Opticap:
Thin capping for in-situ remediation

Gerard Cornelissen, Rahel Brändli, Amy Oen,
Audun Hauge, Espen Eek, Gijs Breedveld

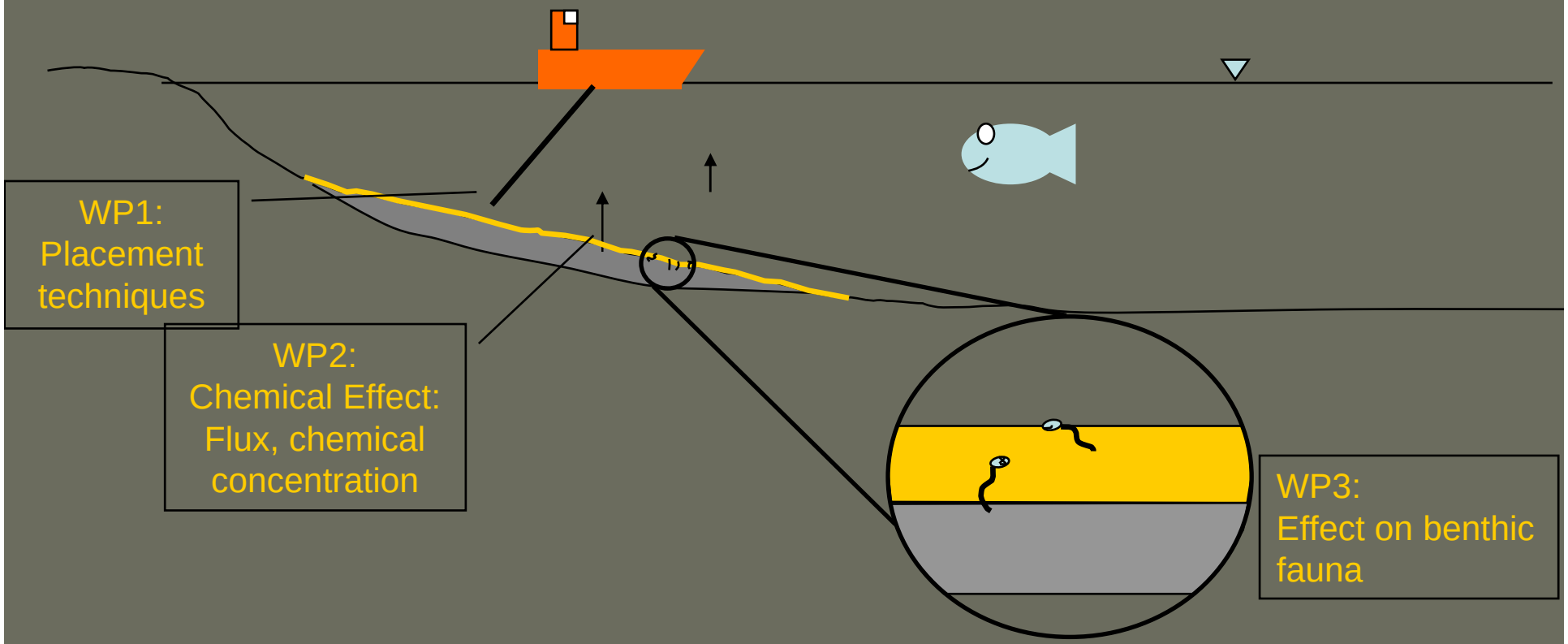
Norwegian Geotechnical Institute (NGI), Oslo, Norway
ITM, Stockholm University, Sweden
Geosciences, University of Oslo, Norway

In cooperation with:
Norwegian Institute for Water Research (NIVA)

Thin capping of sediments (< 15 cm)

- Challenge in Norway:
- Large areas, no maintenance dredging
  - Oslo Harbour
    - 1-5 km^2 (PAH, PCB)
  - Drammensfjord,
    - 1,3 km^2 (TBT)
  - Grenlandsfjords,
    - 5-30 km^2 (dioxins)

Thin capping: ”Opticap”
Research Council of Norway project, 2 mill euro



Opticap:

Partners and materials

- Suspended Calcium Carbonate — industrial byproduct (Hustadsmarmor)
- ”Environmental” gypsum — industrial byproduct (NOAH)
- Sand
- Clay — original seafloor
- Activated Carbon — powdered, granulated

Opticap:

Partners and materials

- Suspended Calcium Carbonate — industrial byproduct (Hustadsmarmor)
- ”Environmental” gypsum — industrial byproduct (NOAH)
- Sand
- Clay — original seafloor
- Activated Carbon — powdered, granulated

⟹ Other partners: - NIVA
- Secora (contractor; placement)
- Agder Marine (contractor; specialized equipment)

Opticap:

Partners and materials

• Suspended Calcium Carbonate	field pilot 2009
• ”Environmental” gypsum	field pilot 2009
• Sand	Kvalstad et al, poster
• Clay	Eek et al, platform tomorrow
• Activated Carbon	this presentation

Activated Carbon (AC) amendment

- Principle:
- **AC binds pollution so strongly that chemical equilibrium is shifted away from the benthic biota (”pollutants cannot be taken up”)**

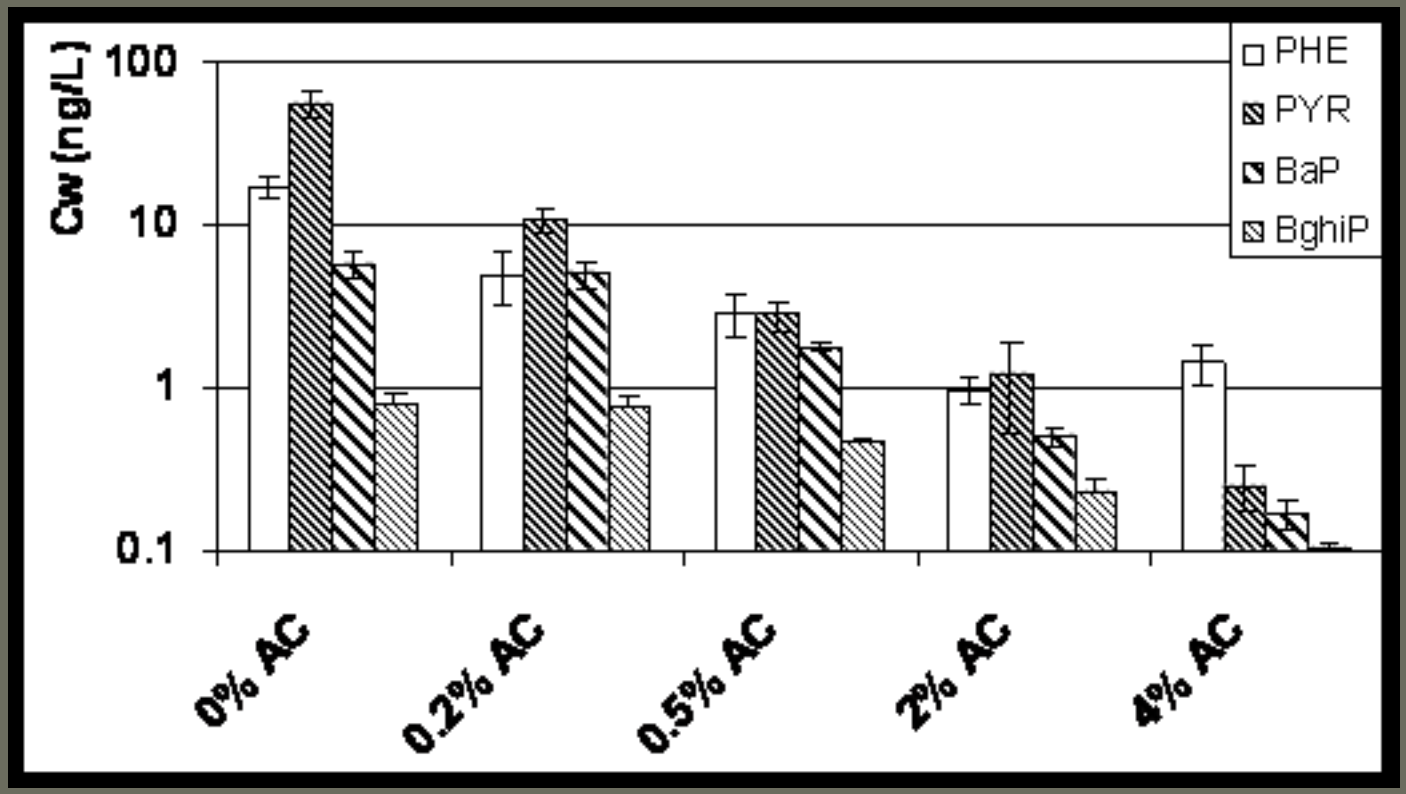
Advantages:

- **”Active” material**
- **No reduced sailing depth**
- **Small quantities (transport, placement)**

Idea/patent:

Luthy and Ghosh, Stanford University

Various AC dosages in Oslo sediment



AC dosage	0.2%	0.5%	2%	4%
Reduction porewater concentration	60%	90%	97%	99%

Cornelissen Breedveld Kalaitzidis Christanis Oen, Environ. Sci. Technol. 2006, 40, 1197.

Sorption to pure AC and AC mixed into sediment

- Phenanthrene:
- $K_{OC} = 10^{4.2}$ L/kg

Cornelissen Breedveld Kalaitzidis Christanis Oen, Environ. Sci. Technol. 2006, 40, 1197.

Sorption to pure AC and AC mixed into sediment

- Phenanthrene:
- $K_{OC} = 10^{4.2}$ L/kg
- K_{AC} pure AC: $10^{8.1}$ L/kg (at 1 ng/L)

Cornelissen Breedveld Kalaitzidis Christanis Oen, Environ. Sci. Technol. 2006, 40, 1197.

Sorption to pure AC and AC mixed into sediment

- Phenanthrene:
- $K_{OC} = 10^{4.2}$ L/kg
- K_{AC} pure AC: $10^{8.1}$ L/kg (at 1 ng/L)
- K_{AC} in sediment-AC mixtures: $10^{6.6\text{-}7.9}$ L/kg

Cornelissen Breedveld Kalaitzidis Christanis Oen, Environ. Sci. Technol. 2006, 40, 1197.

Sorption to pure AC and AC mixed into sediment

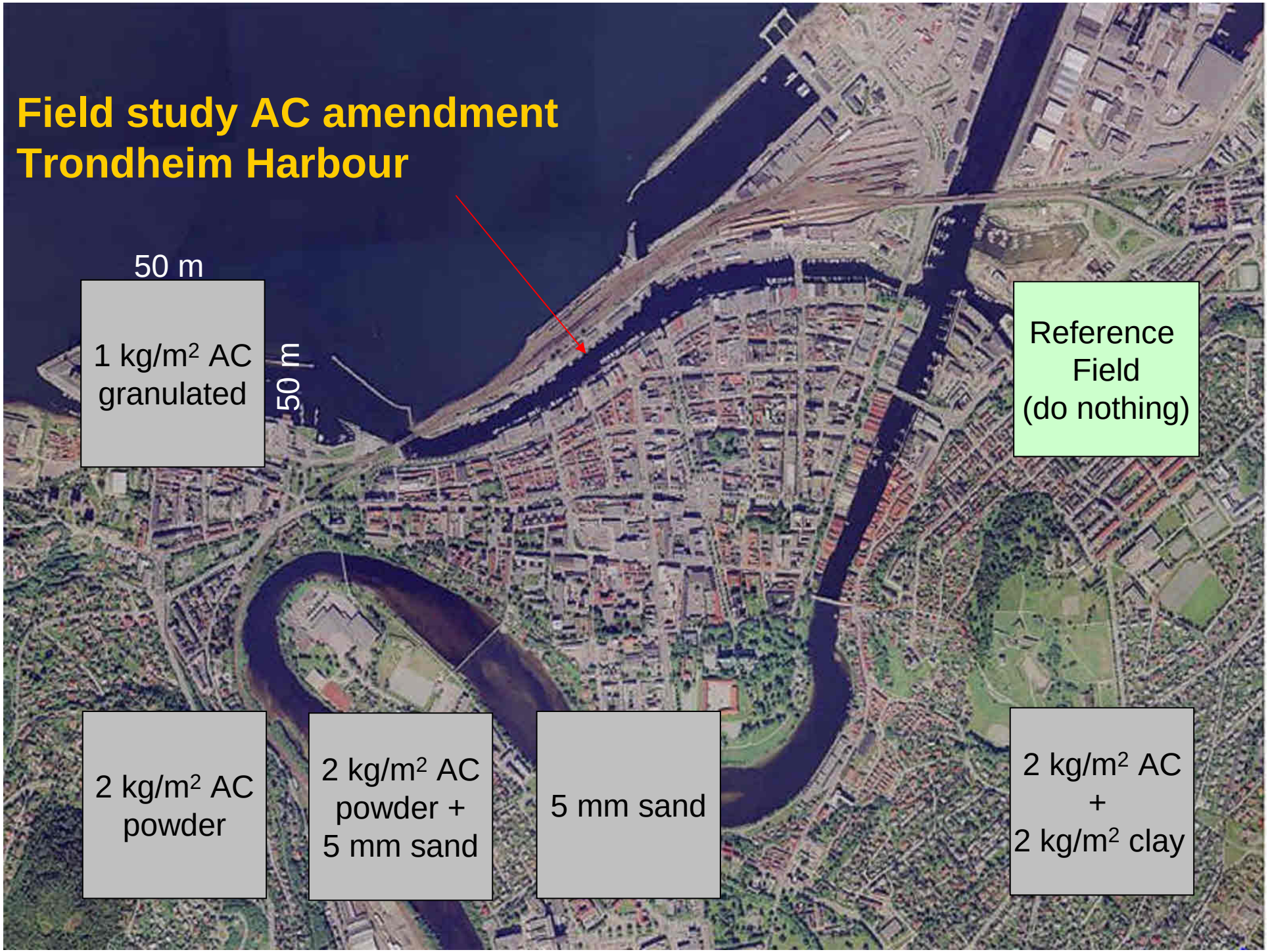
- Phenanthrene:
- $K_{OC} = 10^{4.2}$ L/kg
- K_{AC} pure AC: $10^{8.1}$ L/kg (at 1 ng/L)
- K_{AC} in sediment-AC mixtures: $10^{6.6\text{-}7.9}$ L/kg
- AC sorption 2-27 times weaker in AC-sediment mixture

Cornelissen Breedveld Kalaitzidis Christanis Oen, Environ. Sci. Technol. 2006, 40, 1197.

Bioaccumulation: laboratory tests 2% AC

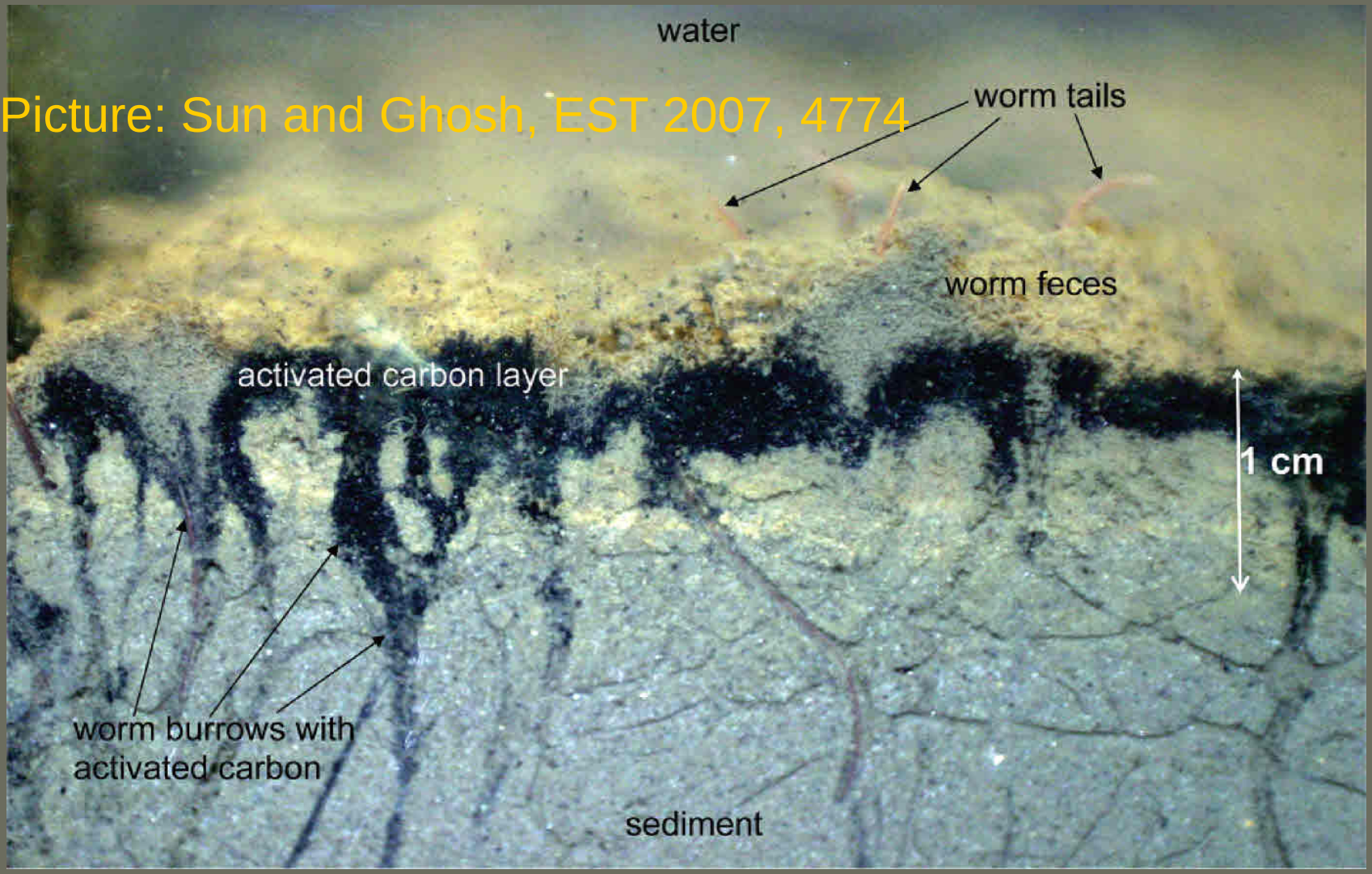
- Free concentrations in water reduced 95-99.5 %
- Uptake in organisms reduced 50-90%
- Lipid contents in two biota
  - Without AC: 1.1 ± 0.3 %
  - With AC: 1.0 ± 0.4%

Cornelissen Næs Oen Ruus Breedveld, Environ. Toxicol. Chem. 2006, 25, 2349-2355


Field study AC amendment
Trondheim Harbour
50 m
50 m
1 kg/m² AC granulated
Reference Field (do nothing)
2 kg/m² AC powder
2 kg/m² AC powder + 5 mm sand
5 mm sand
2 kg/m² AC + 2 kg/m² clay

Mixing of AC into sediment by bioturbation

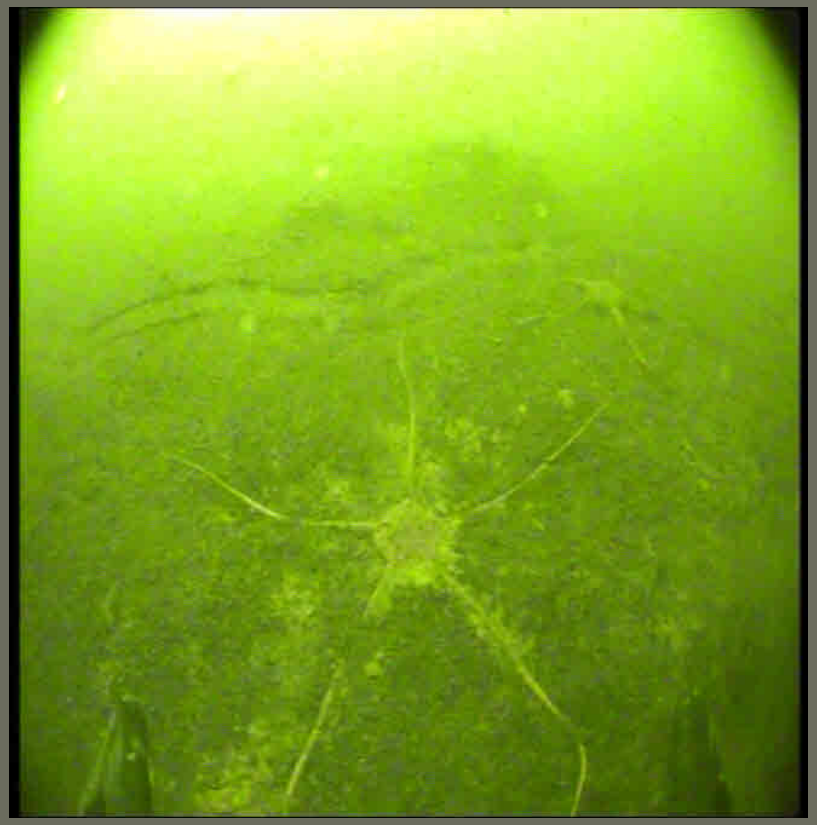
Picture: Sun and Ghosh, EST 2007, 4774



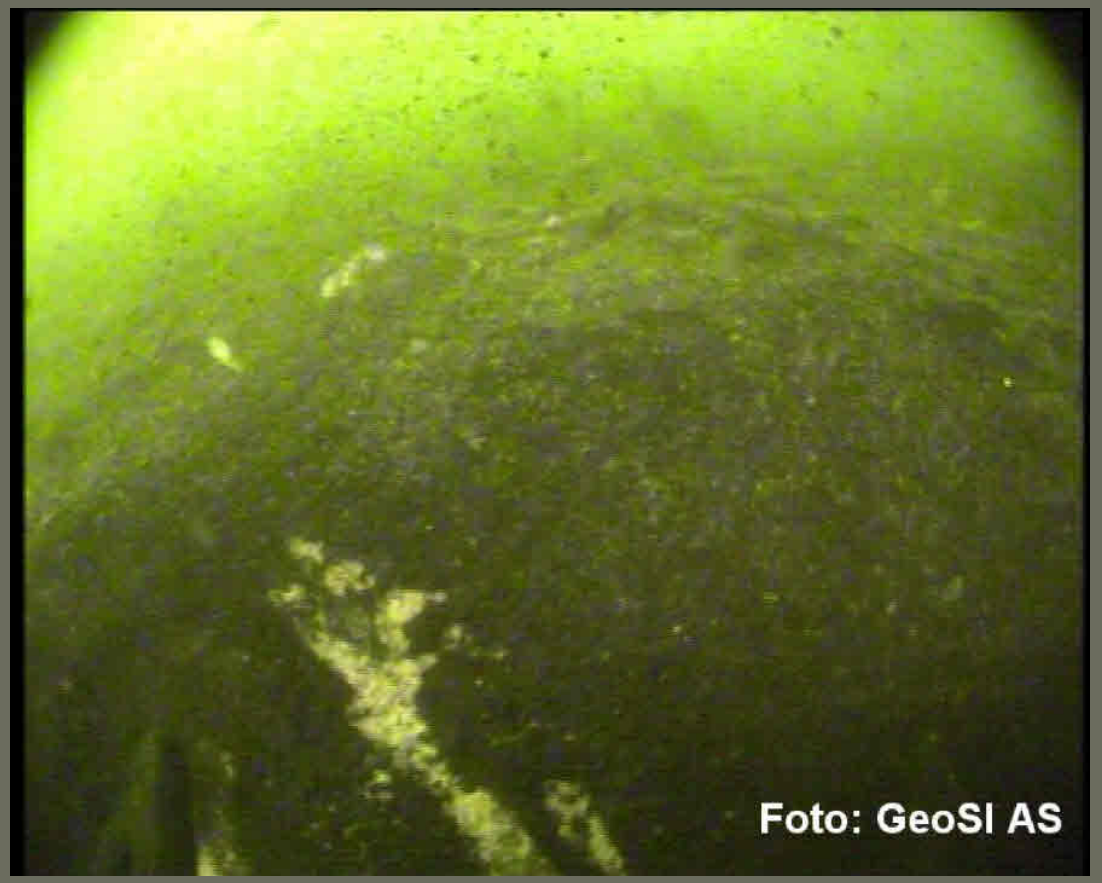
Placement of granulated AC (0.4-1.7 mm)

Powder-AC (0.02 mm): AC-bentonite, pure AC

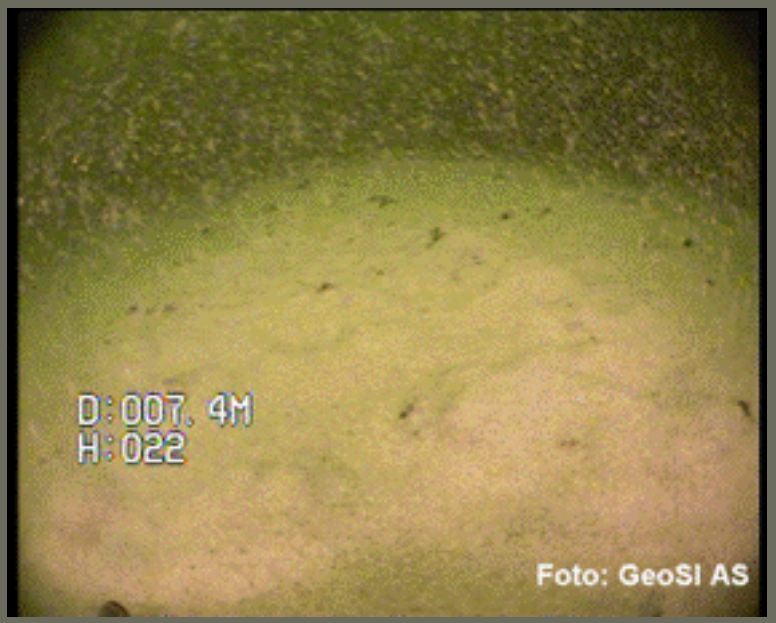
Original seafloor Trondheim Harbour



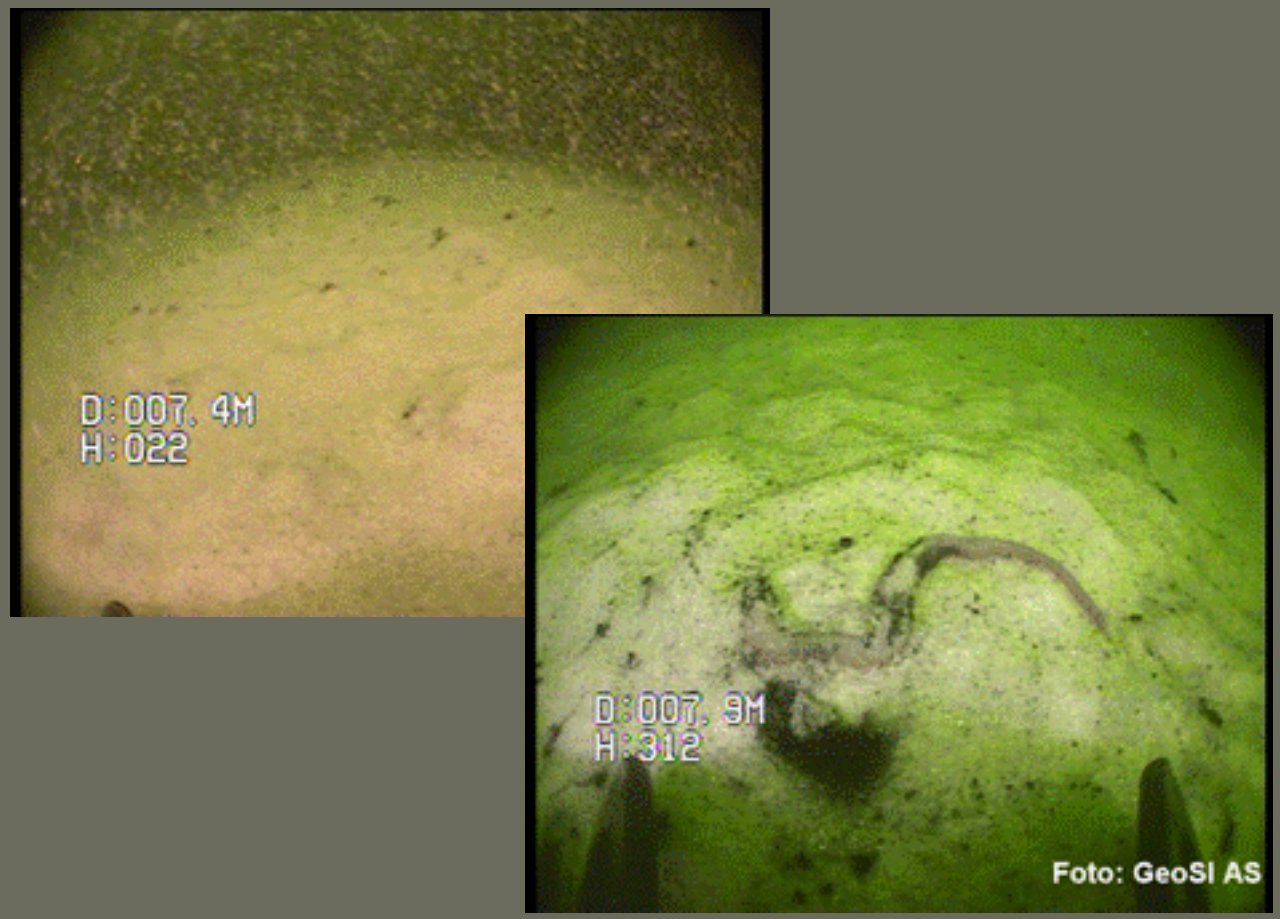
Powder AC suspension after 1 day



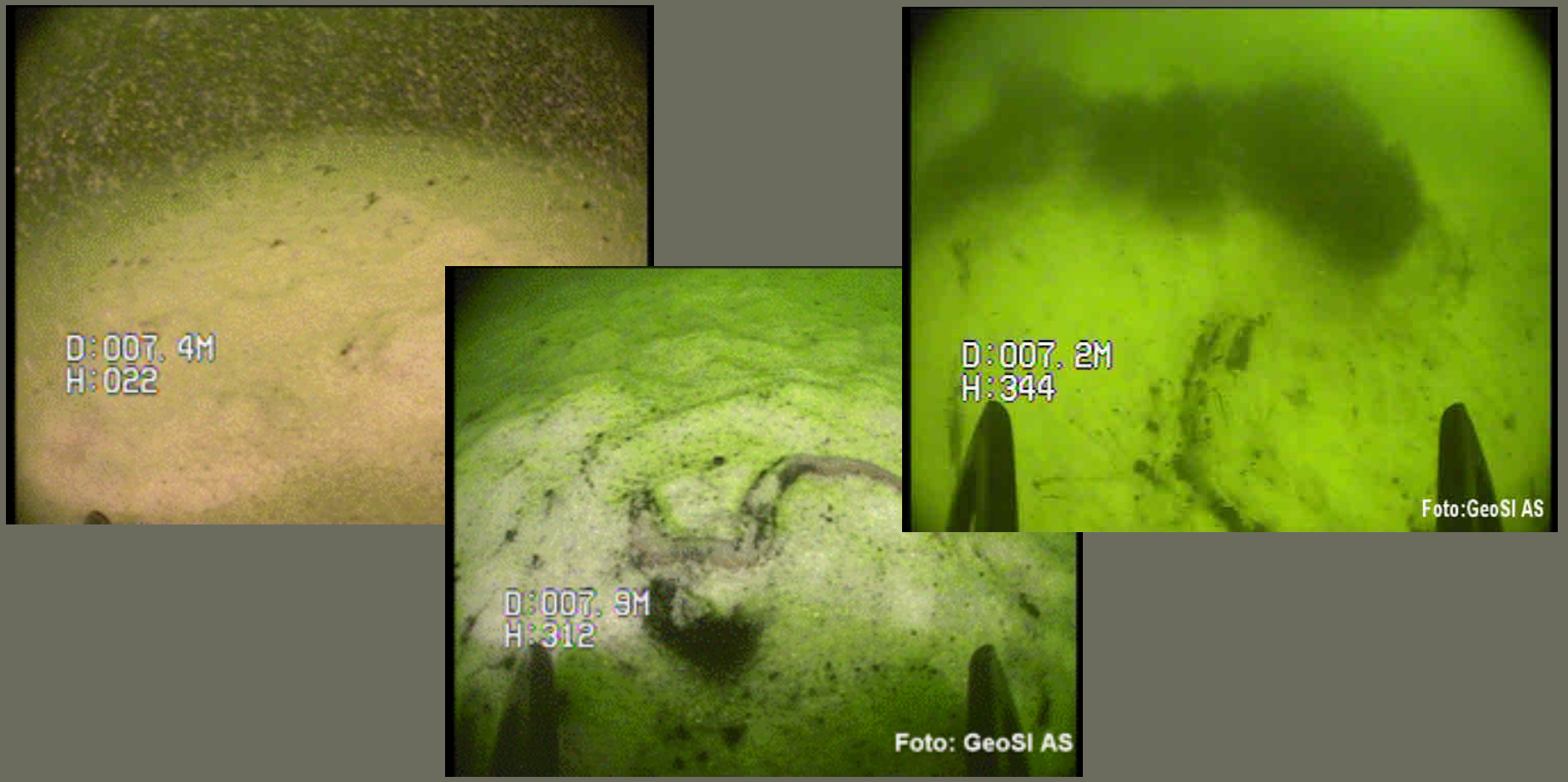
Covering the AC with 5 mm sand



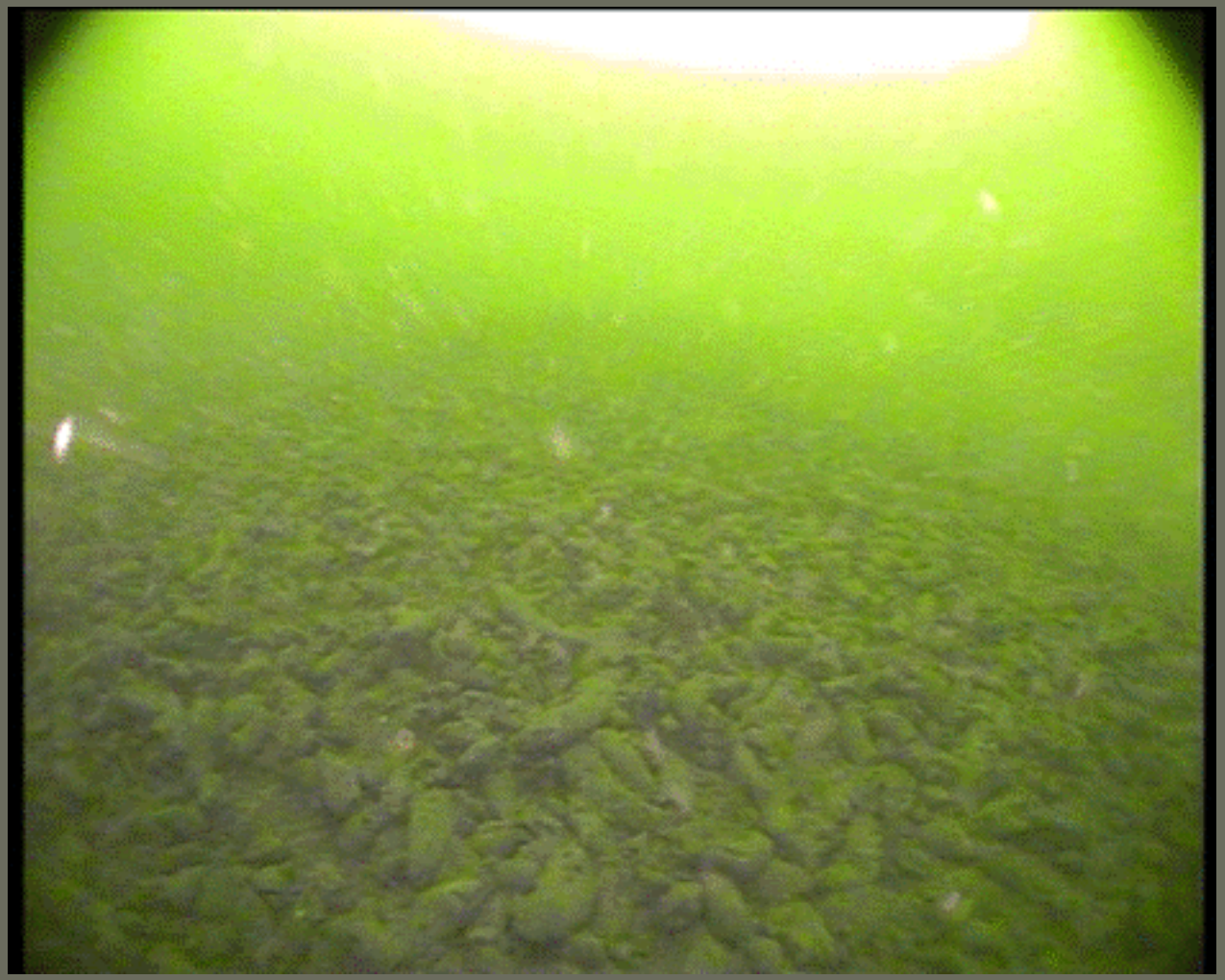
Covering the AC with 5 mm sand



Covering the AC with 5 mm sand



1:1 AC:bentonite suspension



Placement platform

TV coverage

Monitoring

- Physical
  - AC distribution
- Chemical
  - Porewater concentration
  - Surface water concentration
  - Sediment-water flux
- Biological
  - Bioaccumulation
  - Biodiversity

1 grab: 500 individuals, 35 species

Monitoring

- Physical
  - AC distribution
- Chemical
  - Porewater concentration
  - Surface water concentration
  - Sediment-water flux
- Biological
  - Bioaccumulation
  - Biodiversity

”Risk-relevant” freely dissolved concentrations: Equilibrium passive samplers

- **Freely dissolved concentration** deduced from concentration in polymer
- **Overlying water:** field exposure

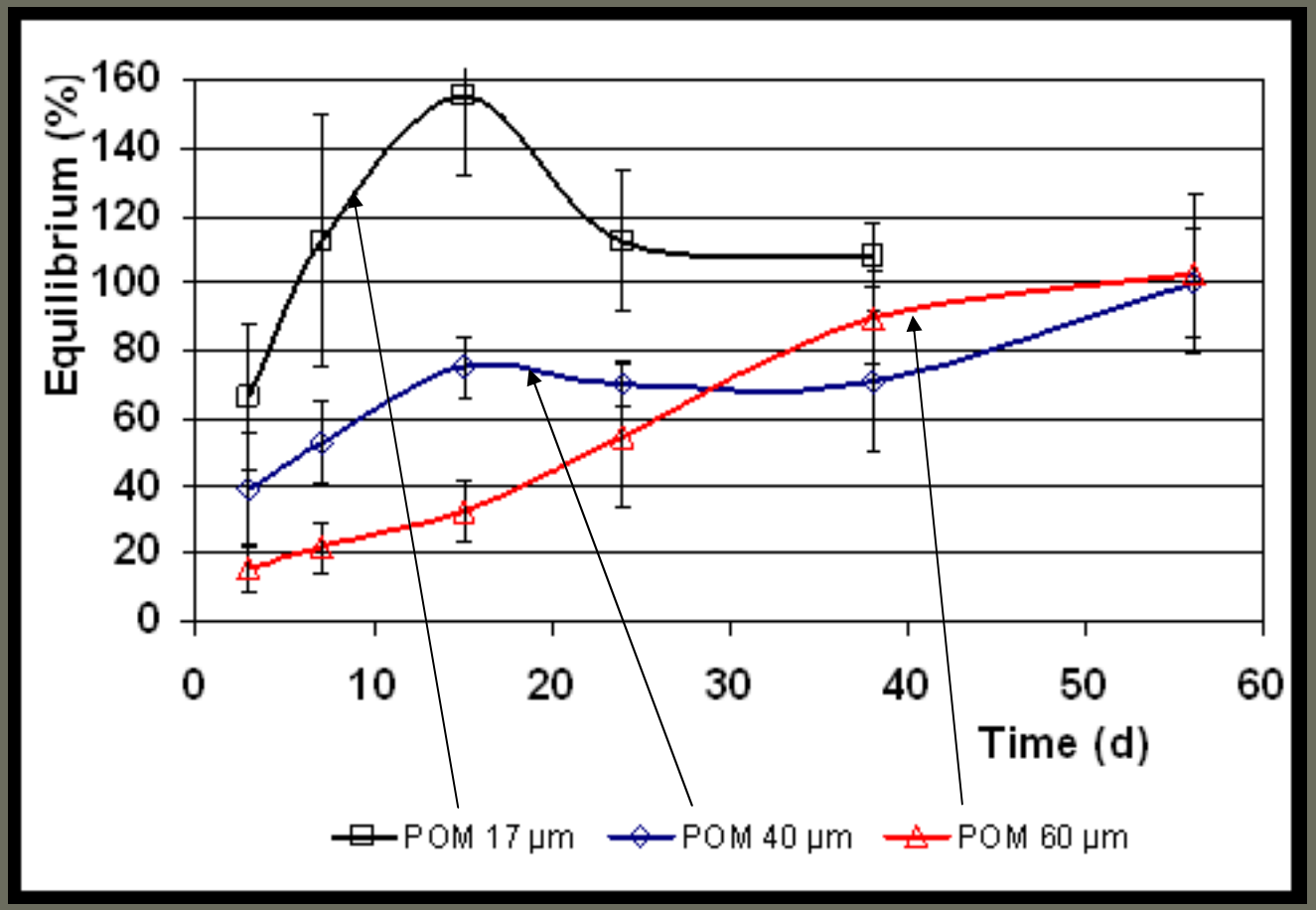
Cornelissen Broman Mayer Eek Breedveld ET&C March 2008

NGIs innovation:
Thin polyoxymethylene (POM) that reaches equilibrium under field conditions

Various POM thicknesses

Time-integrated freely dissolved concentrations

Detection limits 0.1 pg/m^3!



Detection limits thin-POM passive samplers

Expose 10 g passive sampler

OR

Extract 10.000-100.000 L water

”Tusen takk!!”