



Materials Science & Technology

# **Release of Conventional and Nano-Sized Biocides from Coated Wooden Façades during Weathering: Consequences for Functionality and Aquatic Environment**

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## Role of Nanotechnology in Green Materials and Sustainable Construction

### Wood coatings for facades:

- Transparent
  - Water-repellent / self-cleaning
  - Protection against microorganisms
  - Durable / long-lasting
  - Sustainable and environmental friendly
- Nano-sized pigments
  - Nano-structured surfaces
  - Nano-sized biocides



## Conventional organic biocides

Leach out during weathering

Rainwater carries them into the soil or to the storm sewer

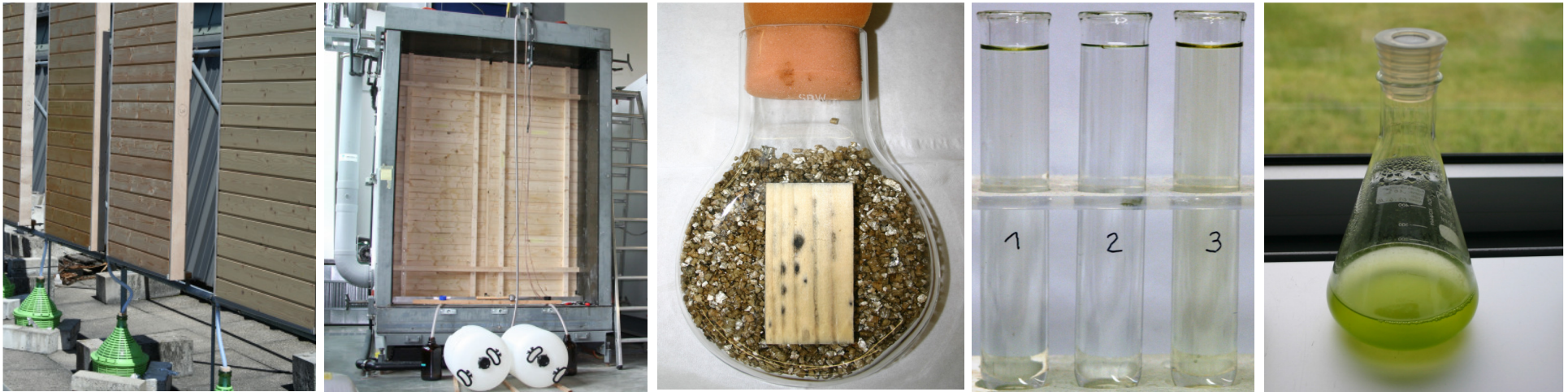
Biocides can:   accumulate in the lakes  
                          harm aquatic organisms

## Silver ions

Effective against bacteria

Nano-sized silver particles?

**Can nano-sized silver particles be an effective, eco-friendly biocide?**



## ■ Material

Norway Spruce (*Picea abies*)

Coating systems (transparent, hydrophobic)

1 m<sup>2</sup> – 1.3 m<sup>2</sup>

(A) Hydrolysed silane <25 ppm Nano-Ag

(B) Hydrolysed silane without Nano-Ag

(C) Oily alkyd resin <1 ppm Nano-Ag

(D) Alkyd <2.5% Propiconazole/ Acryl <0.5% IPBC

## ■ Methods

Natural weathering

Artificial weathering

Overall performance

Antimicrobial effect

Analysis of run-off water

Acute toxicity

1 year

1 month

Before and after weathering

Coating tested against mould, blue stain and algae

Chemical and microscopic

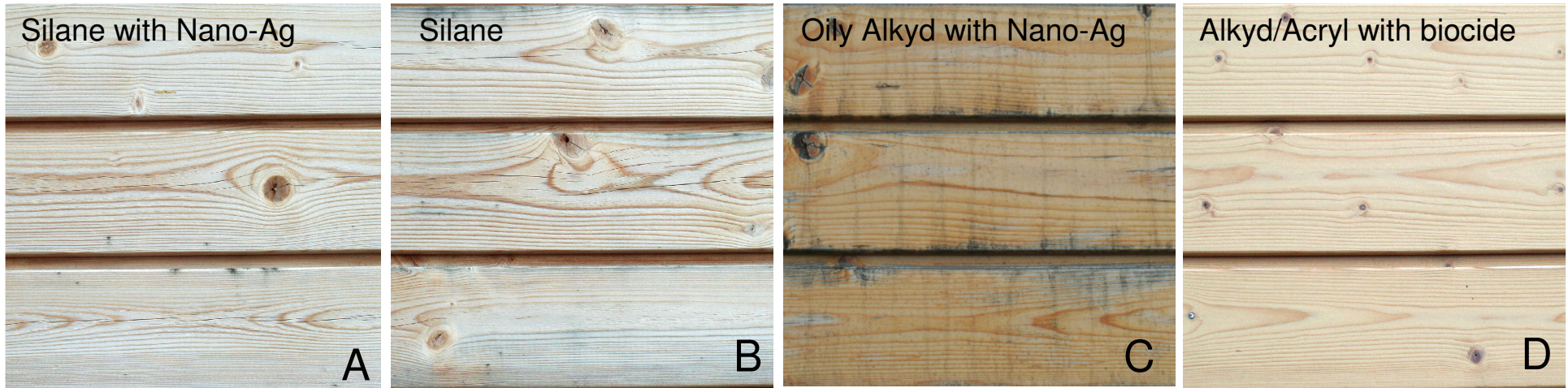
Run-off water tested on algae, water flea and bacteria



## Performance after one year of natural weathering

- Dry film thickness [ $\mu\text{m}$ ]  
 (A) no initial film (B) no initial film (C) 19 (-21%) (D) 39 ( $\pm 0\%$ )
- Colour difference  $\Delta E^* ab$  (SCE)  
 (A) 20.8 (B) 15.6 (C) 17.7 (D) 11.3
- Static contact angle  
 (A)  $130^\circ$  (-6%) (B)  $133^\circ$  (-6%) (C)  $85^\circ$  (-11%) (D)  $102^\circ$  ( $\pm 0\%$ )
- Water vapour permeability [ $\text{g}/(\text{m}^2 \cdot \sqrt{\text{h}})$ ]  
 (A) 41 (-13%) (B) 40 ( $\pm 0\%$ ) (C) 31 (+19%) (D) 29 ( $\pm 0\%$ )
- Liquid water permeability [ $\text{g}/\text{m}^2$ ]  
 (A) 864 (+33%) (B) 994 (+55%) (C) 434 (+161%) (D) 209 (-14%)

(Limit value for semi-stable applications (EN 927-2):  $250 \text{ g}/\text{m}^2$ )

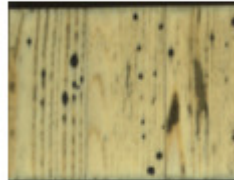
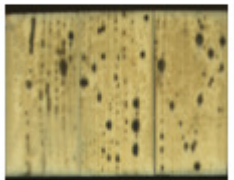


## Protection against microorganisms

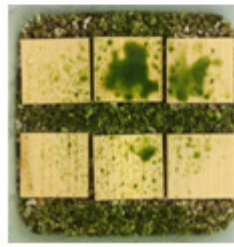
**Mould**  
6 weeks

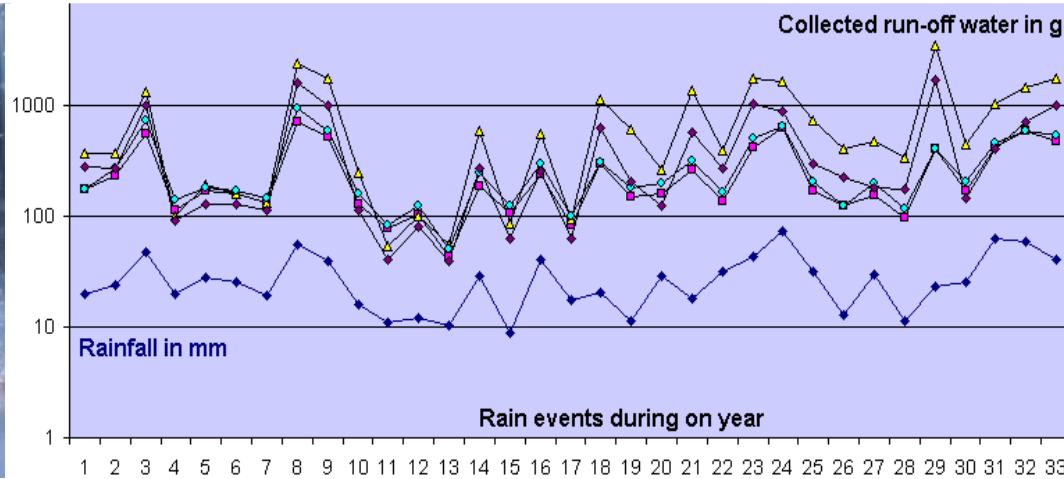


**Blue stain**  
6 weeks



**Algae**  
12 weeks

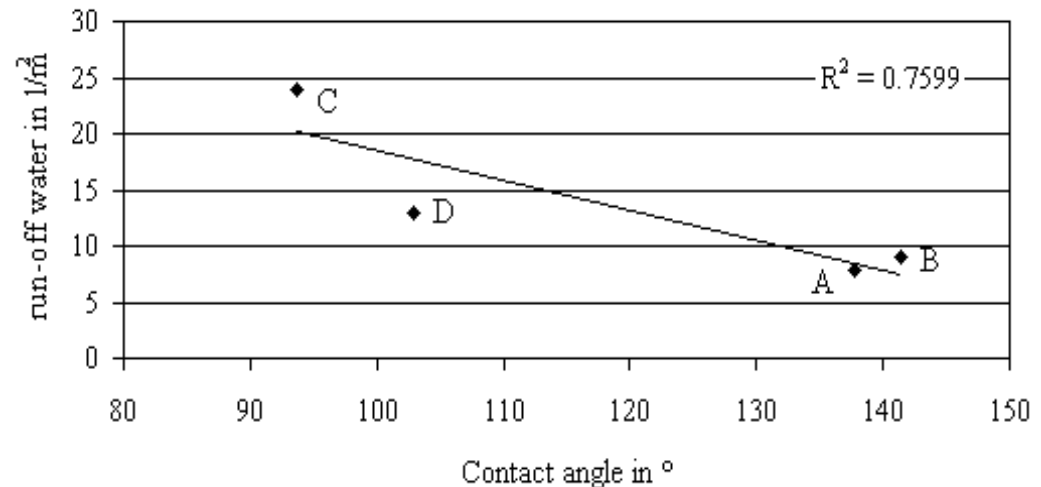


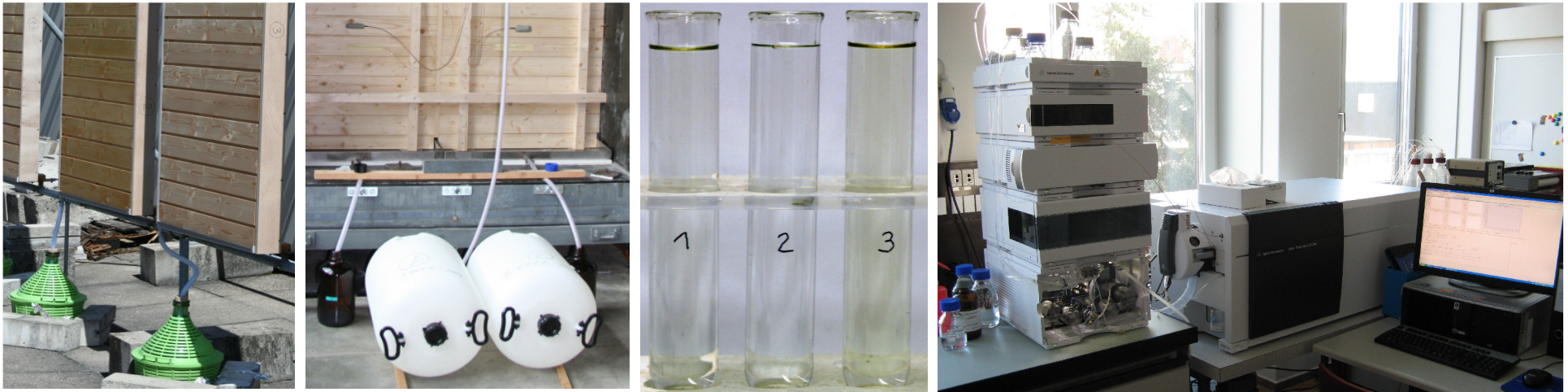


## Collection of rain water during natural weathering

Quantity depending on exposure conditions (*rainfall, wind speed, wind direction*)  
 structural environment (*roof overhang, construction*)  
 wind flow conditions (*pressure distribution*)

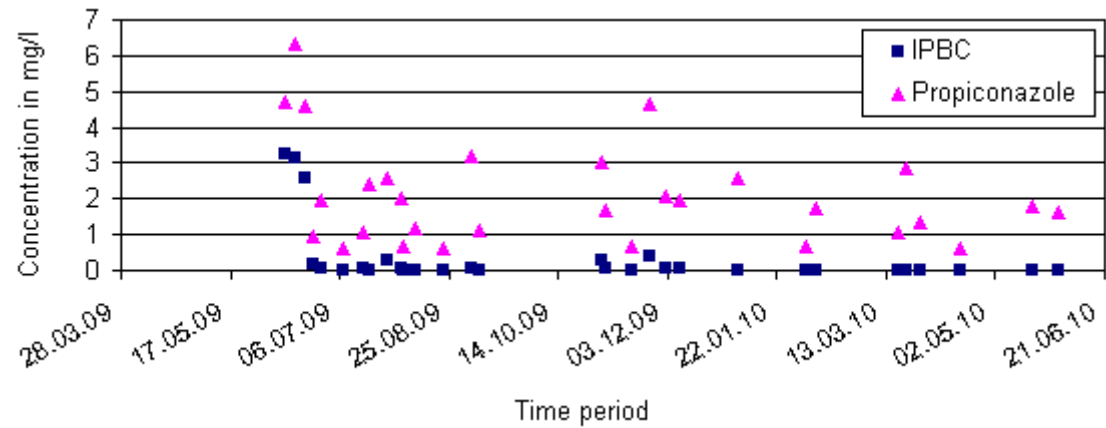
The hydrophobic character of the coating influences the quantity of run-off water of the façade.



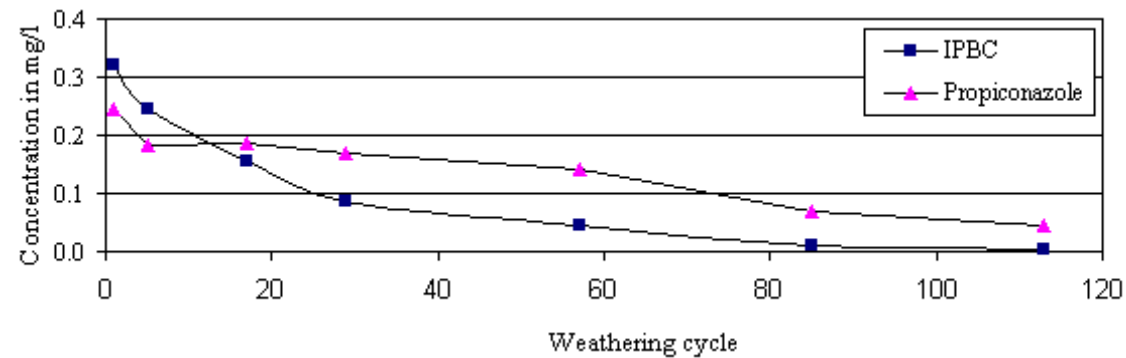


## Release of IPBC and propiconazole during weathering

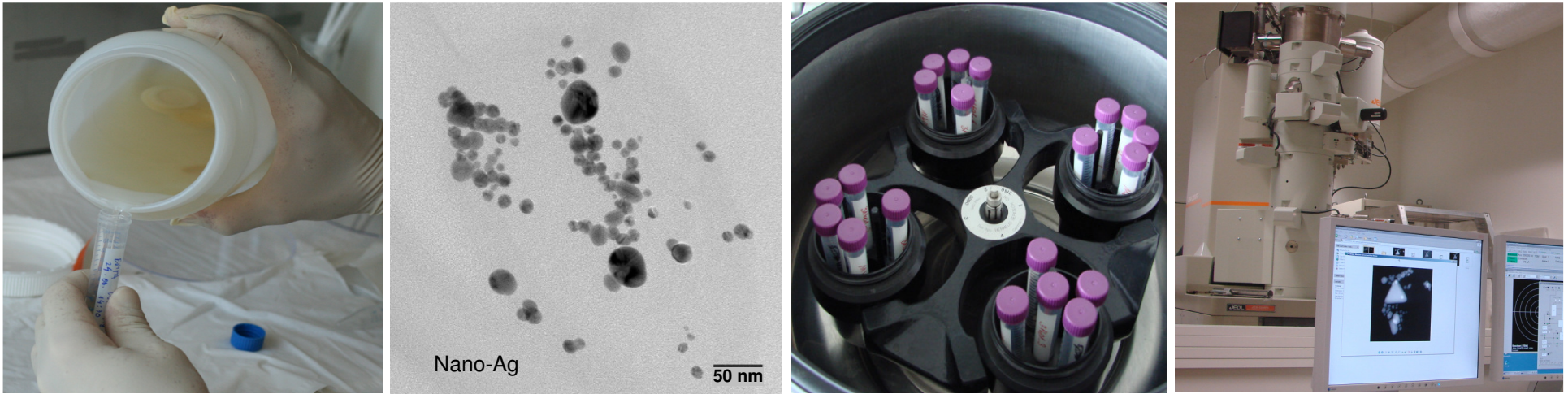
Natural weathering



Artificial weathering

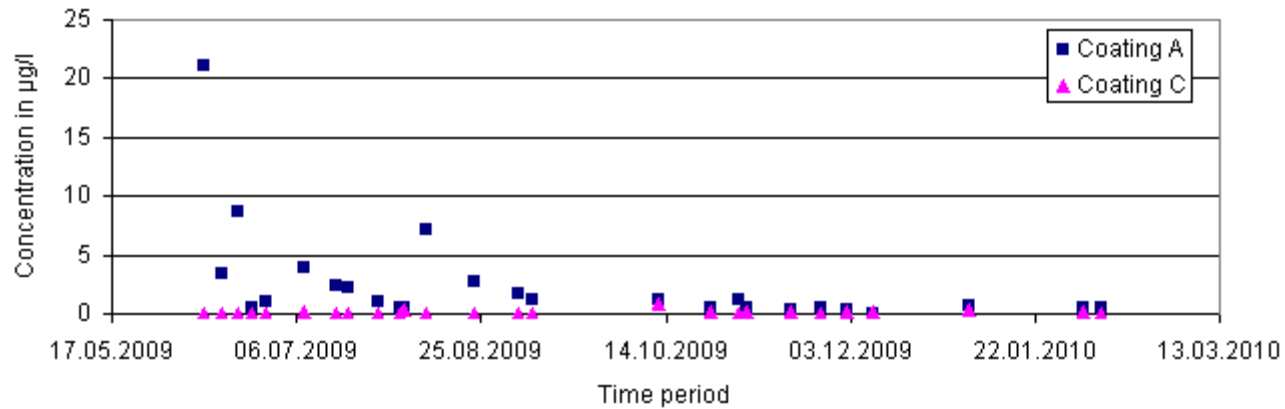




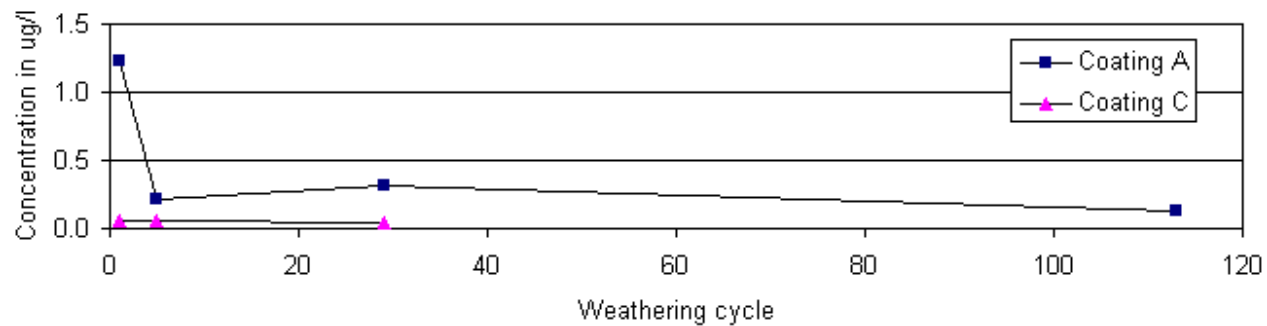


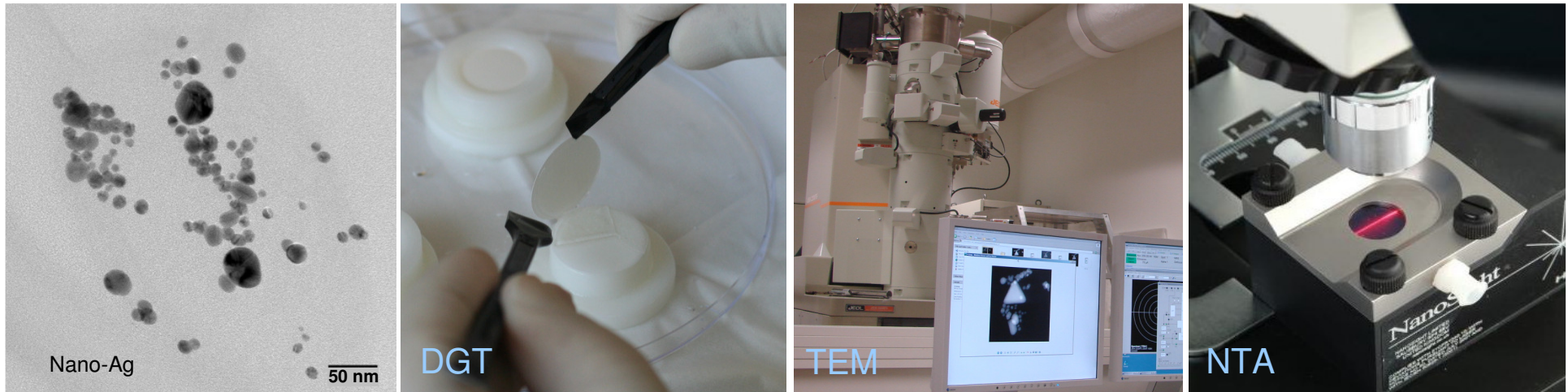
## Release of total silver during weathering

Natural weathering



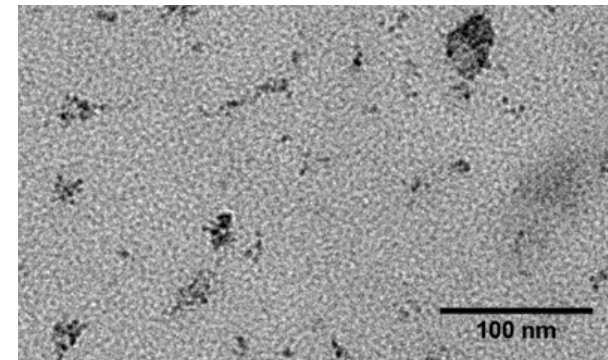
Artificial weathering



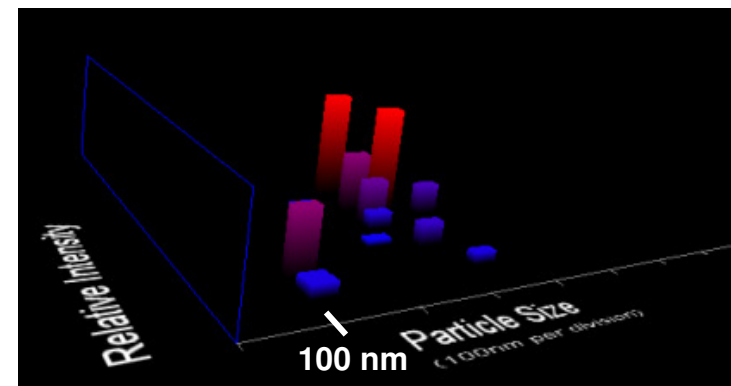


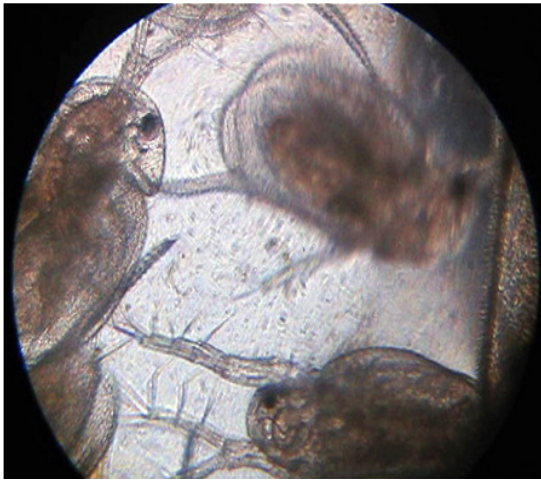
## Characterisation of silver in the run-off water

- ◆ DGT (*Diffusive Gradients in Thin Films*)  
Concentration of dissolved silver ~1.2%
- ◆ TEM (*Transmission Electron Microscopy*)  
Non nano-sized silver particles found  
EDX Mapping in STEM mode:  
Si, Fe, Al, Ca, O
- ◆ NTA (*Nanoparticle Tracking Analysis*)  
Very few particles; all > 100 nm



**Assumption:**  
Silver + sulphur compounds: silver sulphide





## Acute toxicity of the run-off water

- ◆ Acute immobilisation of water flea *Daphnia magna* (OECD Test 202)

IPBC: LC50=0.645 mg/l

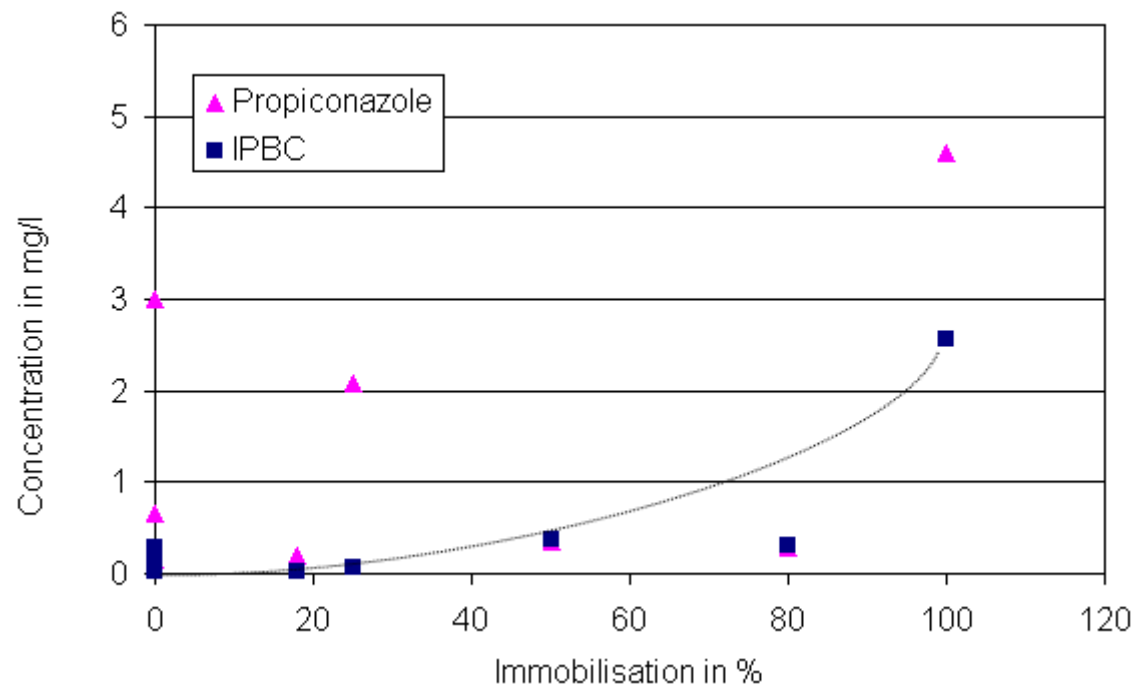
(Henderson 1992)

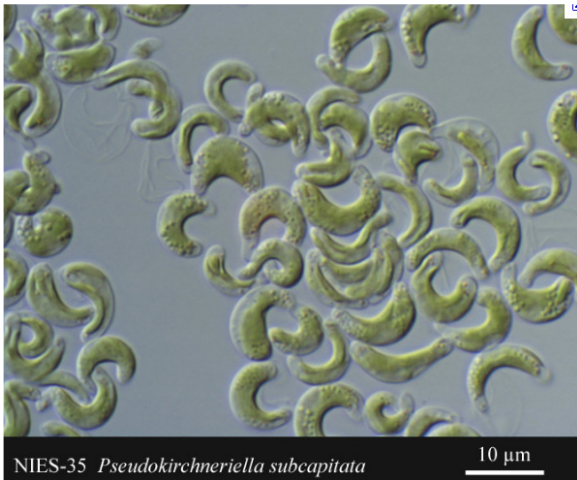
Prop.: LC50=5 mg/l

(Kast-Hutcheson 2001)

Coating D            Immobilisation  
Effect is dominated by IPBC.

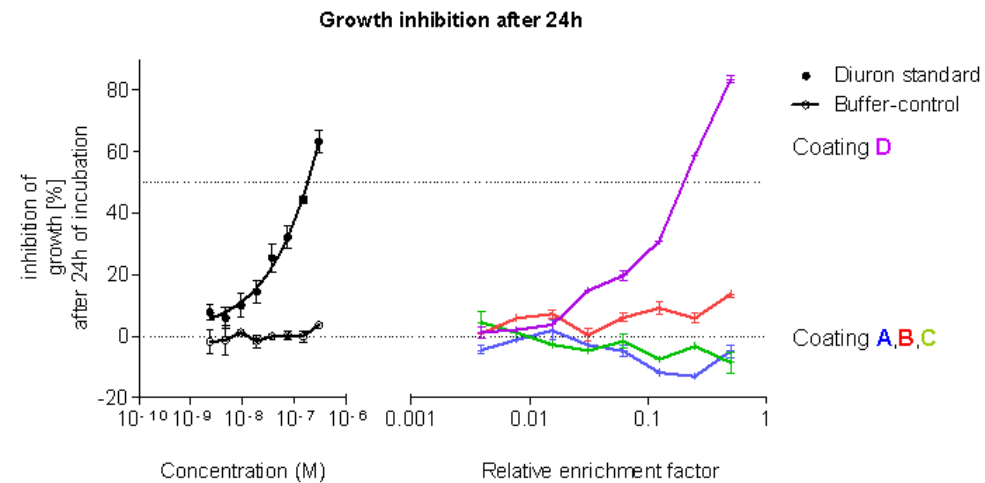
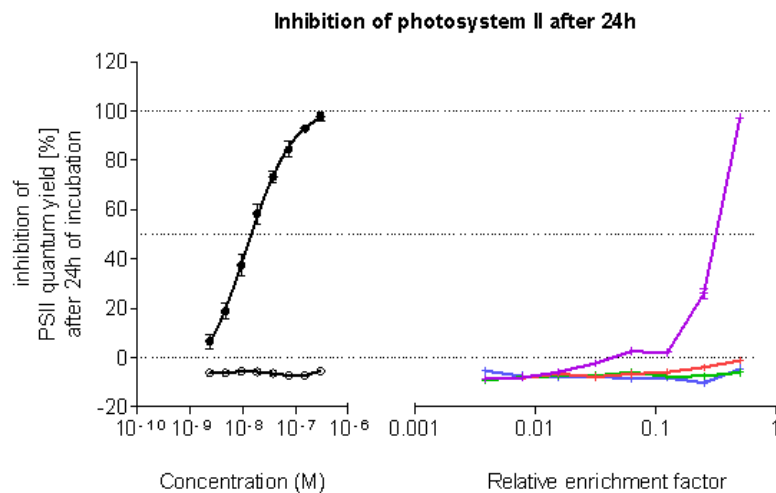
Coatings A,B,C    No effect





## Acute toxicity of the run-off water

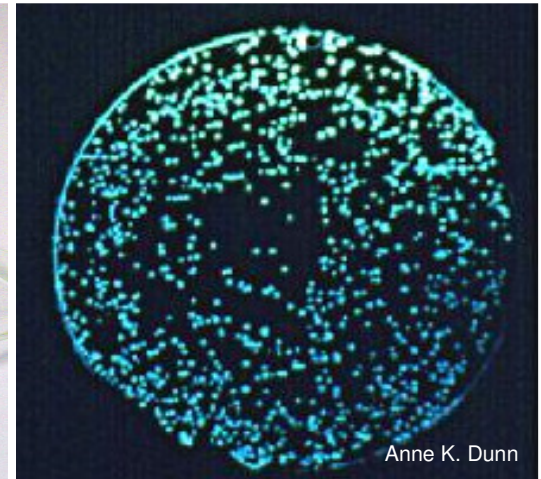
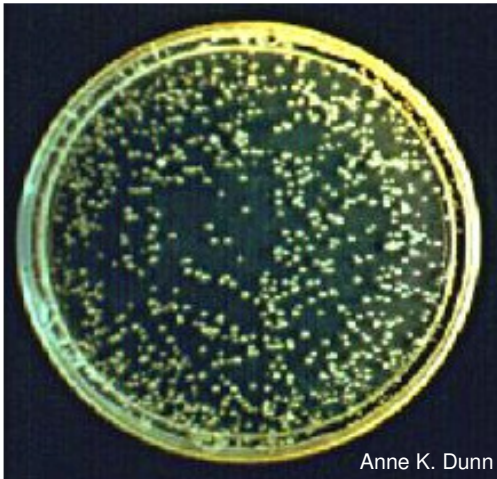
### ◆ Combined Algae Test with *Pseudokirchneriella subcapitata*



Coating **D**  
Coatings **A,C**  
Coating **B**

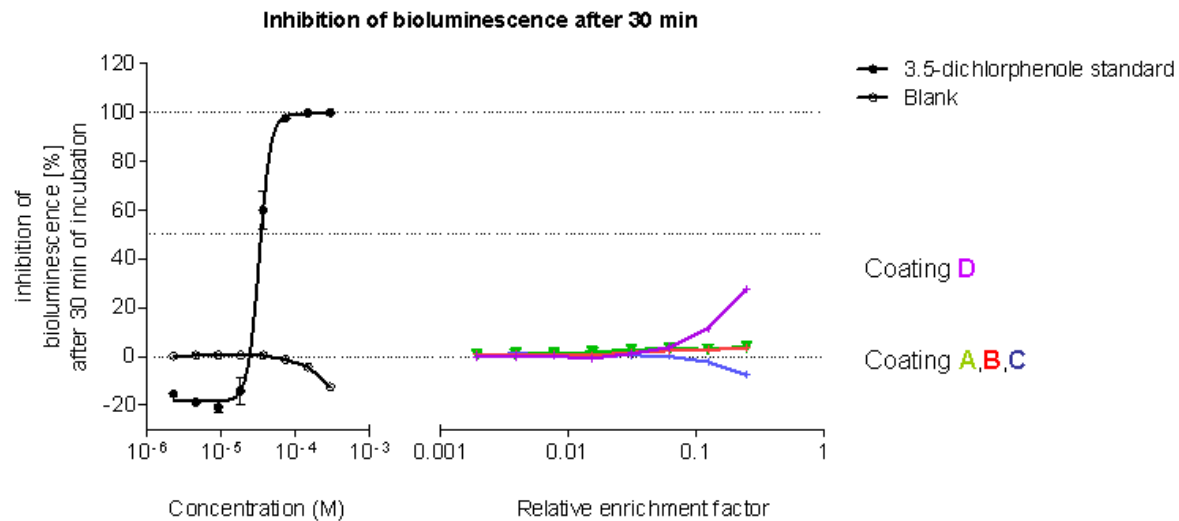
IPBC + Prop.  
silver  
no silver, no biocide

Inhibition of photosynthesis and growing  
No effect  
Slight inhibition of growing (why?)



# Acute toxicity of the run-off water

## ◆ Bacterial Bioluminescence Inhibition Test *Vibrio fischeri*



Coating **D**  
Coatings **A,B,C**

IPBC + Prop.

Inhibition of bioluminescence  
No effect



## Summary

- ◆ Silver in the run-off water
  - ◆ *Very low quantity released to run-off water during natural weathering*
  - ◆ *Not particulate, not in ionic form (assumption: bound as silver sulphide)*
  - ◆ *Measured concentrations did not affect the tested aquatic organisms*
  
- ◆ Nano-sized silver particles in the coating
  - ◆ *Well fixed in the polymer matrix*
  
- ◆ Protective effect against microorganisms
  - ◆ *Current concentrations (<25 ppm) showed no protection against mould, blue stain and algae*



## Can nano-sized silver particles be an effective, eco-friendly biocide in wood coatings?

Under the tested conditions:

**YES**

Low environmental impact

Run-off water did not affect the aquatic microorganisms

**NO**

No protective effect against microorganisms on the façade

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