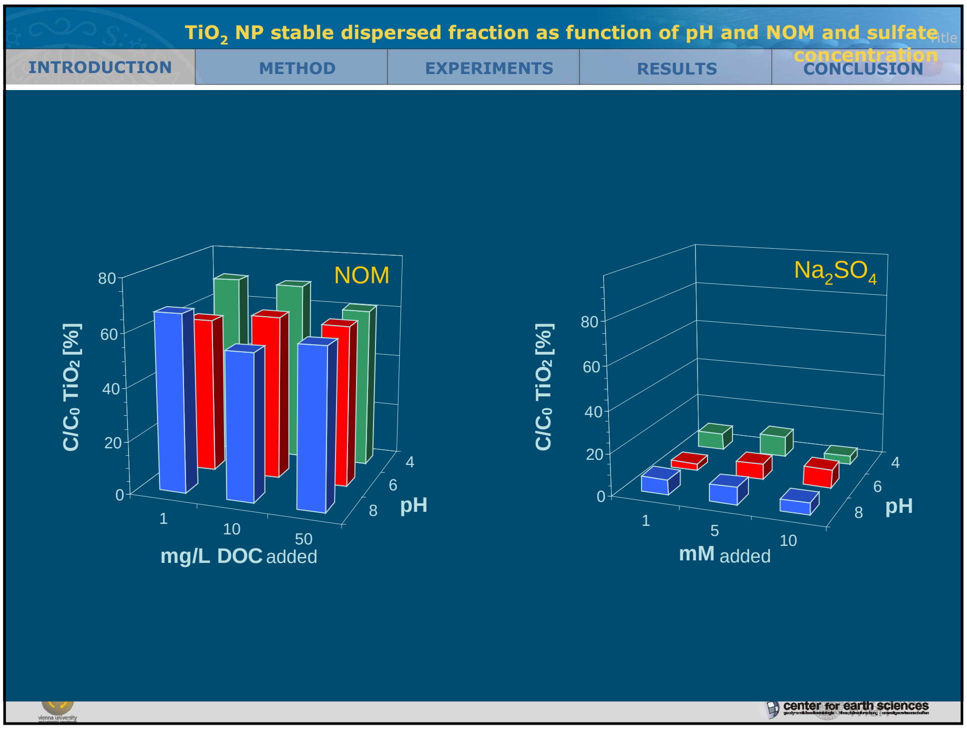
INTRODUCTION | METHOD | EXPERIMENTS | RESULTS | CONCLUSION



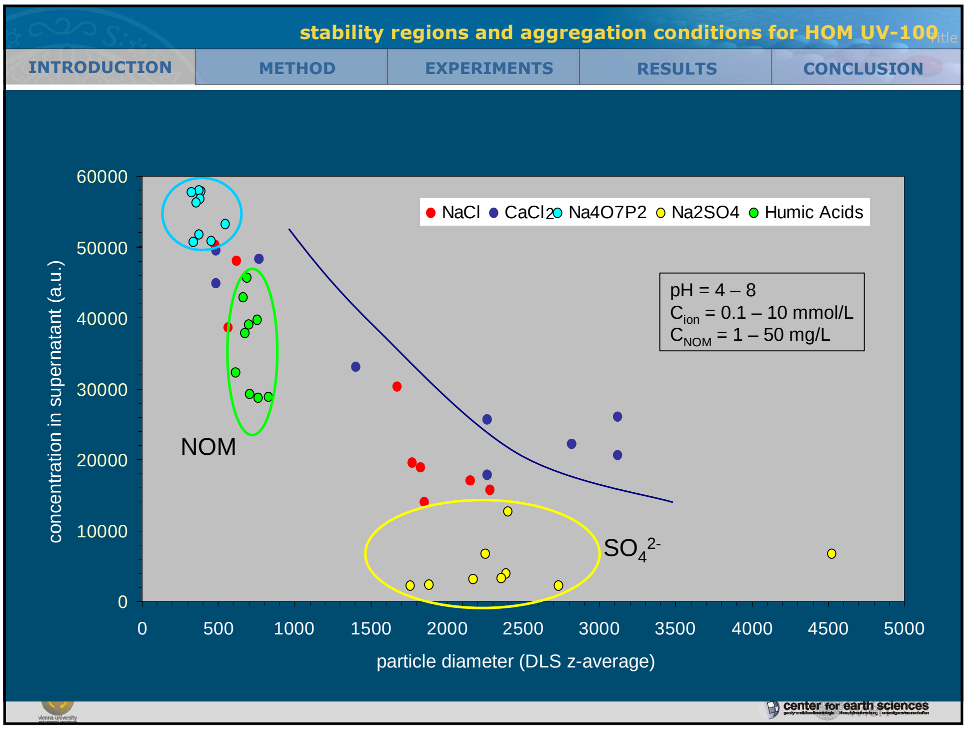
→ stability regions

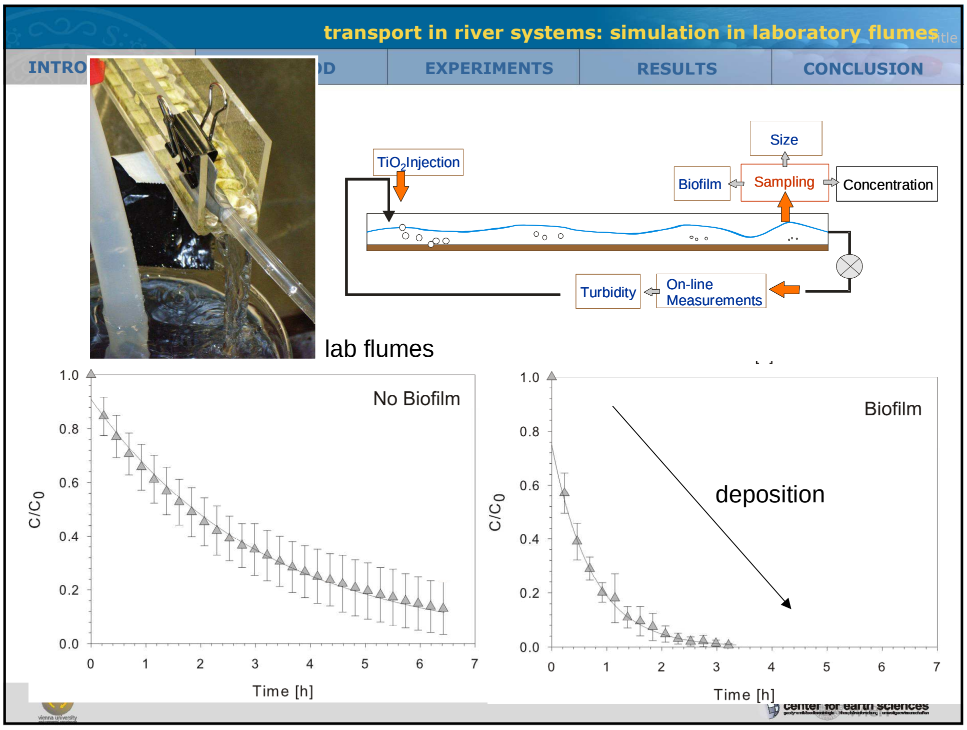


TiO2 NP stable dispersed fraction as function of pH and Na+ and Ca++ concentration
INTRODUCTION
METHOD
EXPERIMENTS
RESULTS
CONCLUSION
NaCl
C/C0 TiO2 [%]
100
10
1
0
1
5
10
mM added
4
6
8
pH
CaCl2
C/C0 TiO2 [%]
100
10
1
0
0.1
0.5
1
mM added
4
6
8
pH
center for earth sciences

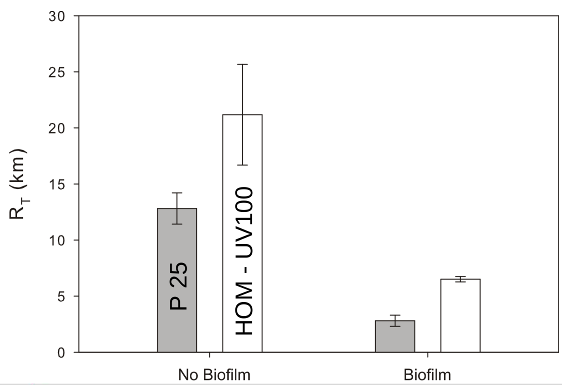


TiO2 NP stable dispersed fraction as function of pH and NOM and sulfate concentration
INTRODUCTION
METHOD
EXPERIMENTS
RESULTS
CONCLUSION
NOM
C/C0 TiO2 [%]
80
60
40
20
0
1
10
50
mg/L DOC added
4
6
8
pH
Na2SO4
C/C0 TiO2 [%]
80
60
40
20
0
1
5
10
mM added
4
6
8
pH
center for earth sciences

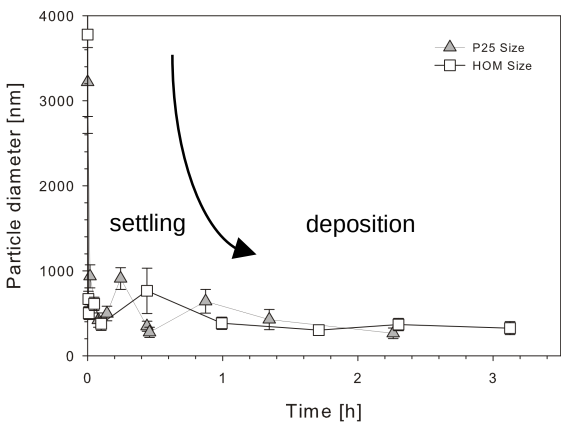

stability regions and aggregation conditions for HOM UV-100
INTRODUCTION
METHOD
EXPERIMENTS
RESULTS
CONCLUSION
NaCl
CaCl2
Na4O7P2
Na2SO4
Humic Acids
pH = 4 – 8
C_{ion} = 0.1 – 10 mmol/L
C_{NOM} = 1 – 50 mg/L
NOM
SO_4^{2-}
concentration in supernatant (a.u.)
0
10000
20000
30000
40000
50000
60000
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
particle diameter (DLS z-average)
center for earth sciences


transport in river systems: simulation in laboratory flumes
INTRO
EXPERIMENTS
RESULTS
CONCLUSION
TiO_2 Injection
Size
Biofilm
Sampling
Concentration
Turbidity
On-line Measurements
lab flumes
No Biofilm
Biofilm
deposition
C/C_0
Time [h]
center for earth sciences

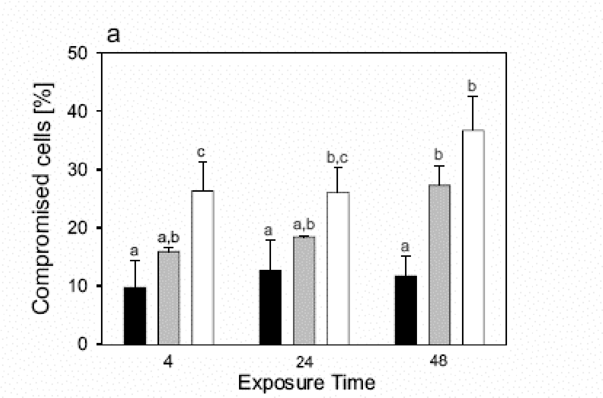
Travel distance until 99% removal from water column



Particle size over time in flume experiments



percentage of compromised cells (life/dead kit) in biofilms of flume experiments



What we know

- **colloid chemistry is still valid → prediction possible for "simple" systems**
- **knowledge about natural colloids/nanoparticles is applicable**
- **ENPs show effects on organisms in natural waters**

What we don't know still

- **emission scenarios (what, where and how much)**
- **behaviour in "real" highly complex systems**
- **analytical methods to detect and quantify ENPs in natural waters**
- **background problem unsolved**
- **what causes effects and what attenuates them**

… to be continued …