

Aging effects on the toxicity of silver nanoparticles to soil bacteria in artificial media and soil pore water

Carolin Schultz¹, Joanna Gray², Marianne Matzke¹,
Claus Svendsen¹, Liz Shaw², Elma Lahive¹

Nanoparticles undergo transformations during release and after entering environment

Dissolution drives observed effects

In environmental media presence of ligands mediates toxicity

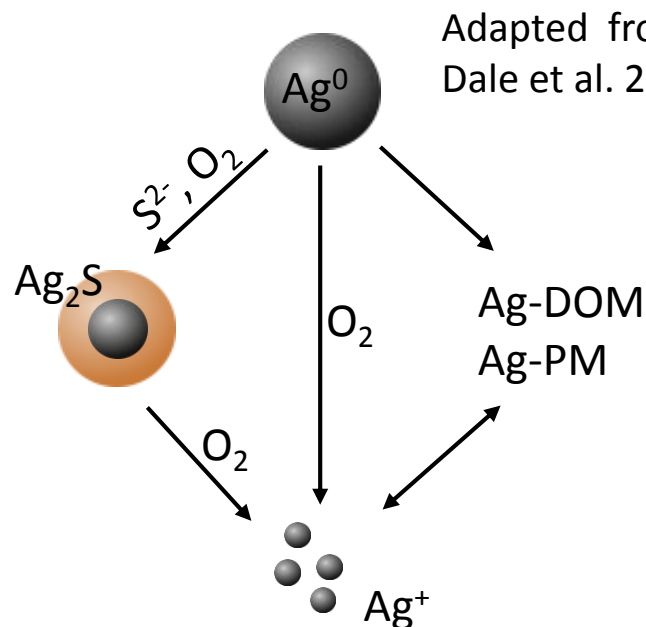
Hypotheses

Aging affects toxicity (increases dissolution but also binding to DOM)

→ Aging Ag NPs in ISO 10712 standard test medium and extracted soil pore waters

Level of observed dissolution explains level of toxicity

→ Comparing toxicity of unaged (total) and aged (total and dissolved fractions)



Bacteria species

Arthrobacter globiformis

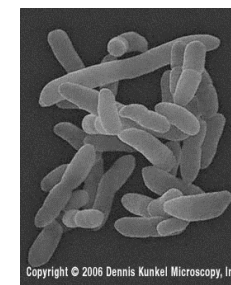
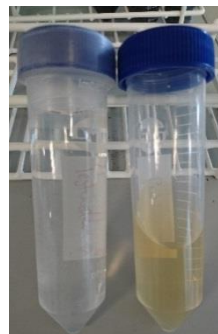
Pseudomonas putida

Media

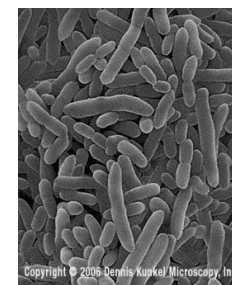
Media: ISO 10712, pH 7

Soil: Dorset, UK

Acidic heath land, natural $\text{pH}_{\text{H}_2\text{O}}$ 4.2



A. globiformis

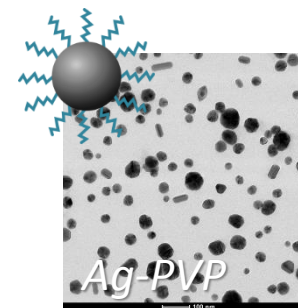


P. putida

Nanoparticles

ID	Size (NTA/TEM)	Coating	Zeta-potential
Ag-TA	60 nm/ 49 nm	Tannic Acid	-50.0 mV
Ag-PVP	88 nm/ 52 nm	PVP	-11.6 mV
Ag ₂ S	81 nm/ 36 nm	PVP	-25.7 mV

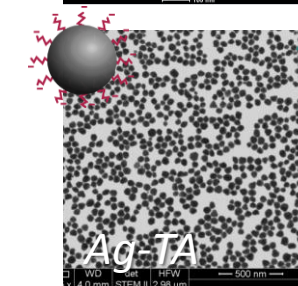
Exposure characterisation over test duration using NTA



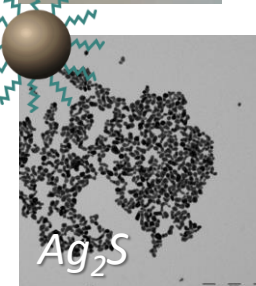
Ag-PVP



AgNO₃

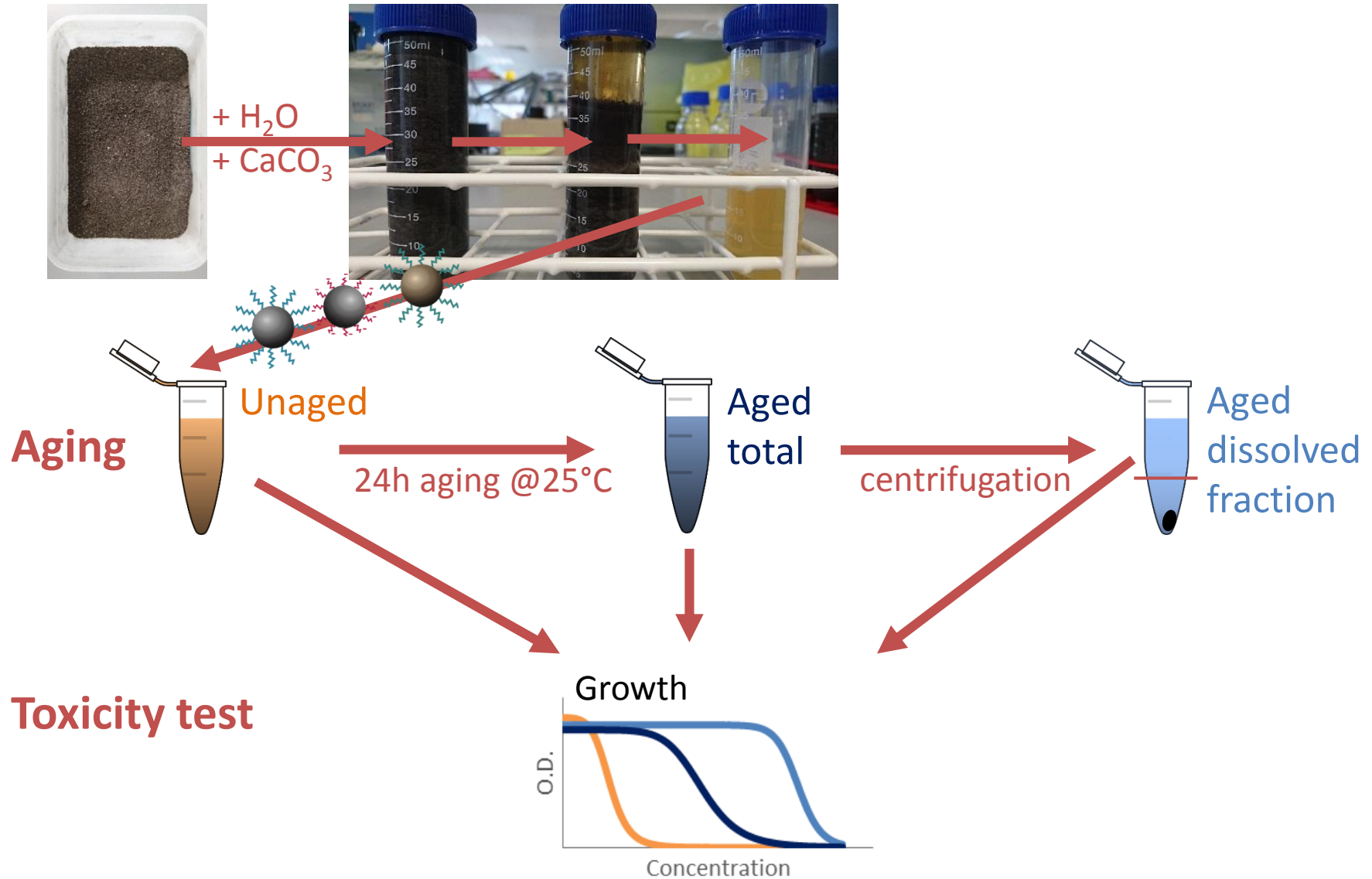


Ag-TA



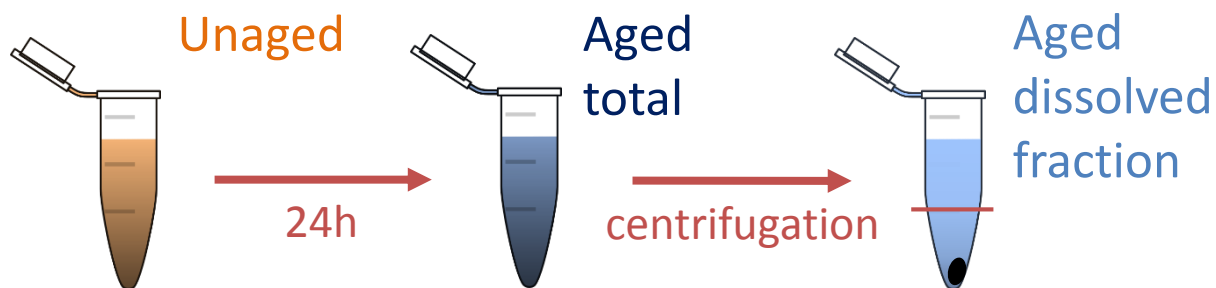
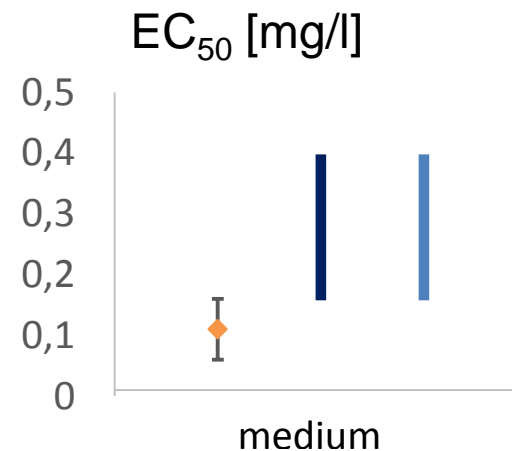
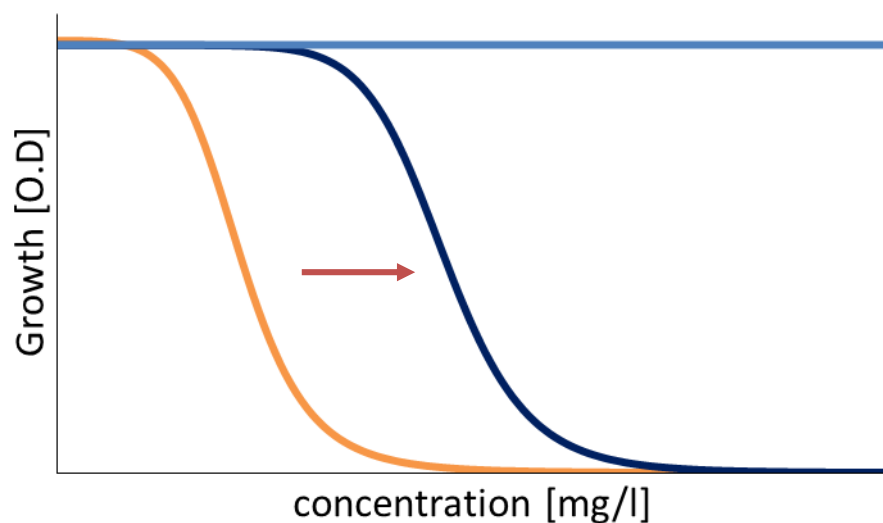
Ag₂S

Pore water extractions



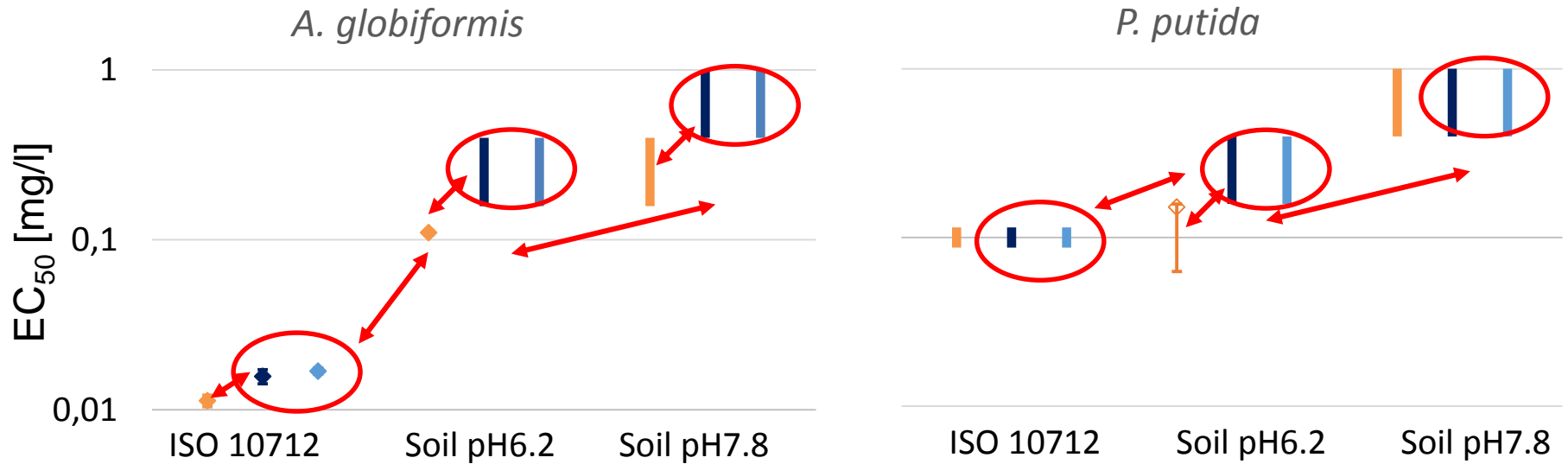
Results

Toxicity tests: Effects on growth



Results

AgNO₃



A. globiformis more sensitive than *P. putida*

Aging reduces toxicity

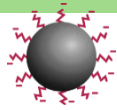
Dissolution fraction drives toxicity in aged exposures

Soil pore water exposures reduces toxicity

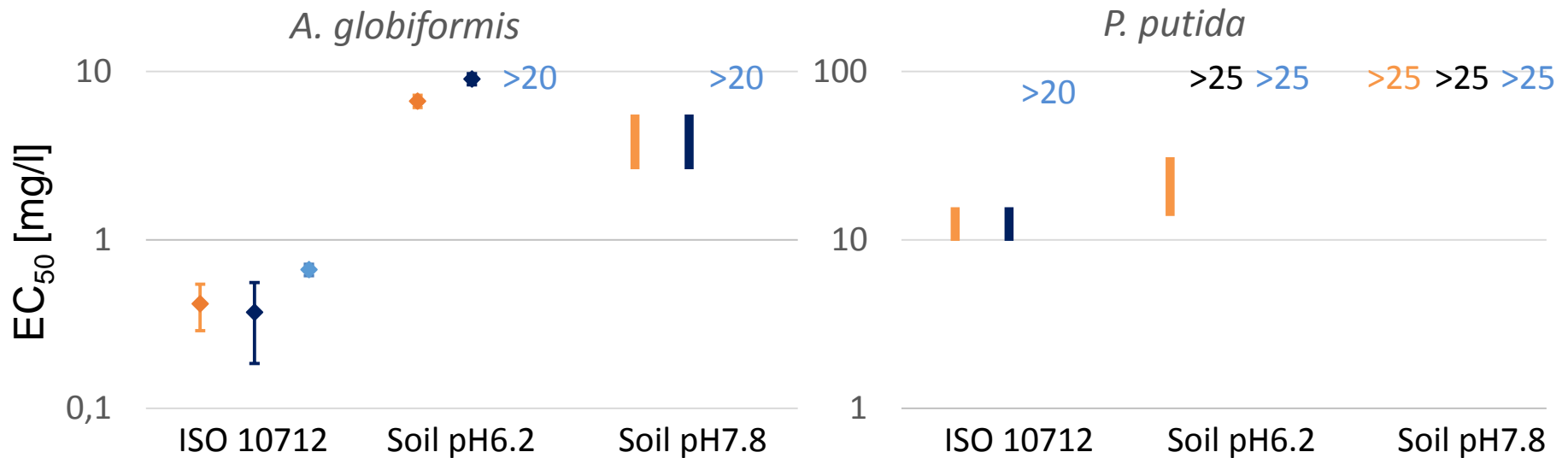
Higher toxicity at low pH

Unaged
Aged total
Aged dissolved
fraction

Results



Ag-TA



Aging reduces toxicity at low pH

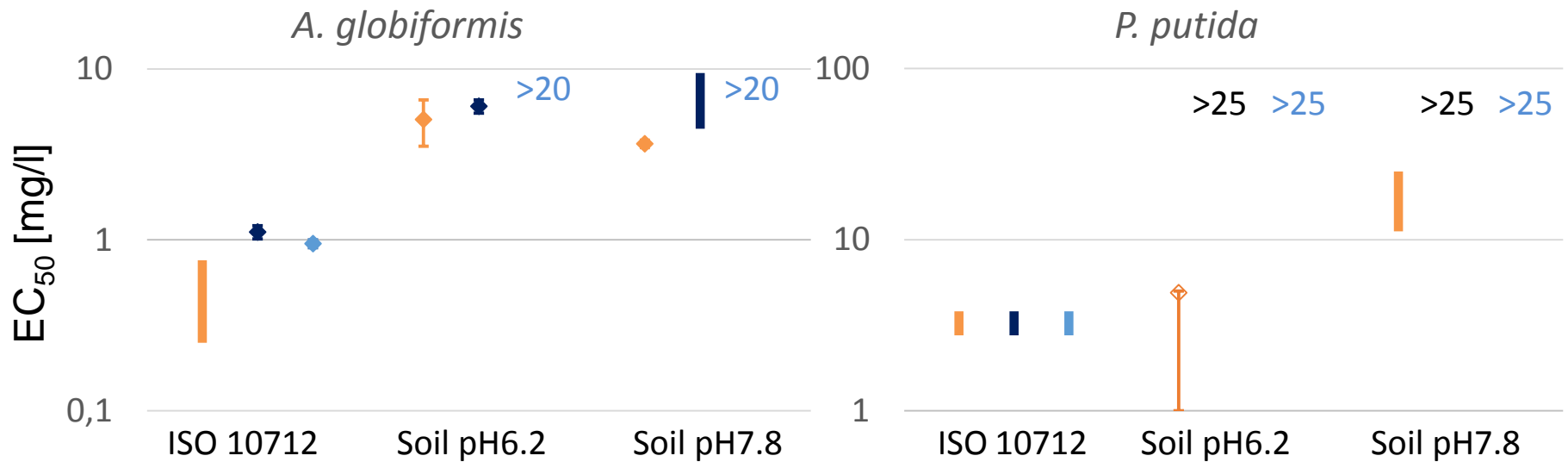
Dissolution only contribute to toxicity in ISO for *A. globiformis*

Pore water pH effect species dependent

Unaged
Aged total
Aged dissolved
fraction

Results

Ag-PVP



Aging reduces toxicity

Dissolution does not contribute to toxicity in soil pore water

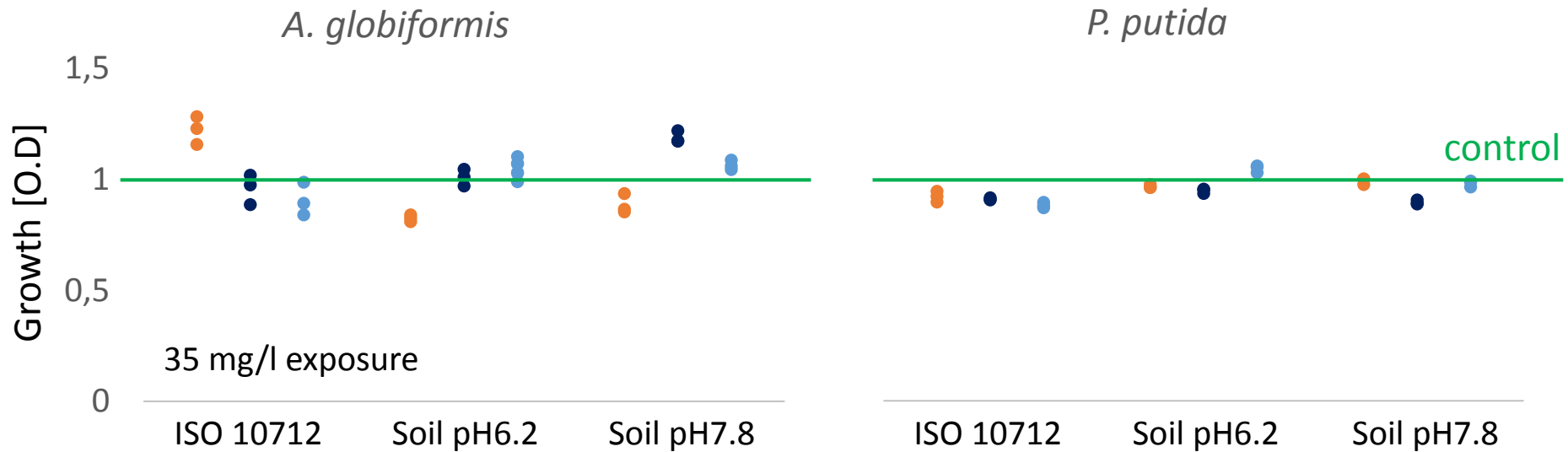
Higher toxicity at low pH for *P. putida*

Toxicity *A. globiformis* : Ag-TA > Ag-PVP

P. putida: Ag-PVP > Ag-TA

Unaged
Aged total
Aged dissolved
fraction

Results

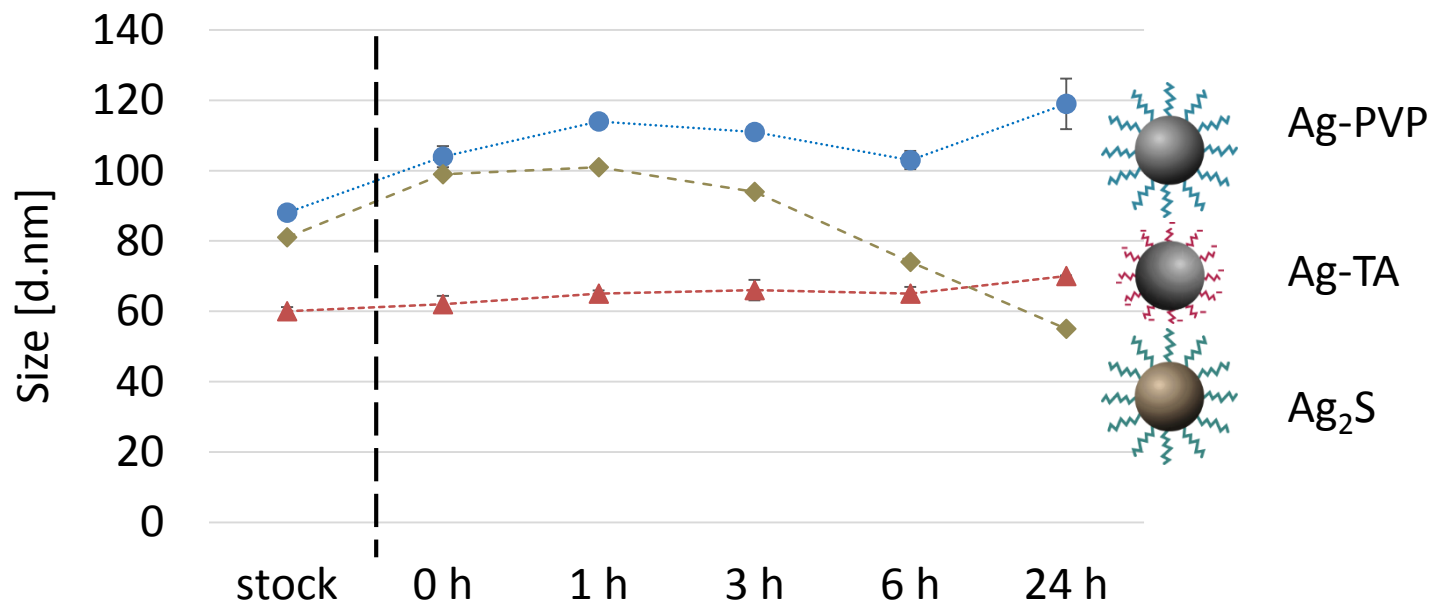


No changes in growth compared to controls after 35 mg/l exposures to Ag₂S

Unaged
Aged total
Aged dissolved
fraction

Results

Stability in ISO medium over 24h
using NTA



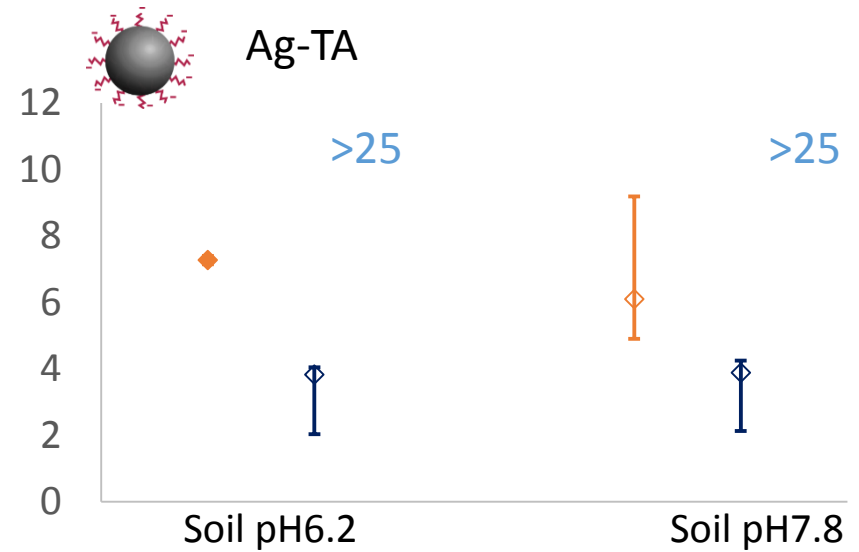
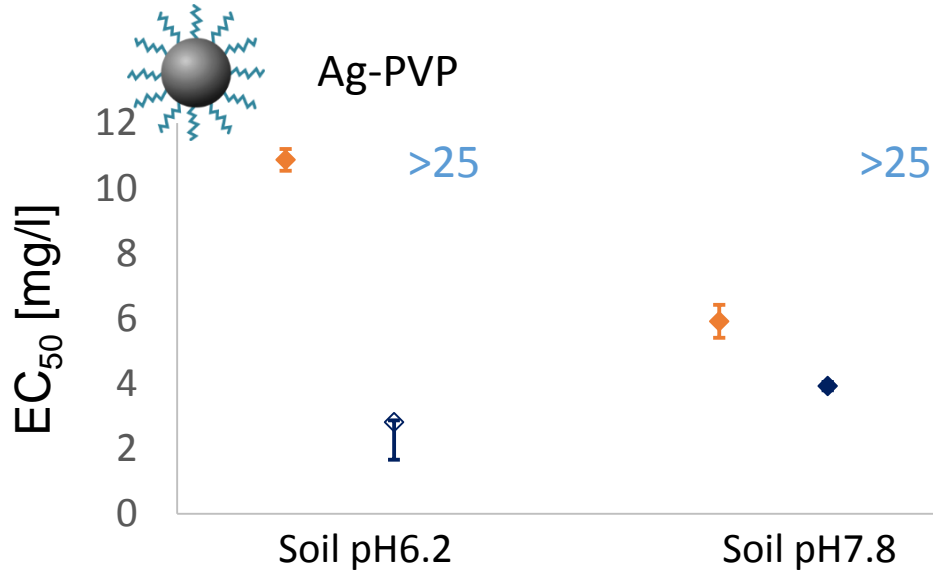
Ag-PVP and Ag-TA slightly increase in size

Interference during characterisation in soil pore water extracts

Results

Temperature effects 4°C

A. globiformis



Greater toxicity of aged particles

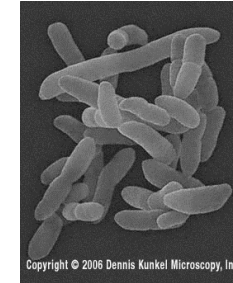
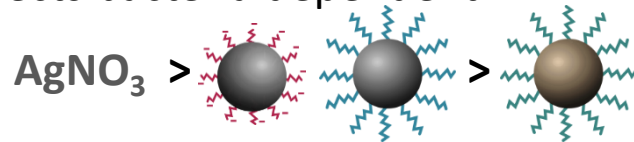
Unaged
Aged total
Aged dissolved
fraction

Conclusions

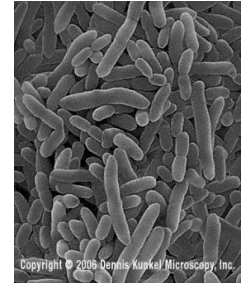
A. globiformis more sensitive than *P. putida*

Toxicity: $\text{AgNO}_3 > \text{Ag-PVP} = \text{Ag-TA} > \text{Ag}_2\text{S}$ in all media

Coating effects bacteria dependent



A. globiformis



P. putida

Hypotheses

→ Aging reduces toxicity in pore waters at 25°C

→ Dissolution main driver of toxicity in ISO medium but does not contribute to toxicity in pore waters

Waiting for concentration analysis to confirm

Complex interactions make read across/predictions difficult

Acknowledgements

Joanna Gray, Marianne Matzke, Claus Svendsen, Liz Shaw, Elma Lahive

GUIDE *nano* 

FP7/2007-2013 grant agreement No 6043387



Rudo Verweij



Jason Unrine



Anne Dudley



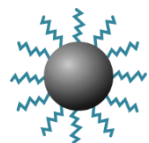
Beatriz Macarena Cobaleda Siles
Ariadna Peral

Soil Properties

Soils	Origin		Sand %	Silt %	Clay %	OM %	100% WHC [ml]	CEC (mval/100g)
Dorset	Acidic heath	Sandy	91.7	4.7	3.5	8.00	49.2	5.4
Texture, total carbon and nitrogen			% Coarse sand	% Fine sand	% Clay	% Silt	% Total C	% Total N
			51.5	40.2	3.5	4.7	4	0.1
pH and conductivity			pH _{H2O}	pH _{CaCl2}	Conductivity (µS)			
			4.2	3.1	422			
Exchangeable cations (cmol(+)/kg)			Ca	Mg	K	Na	CEC	% BS
			1.4	0.6	0.1	0.1	5.4	41
Extractable Fe and Al			% Fe _{ox}	% Al _{ox}	% Fe _{CBD}	% Al _{CBD}		
			0.04	0.03	0.11	0.03		

Results

Stability in soil pore water over 24h
using UV vis



Ag-PVP

