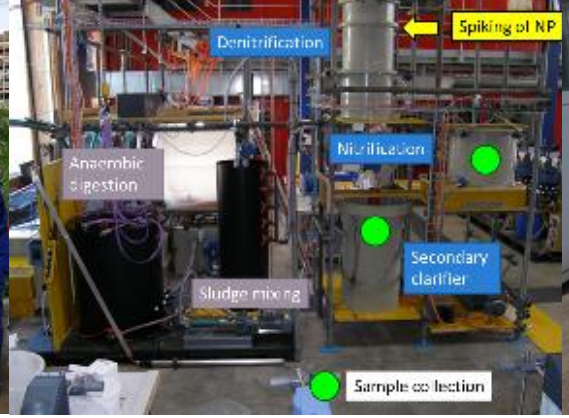

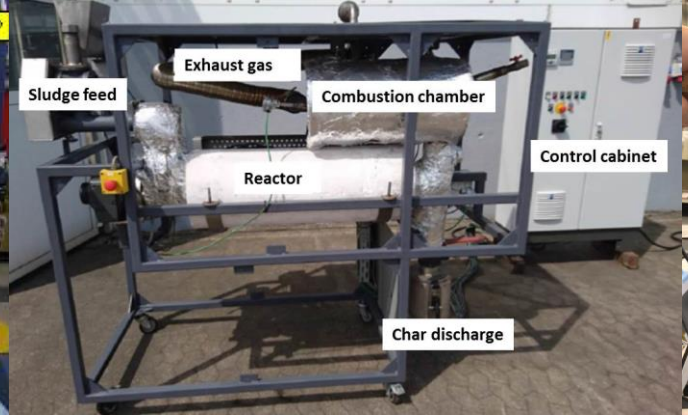

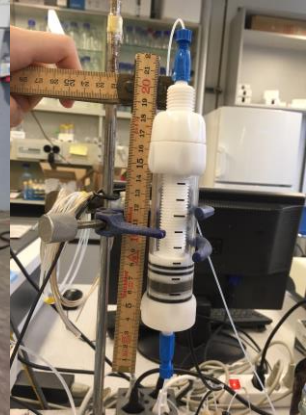

Fate of Nanoparticles in Managed Waste Facilities

NERC SCIENCE OF THE ENVIRONMENT

CEH Centre for Ecology & Hydrology
NATURAL ENVIRONMENT RESEARCH COUNCIL

Alex Gogos Brian Sinnet
Jonas Wielinski Ralf Kaegi
ralf.kaegi@eawag.ch

NanoFASE

EU H2020 (2015-19)

Claus Svendsen & 65 others
NERC-CEH, Wallingford, United Kingdom

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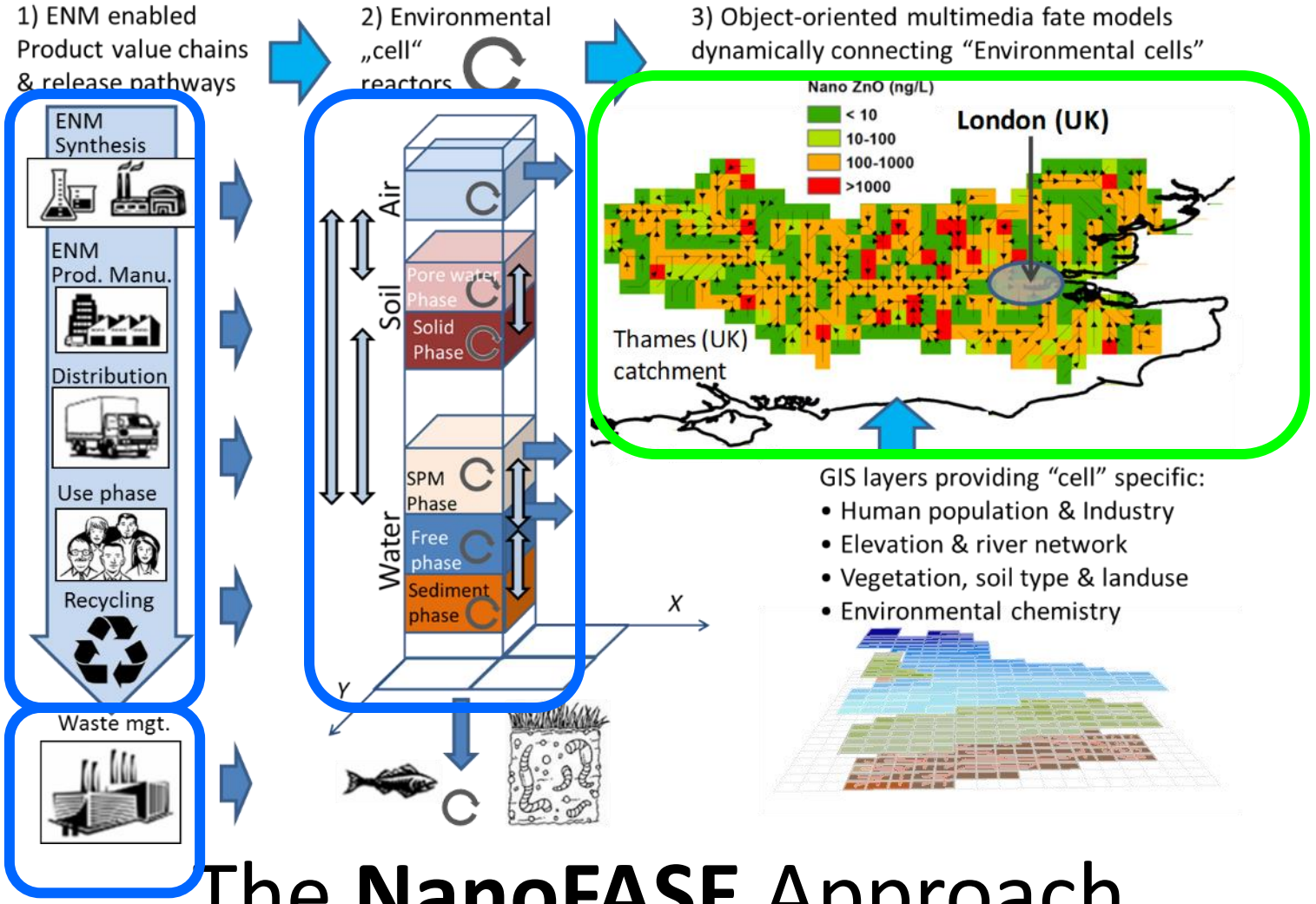
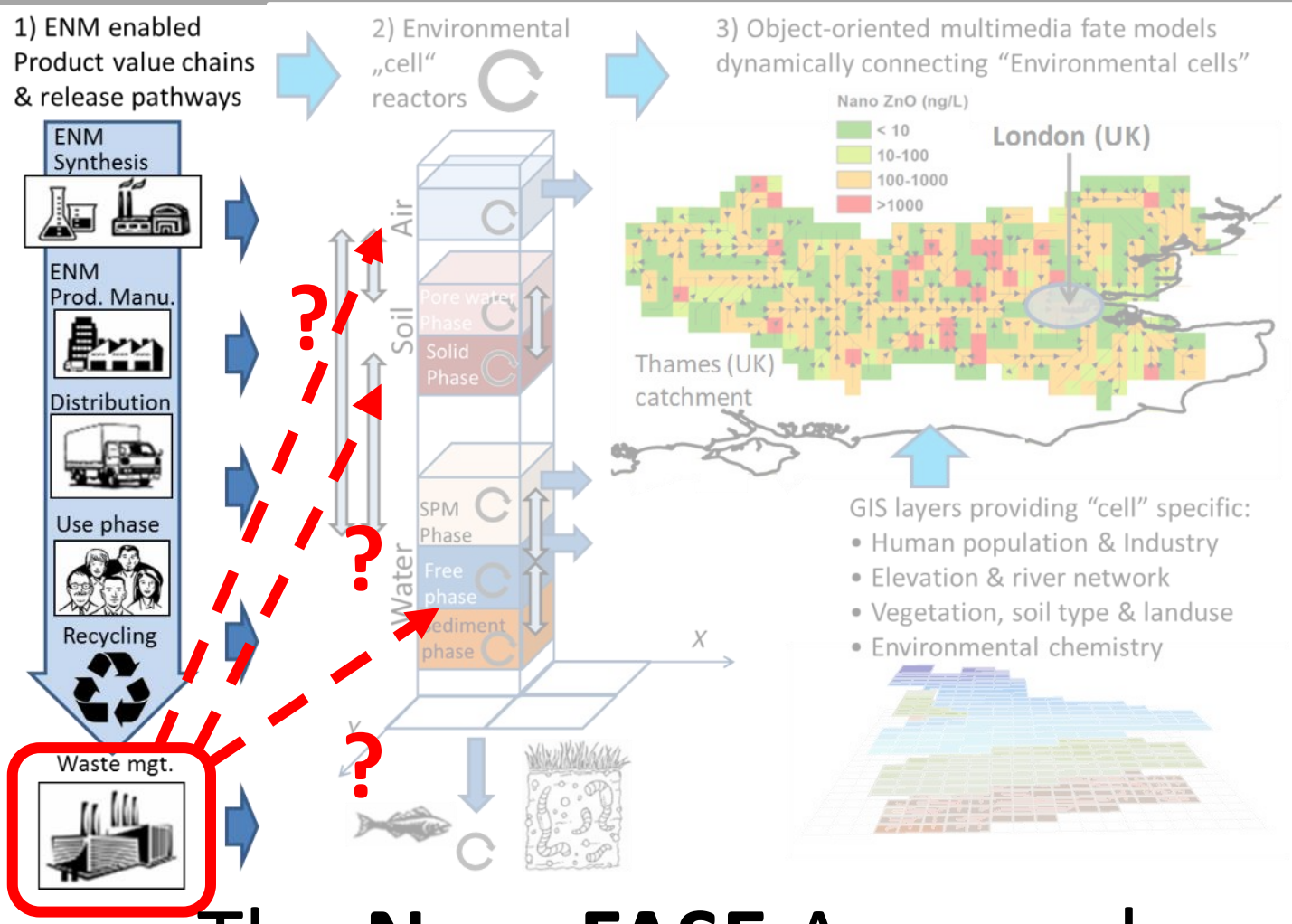
Exposure assessment (of Nano) in the environment: How much is released, and where does what go?



The **NanoFASE** Approach

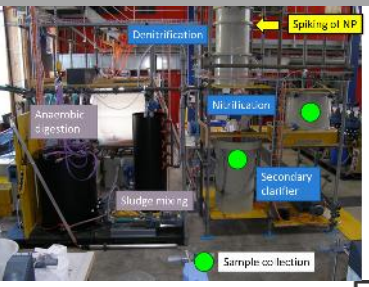
Exposure assessment (of Nano) in the environment: How much is released, and where does what go?

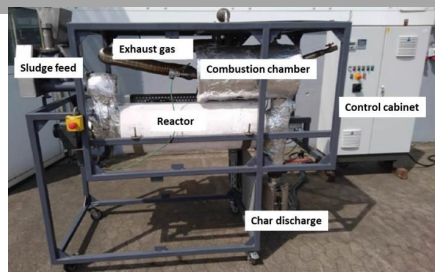


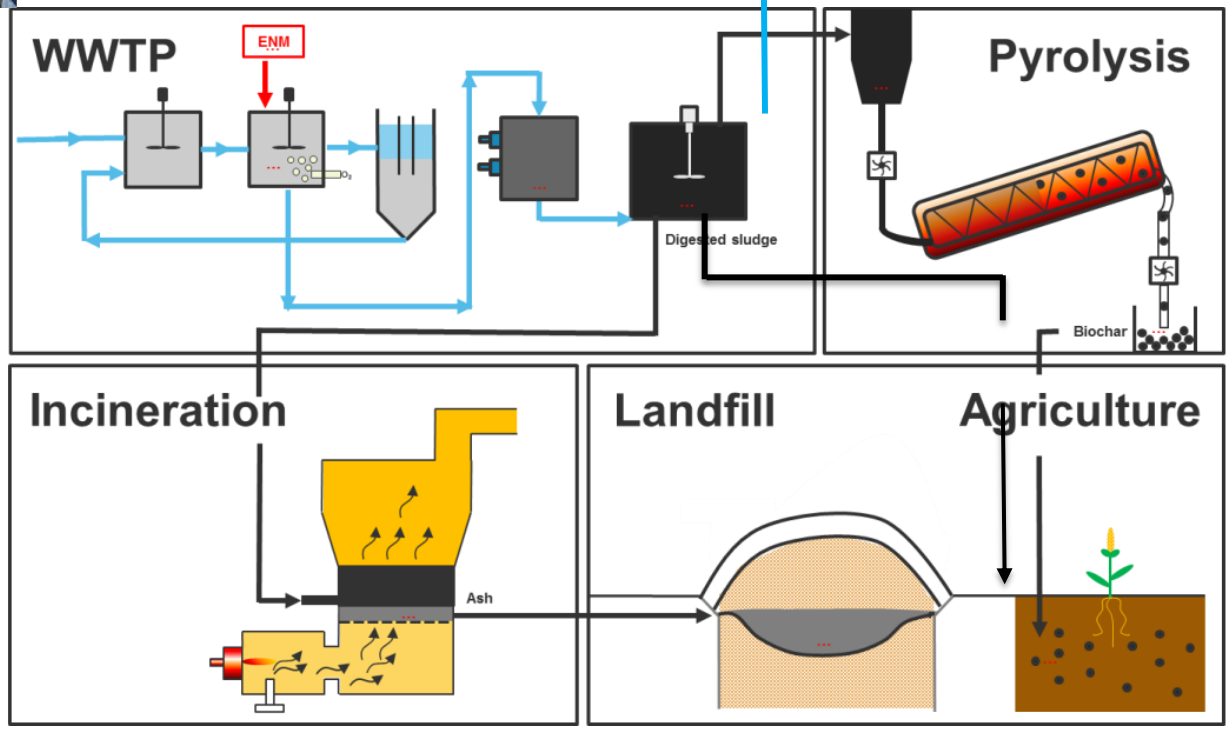
The **NanoFASE** Approach

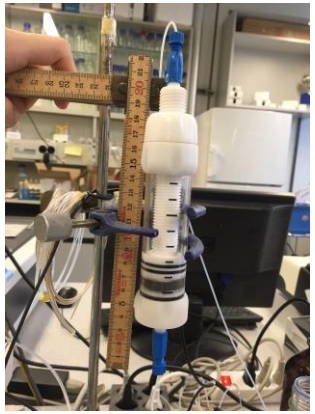
Investigating forms leaving end of life stage (WP5)

Investigate fate and transformation of ENM in major **WASTE REACTORS**:

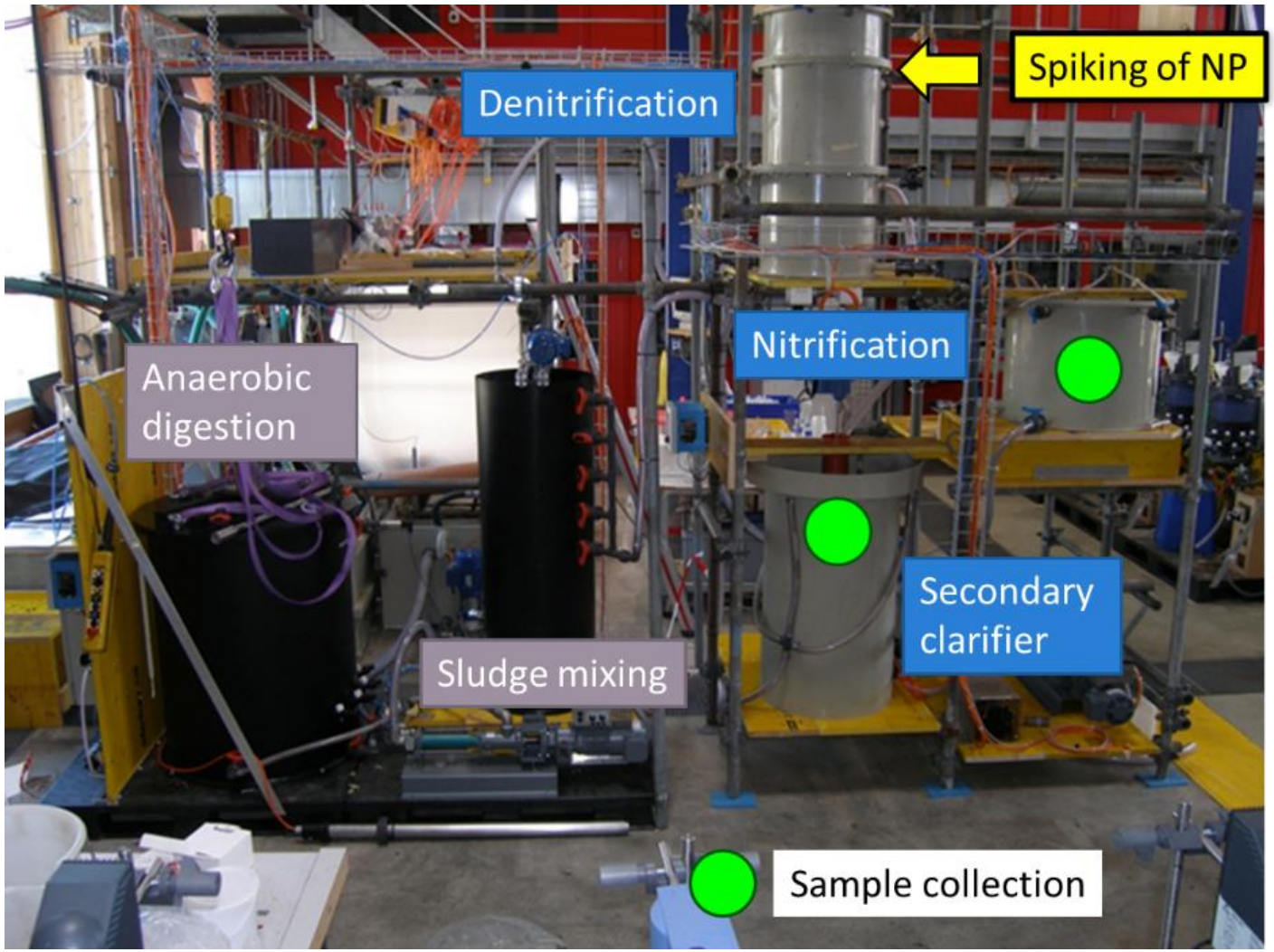




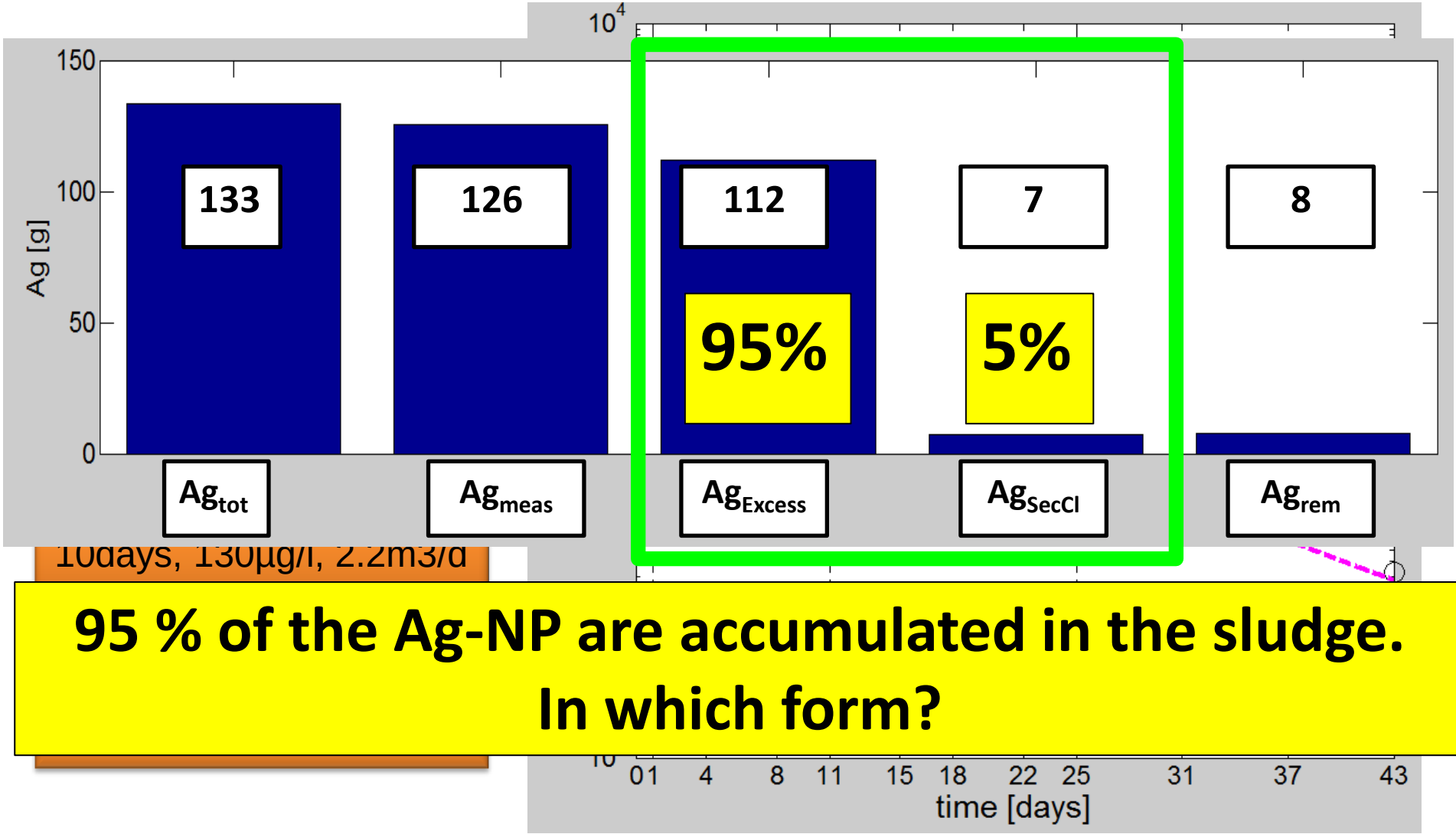




Fate of Ag-NP in WWTP: Mass Balance and Transformation



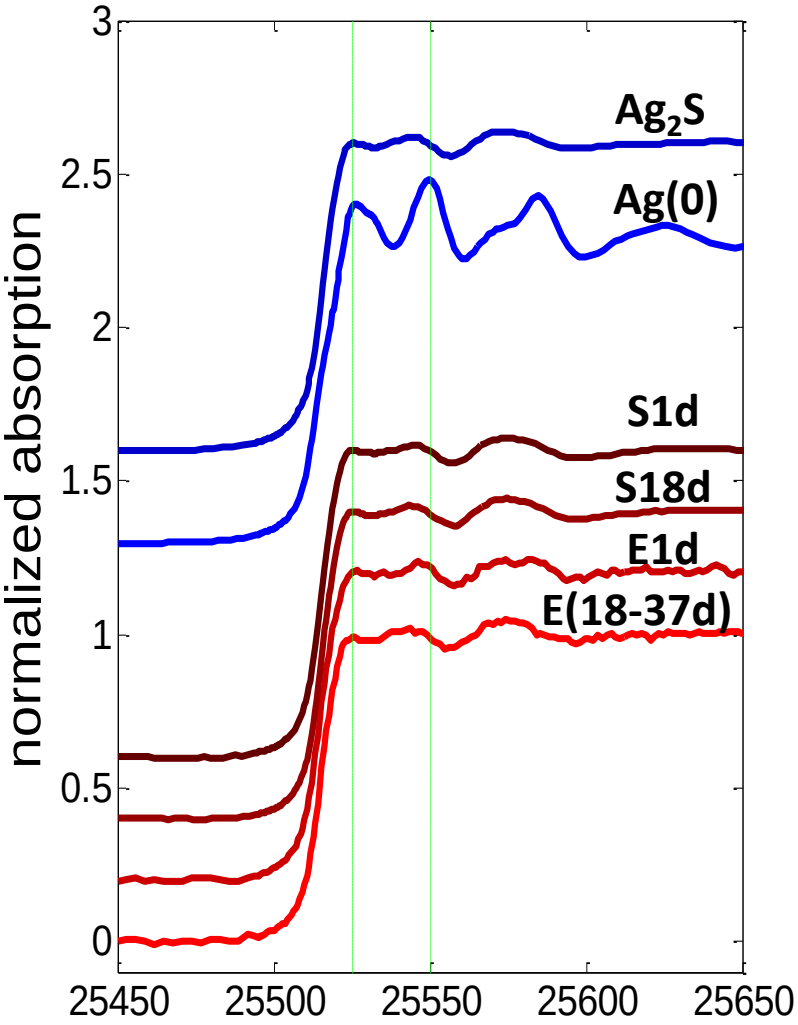
Ag- (NP) Mass Balance



95 % of the Ag-NP are accumulated in the sludge. In which form?

Ag-Speciation and Structural Arrangement of the Ag-NP

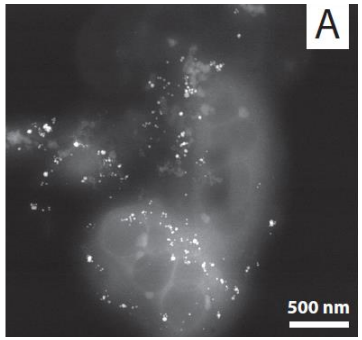
XANES

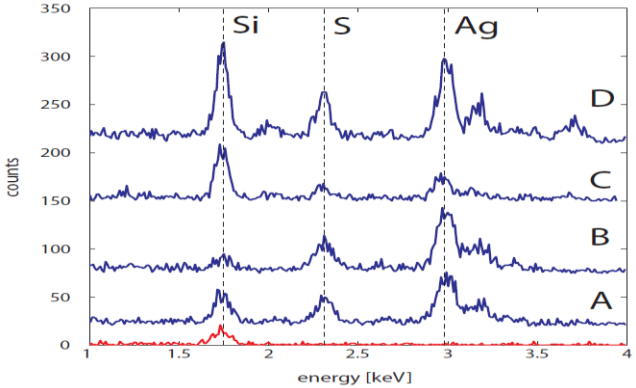


Linear combination fits (%)

Pilot WWTP	Ag(0)	Ag_2S
Sludge(1d)	2	99
Sludge(18d)	3	98
Effluent (1d)	0	100
Effluent (18-37d)	15	86

Electron microscopy





Kaegi, R. et al. *ES&T*, **45**, 3902–3908 (2011).

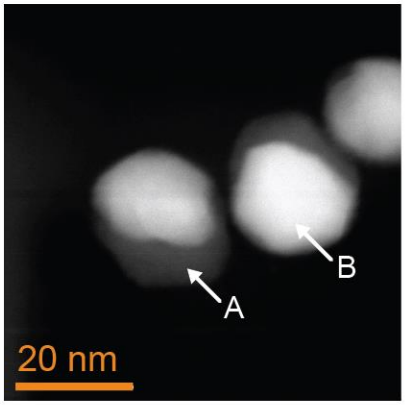
Morphology and Structure of the Ag-NP

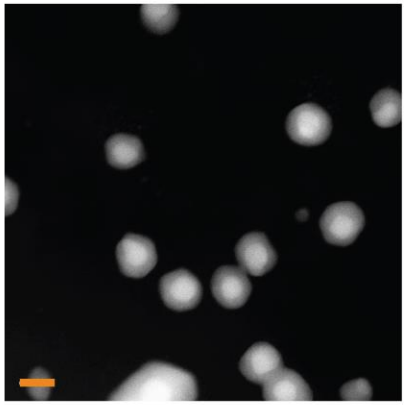
0 mg_{HA} L^{-1}

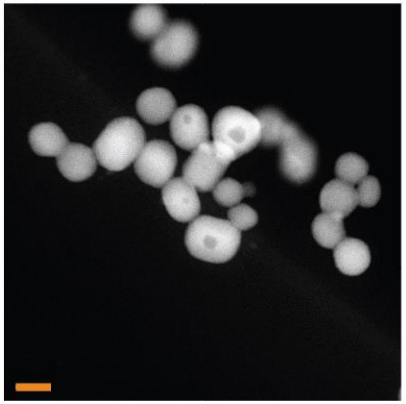
250 mg_{HA} L^{-1}

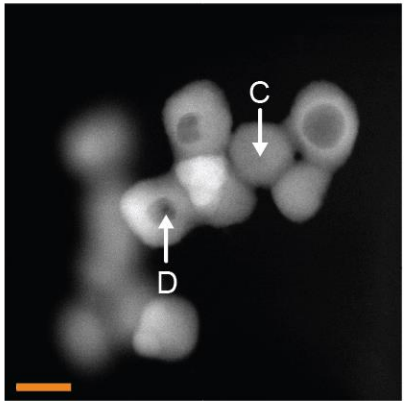
5 min

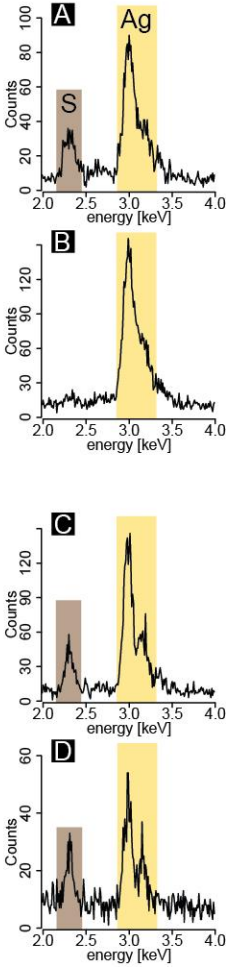
45 min



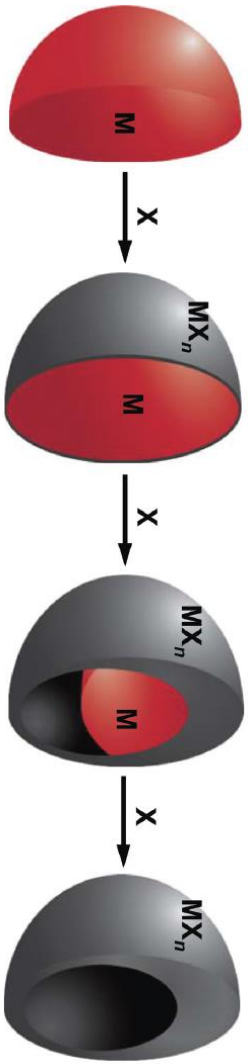








Thalmann et *al.* 2016, ES Nano, DOI: 10.1039/c5en00209e

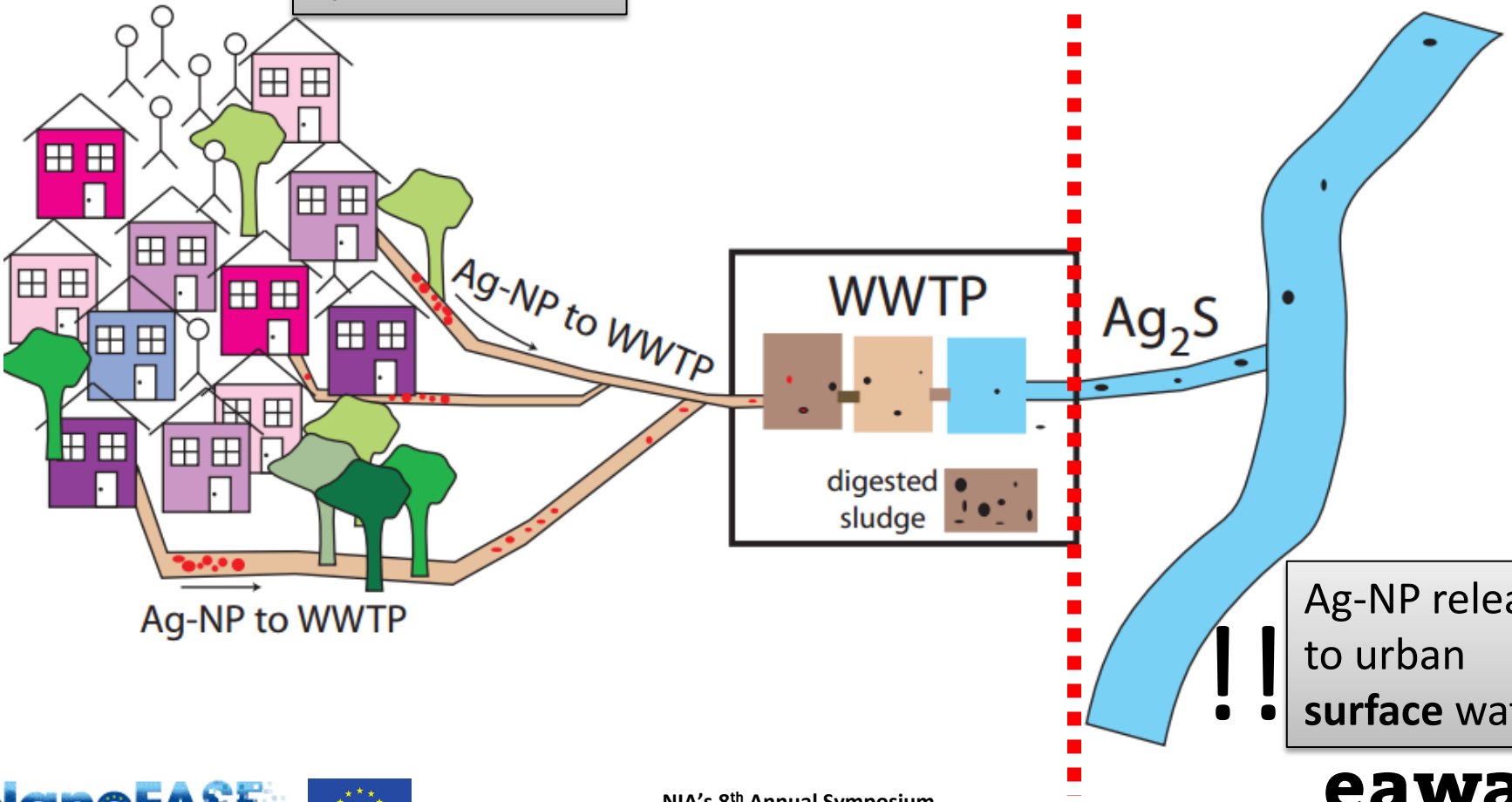


Anderson and Tracy, 2014, Nanoscale, 6,21, pp 12195-12216

What goes in is NOT what goes out

! Ag-NP released to the **sewer** system

Interface between 'WASTE' and 'ENVIRONMENTAL' reactors

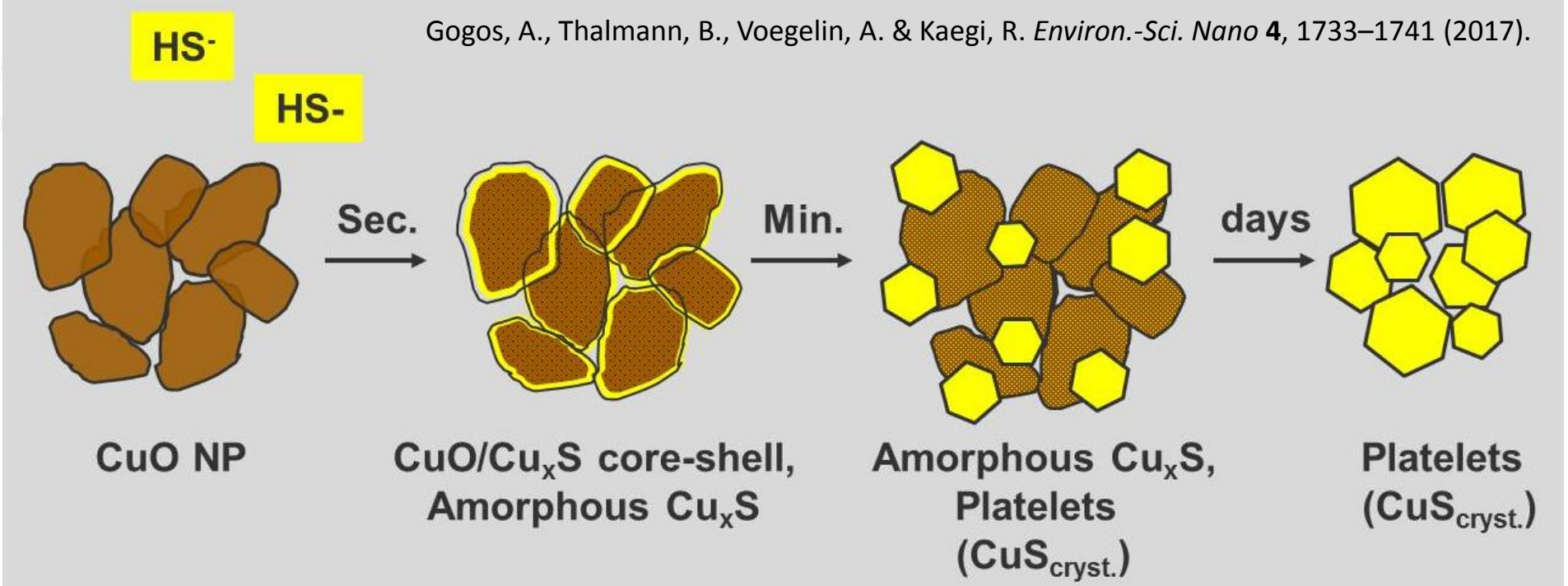


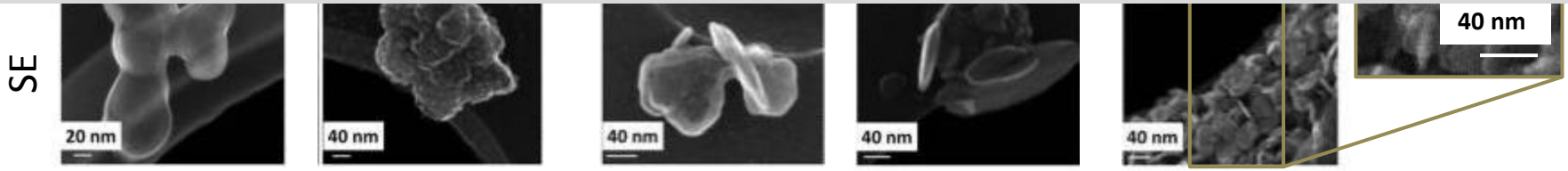
!! Ag-NP released to urban **surface** water

Will CuO – NP survive the wastewater / sludge treatment?

XAS-LCF analysis and electron microscopy

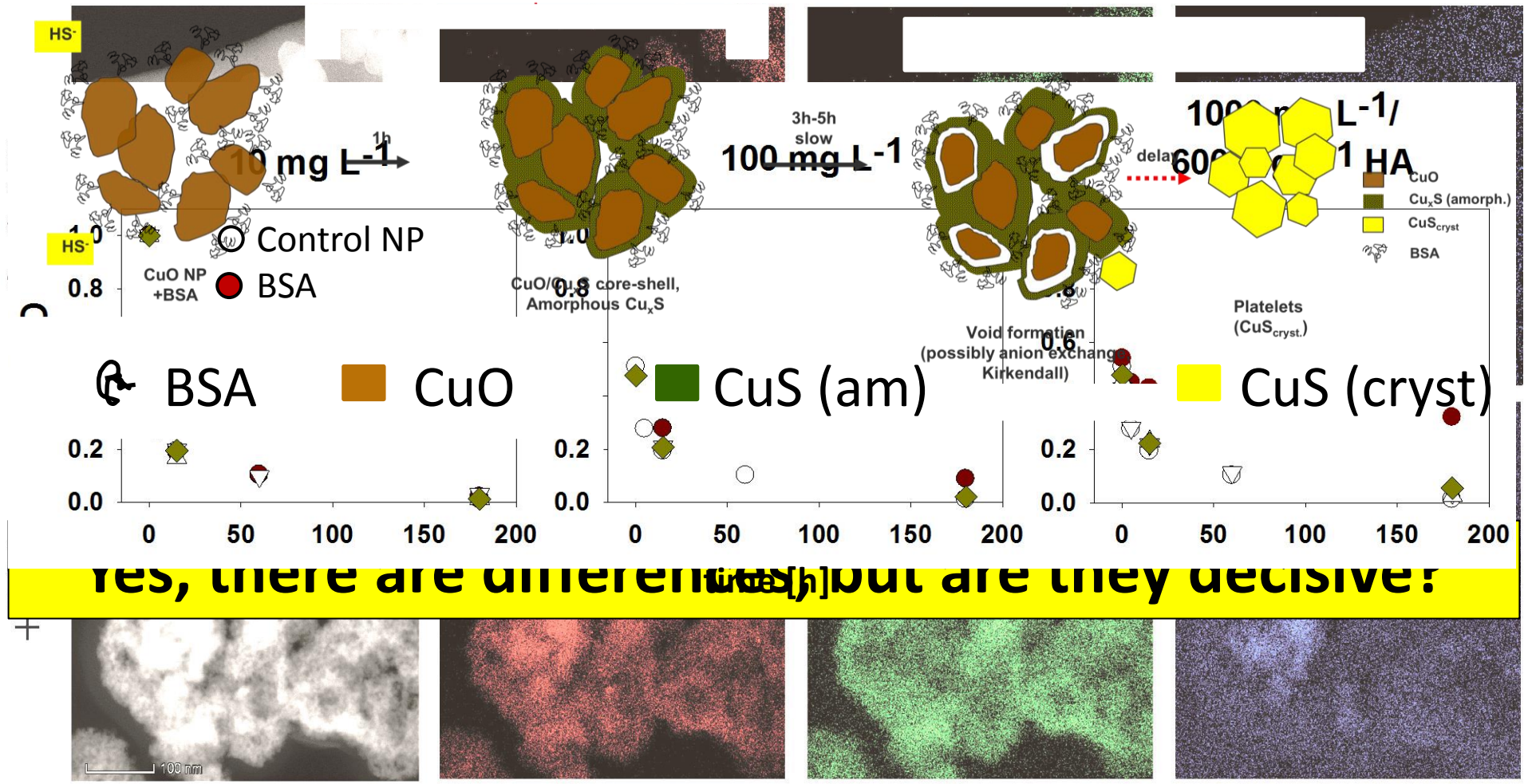
Gogos, A., Thalmann, B., Voegelin, A. & Kaegi, R. *Environ.-Sci. Nano* **4**, 1733–1741 (2017).





Sulfidation kinetics in the presence of 'organics'

Gogos, A., Voegelin, A. & Kaegi, R. Environ. Sci. Nano 5, 2560–2569 (2018).



Yes, there are differences, but are they decisive?

Dissolved Cu^{2+} / Zn^{2+} vs. Cu- / Zn-NP

Differences in speciation of Cu and Zn determined by XAS

+ ZnO-NP or CuO-NP

Control sludge

+ Zn^{2+} or Cu^{2+}

CH_4

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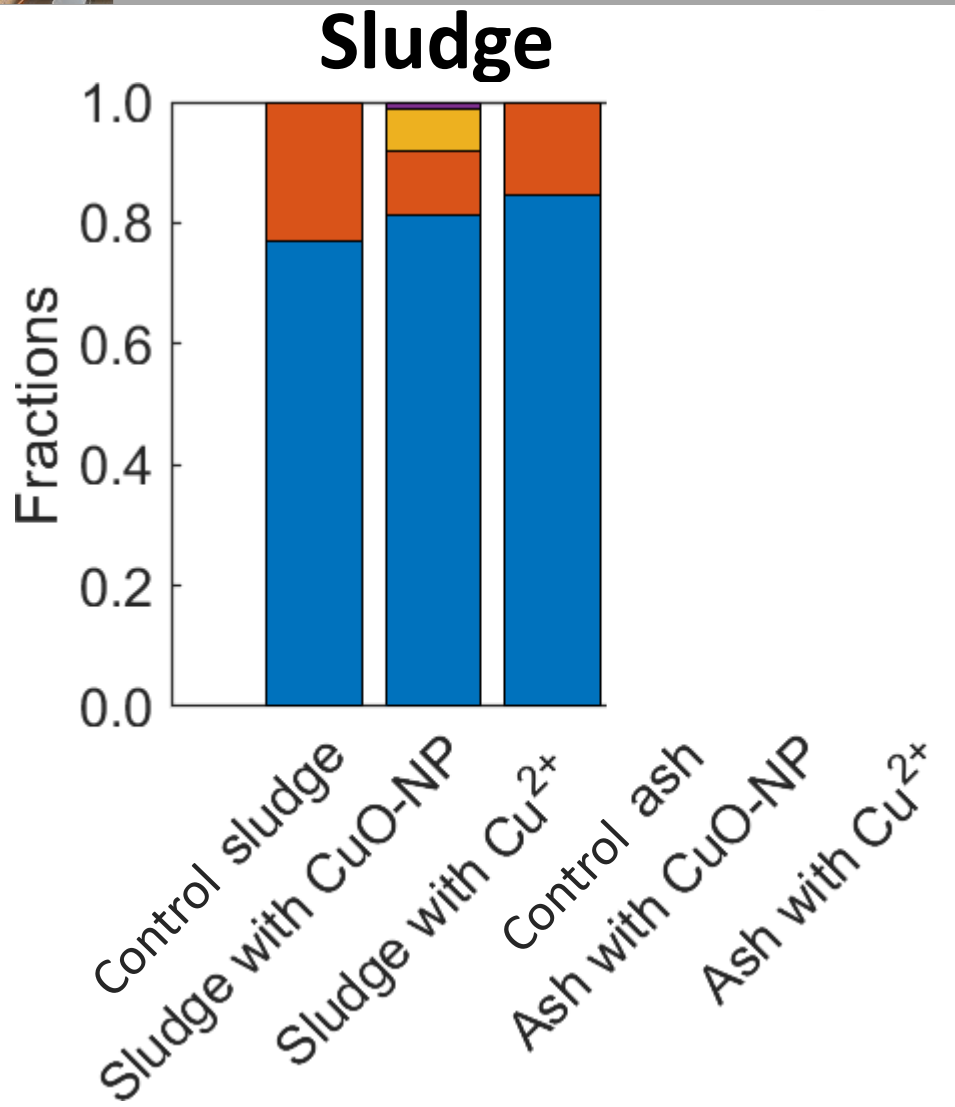
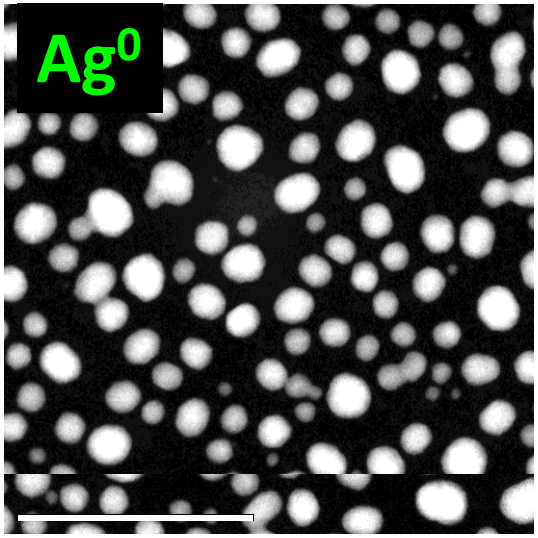
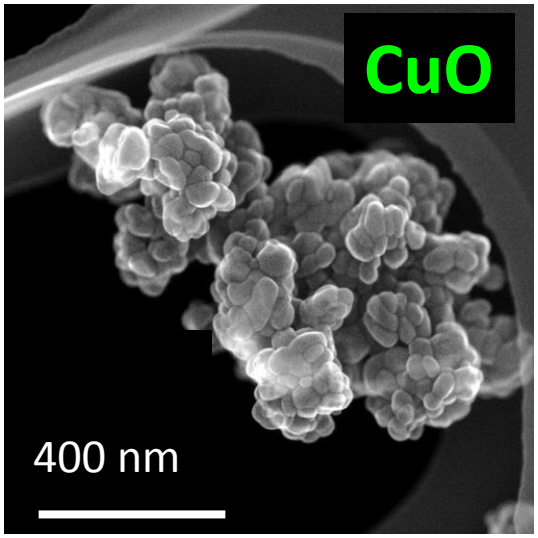
CuO: Incineration makes it alike

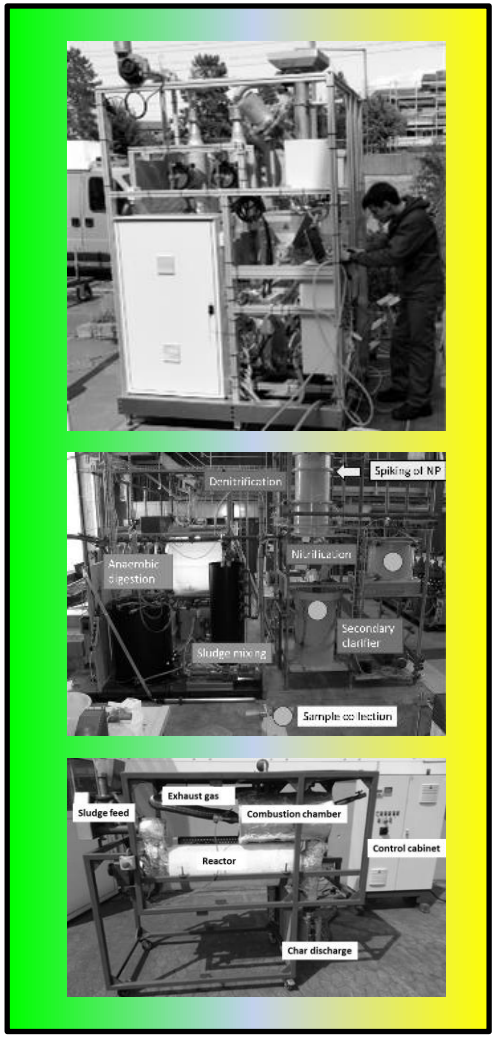


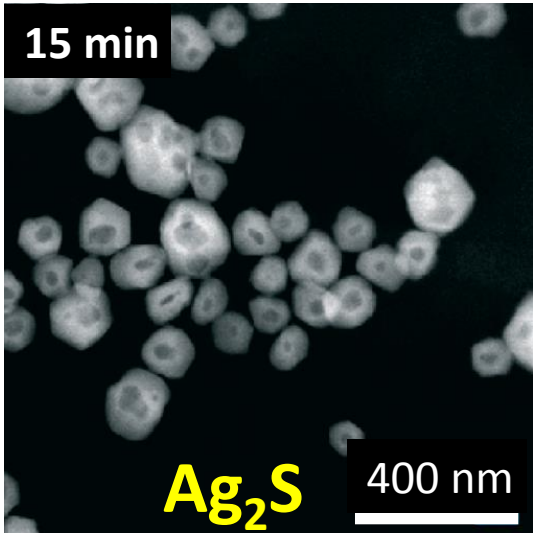
A ≠ B

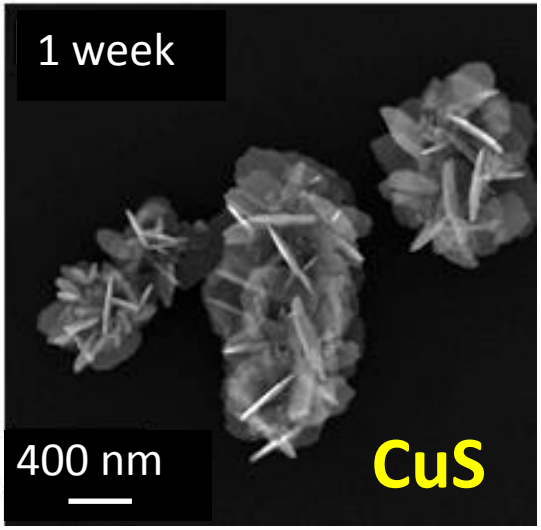
Waste Reactors Transform ENMs











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Exposure assessment (of Nano) in the environment:

How much is released, and where does what go?

1) ENM enabled Product value chains & release pathways

2) Environmental „cell“ reacto

3) Object-oriented multimedia fate models dynamically connecting “Environmental cells”

ENM Synthesis

ENM Prod. Manu.

Distribution

Use phase

Recycling

Waste mgt.

Waste Water
95% Sludge
5% Effluent

Air

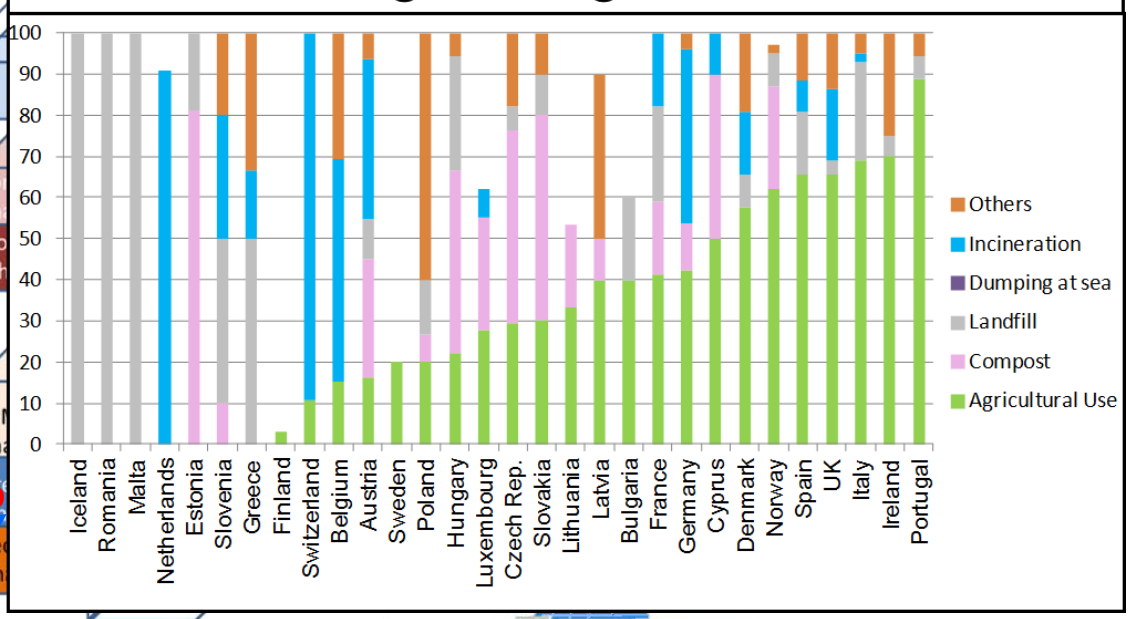
Soil

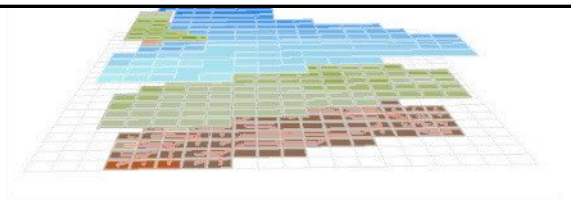
Water

?

0-95%

5%

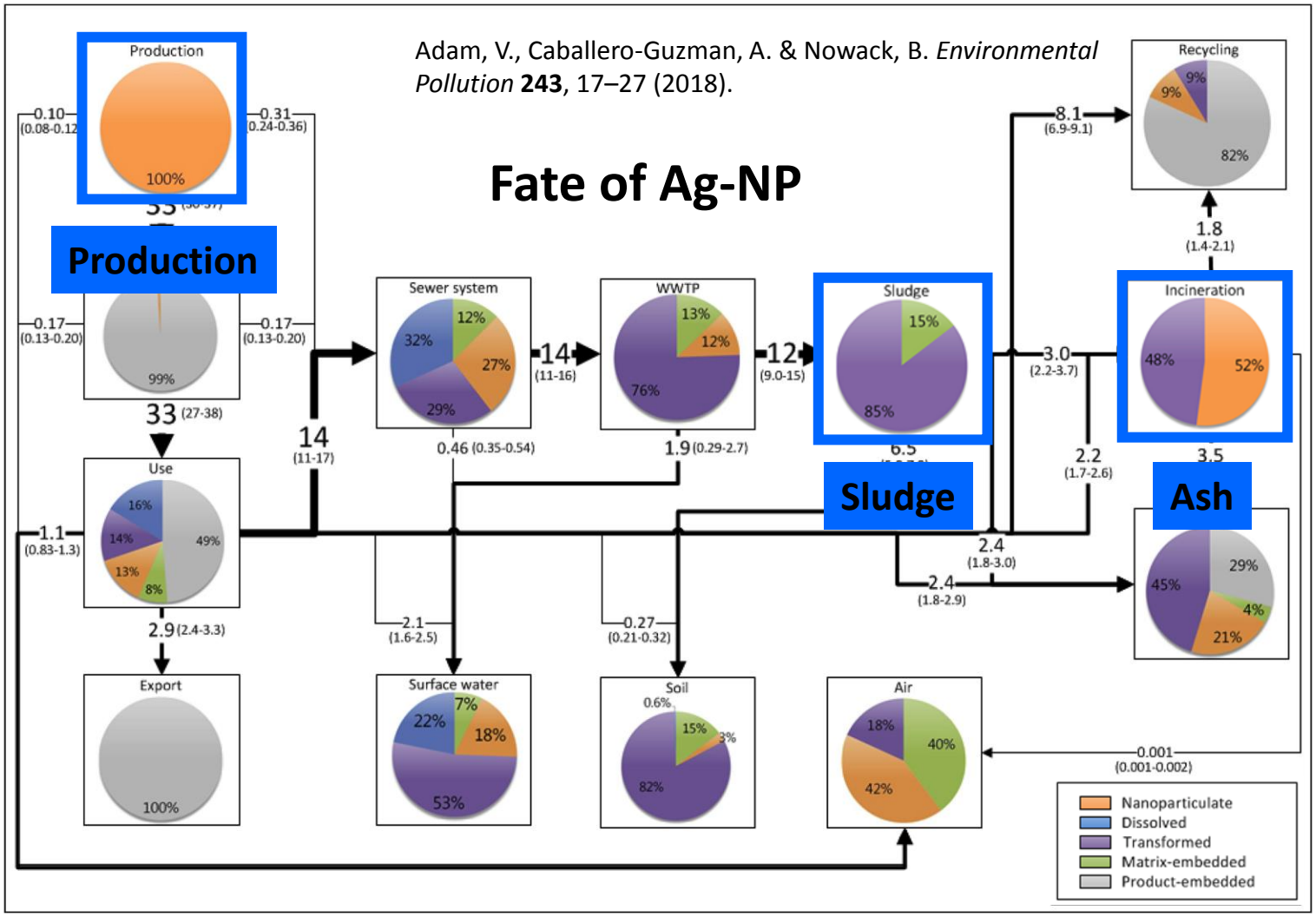




Waste Water Treatment Plant

Exposure assessment (of Nano) in the environment:

How much is released, and where does what go?

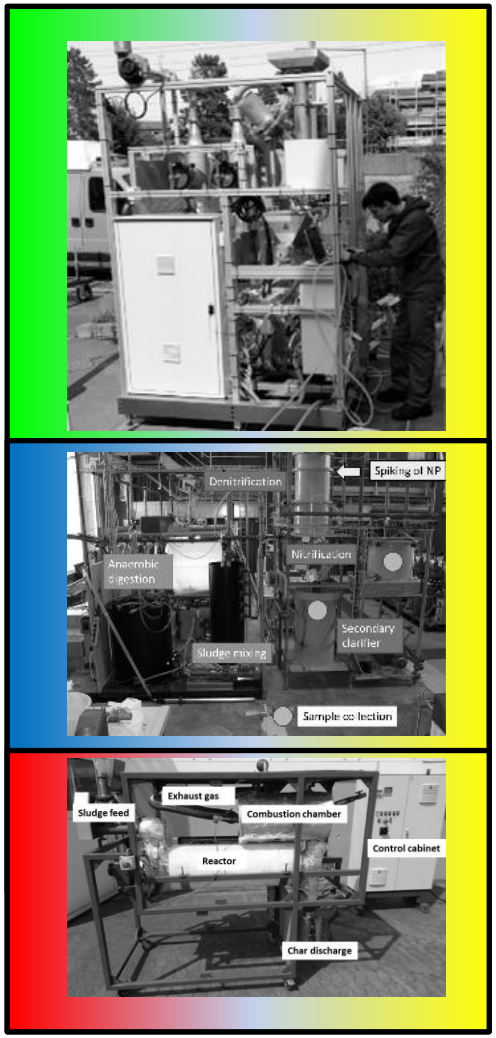


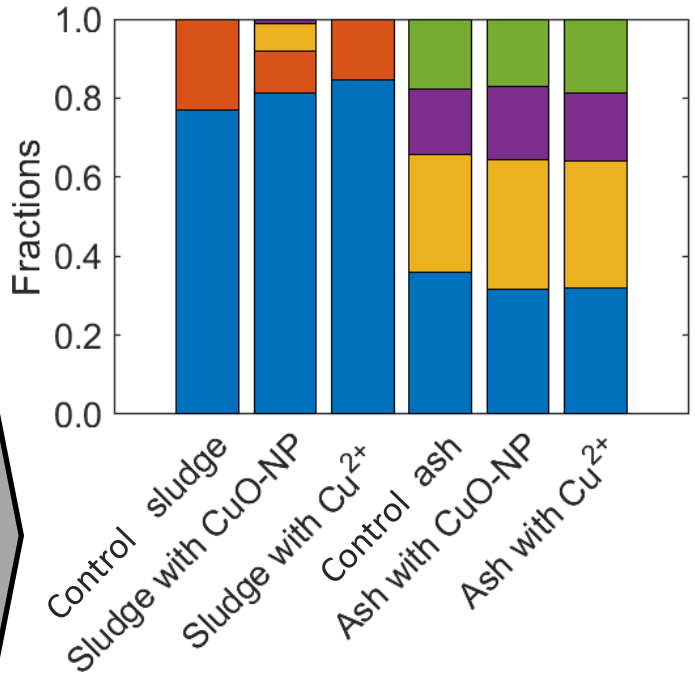
A
B
C
D

Waste Reactors Unify ‘ENMs’

+ ZnO-NP
or
CuO-NP

+ Zn^{2+}
or Cu^{2+}





CuS (amorphous)
$CuFeS_2$ (chalcopyrite)
CuO (tenorite)
$CuSO_4$ (copper sulphate)
$CuFe_2O_4$ (cuprospinel)

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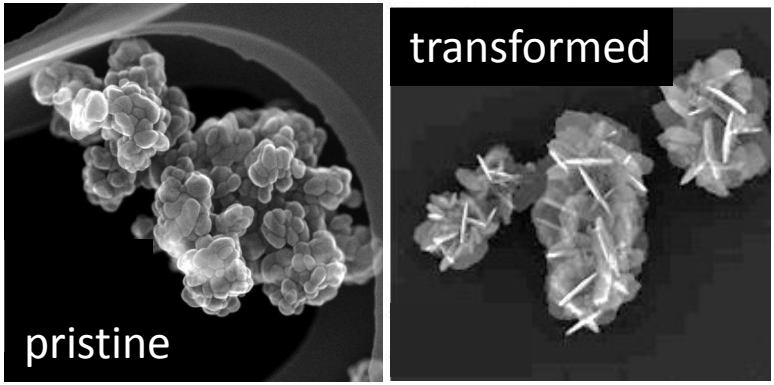
Conclusions and remaining questions

???

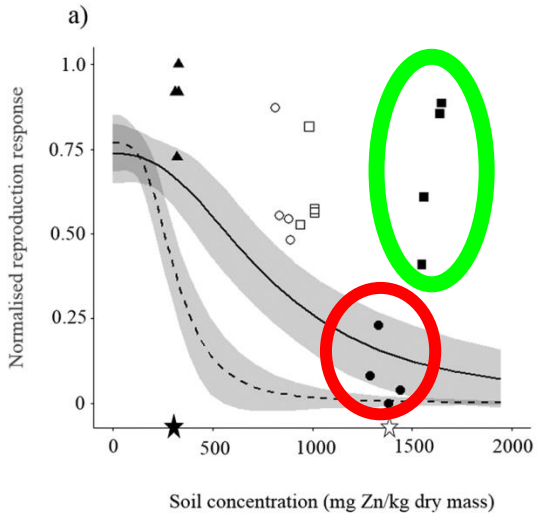
‘Reactive’ NP **transform** in Waste Reactors **->** biota is **exposed** to transformed rather than to pristine NP

What are the **impacts** of the transformation products on biota?



‘Reactive’ NP **unify** in Waste Reactors

Are also the **impacts** unified?



Lahive, E. et al. Environ.-Sci. Nano 4, 78–88 (2017).