

# **Innovative methods to determine efficiency of remediation by sediment capping**

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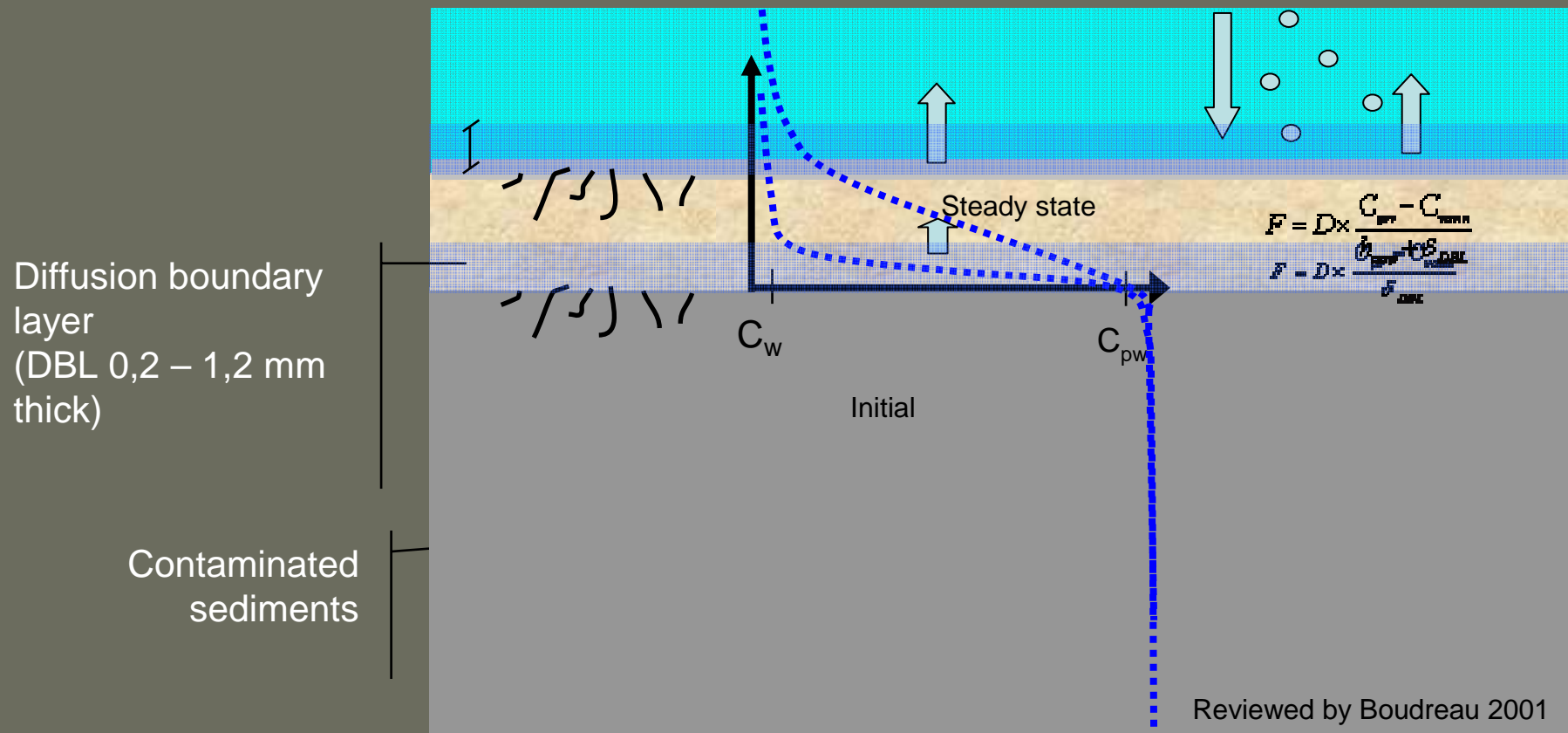
# Outline

- What determines capping efficiency
- Mechanisms of contaminant transport from capped sediment
- Methods to determine contaminant transport and capping efficiency
- Case: Capping with clay in Oslo Harbour

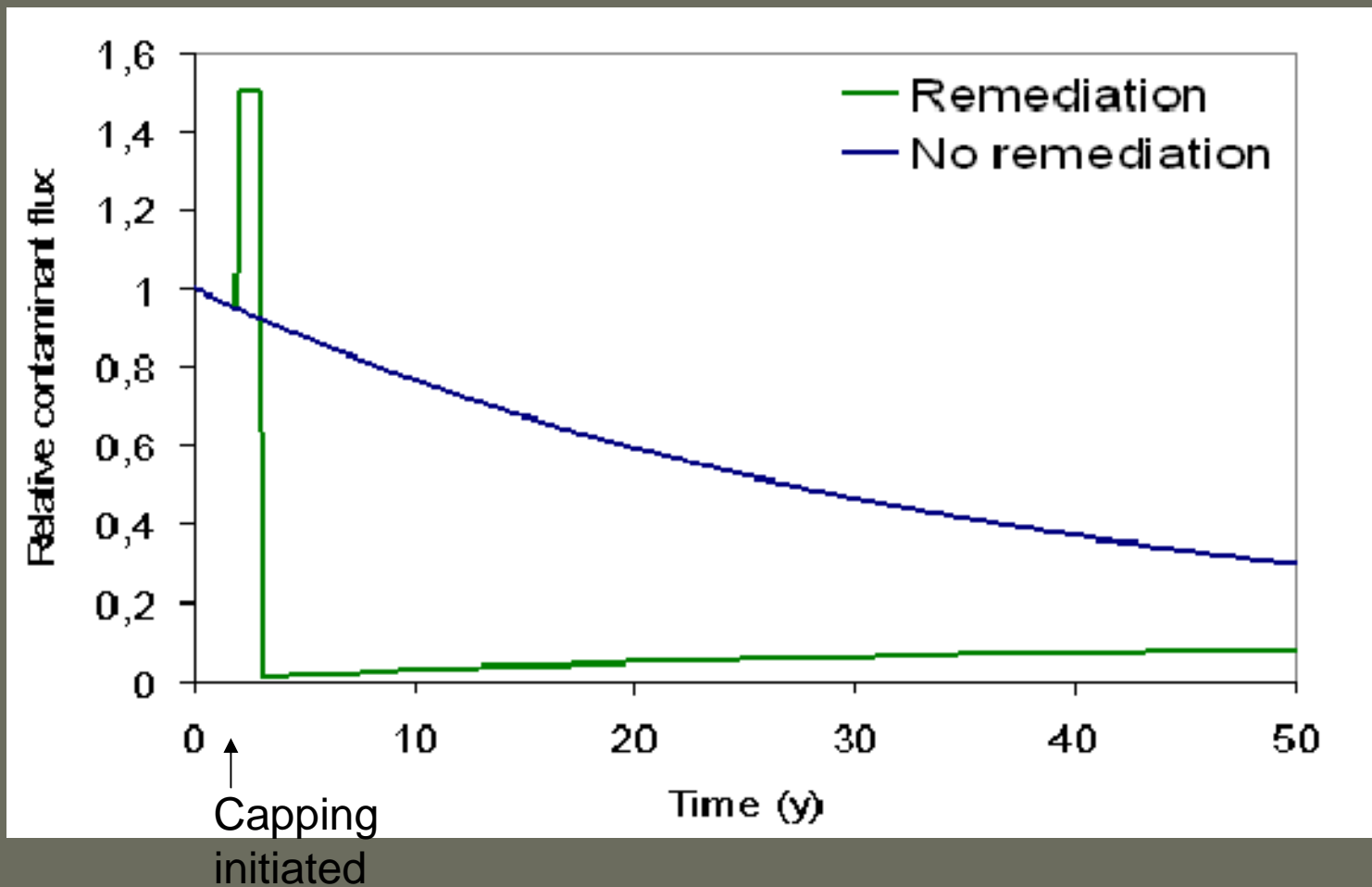
# What determines Capping Efficiency

- Capping Efficiency= Flux reduction
- Flux before capping
  - Diffusion through the Diffusive boundary layer (DBL)
  - Bioturbation
  - Wave or current induced advection
- Flux after capping
  - Diffusion through stagnant part of the cap
  - More rapid transport through upper part of cap influenced by:
    - Bioturbation
    - Wave or current induced advection

# What determines capping efficiency

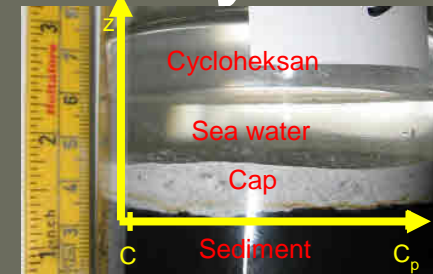


# Methods to determine Capping Efficiency



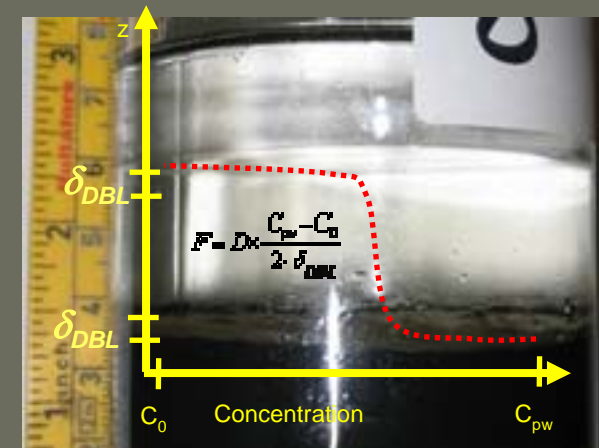
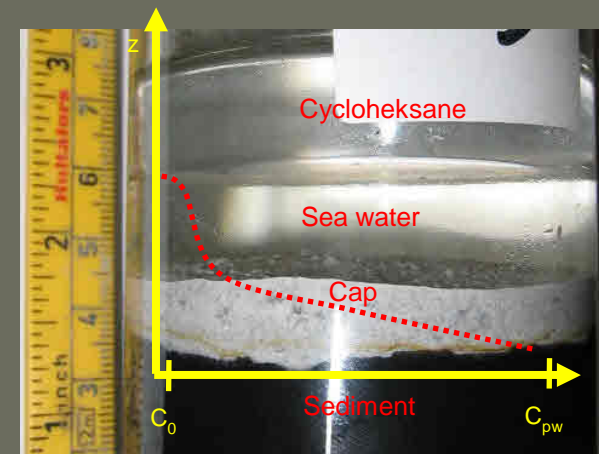
# Methods to determine Capping Efficiency (or flux before and flux after)

- Infinite sink microcosm
- Infinite sink in-situ flux chamber
- In-situ equilibrium passive samplers



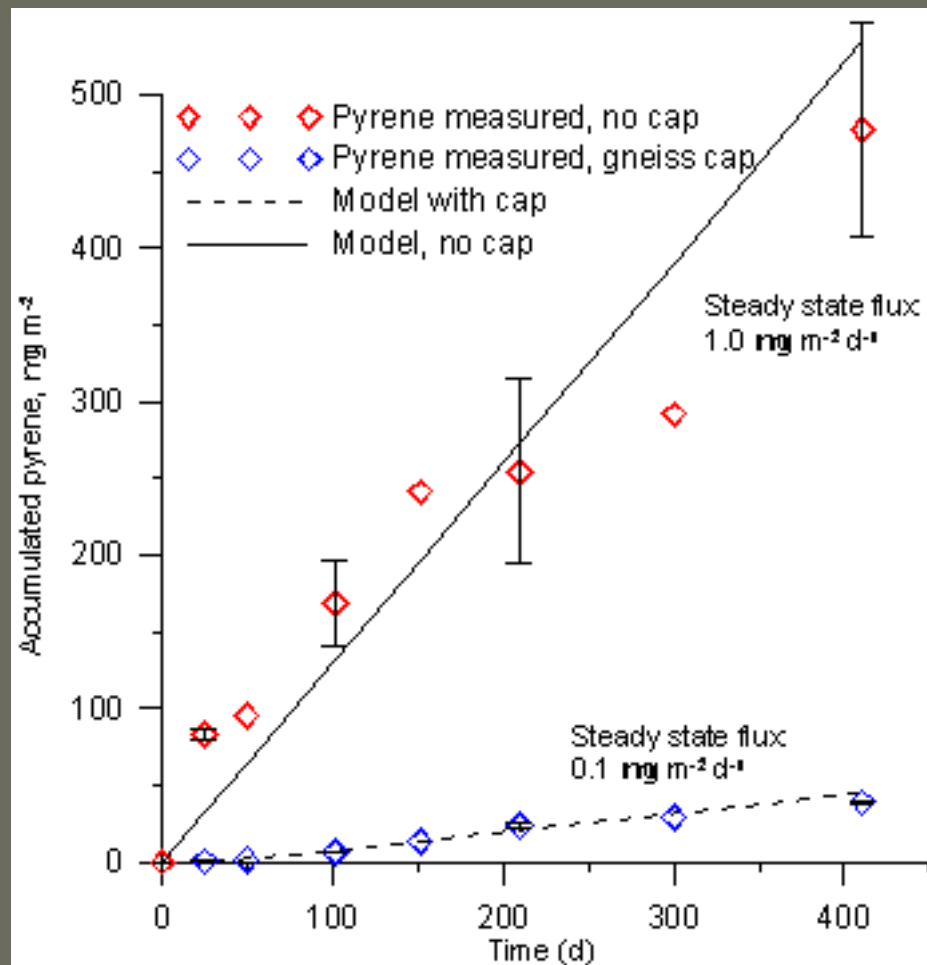
# Diffusion transport microcosms

- Diffusion from sediment through water phase into an organic phase
- Native concentrations, no spiking
- Organic contaminants (PAH and PCB) collected in organic phase
- Different capping materials



Eek, E., et al 2008 Chemosphere. 71: 1629 - 1638

# Diffusion transport microcosms

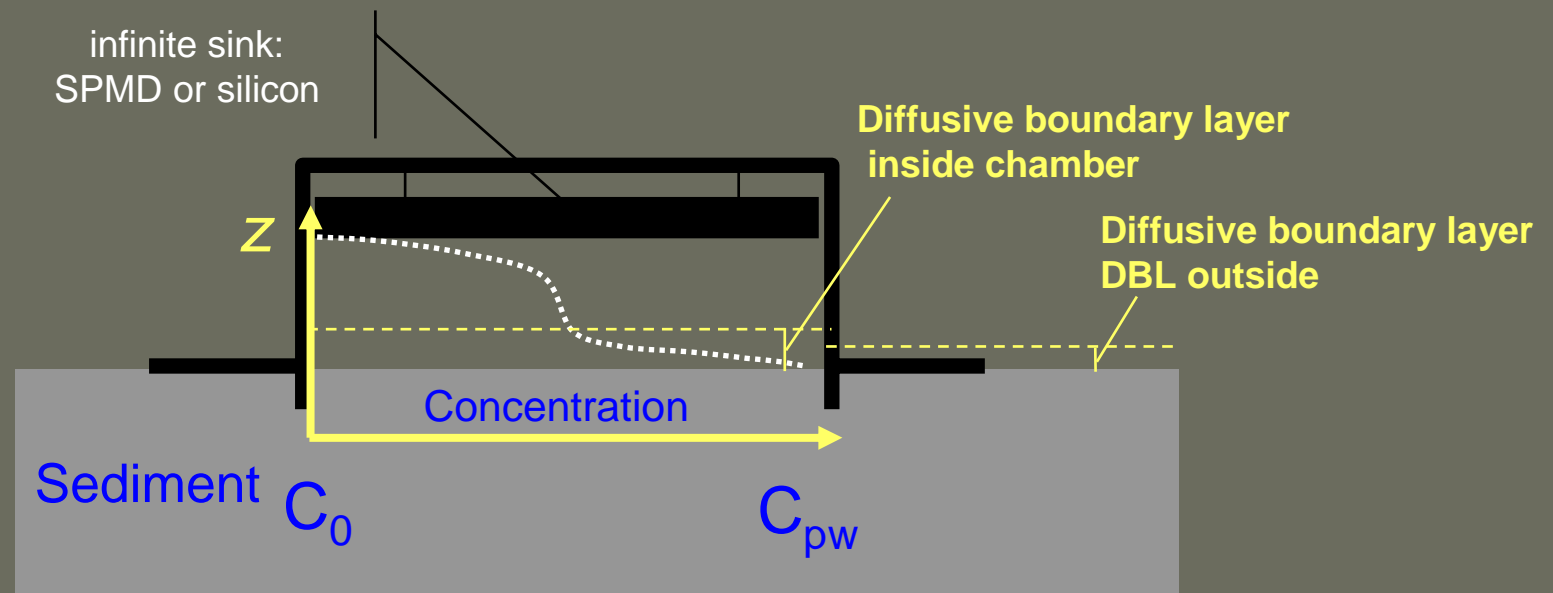


- Microcosm test

- Diffusive boundary layer 3.7 mm
- Cap 10 mm
- $D_{\text{effective}}/D_{\text{molecular}} = 0.33$
- Capping Efficiency= 90%



# Flux chamber for *in situ* measurements





U5 H65 208HD+2 CA-30 02FEB07  
D5 0008.0MS 04C 14:03:31

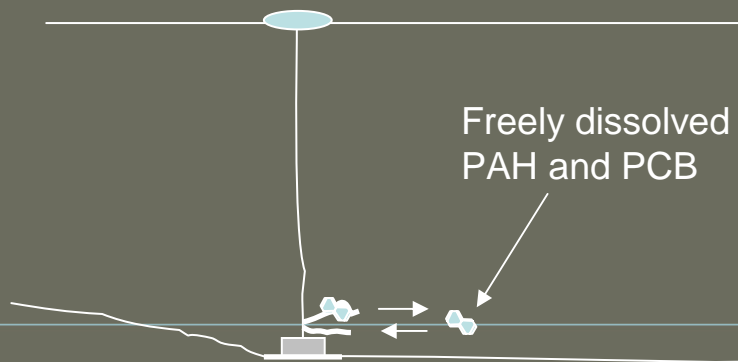


U5 H65 221HD+2 CA-30 02FEB07  
D5 0015.1MS 04C 14:04:02



U5 H65 249HD+2 CA-45 02FEB07  
D5 0015.4MS 05C 14:10:30

# Equilibrium passive samplers



Cornelissen et al. 2008 Environ. Toxicol. Chem. 27: 499-508

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## Calculated vs. field measured PAH fluxes

$$F = D \times \frac{C_{pv} - C_{vann}}{\delta_{DEL}}$$

$$\text{Flux} = \frac{\text{Diffusion coefficient} \times \text{Concentration difference}}{\text{Thickness of diffusive boundary layer}}$$

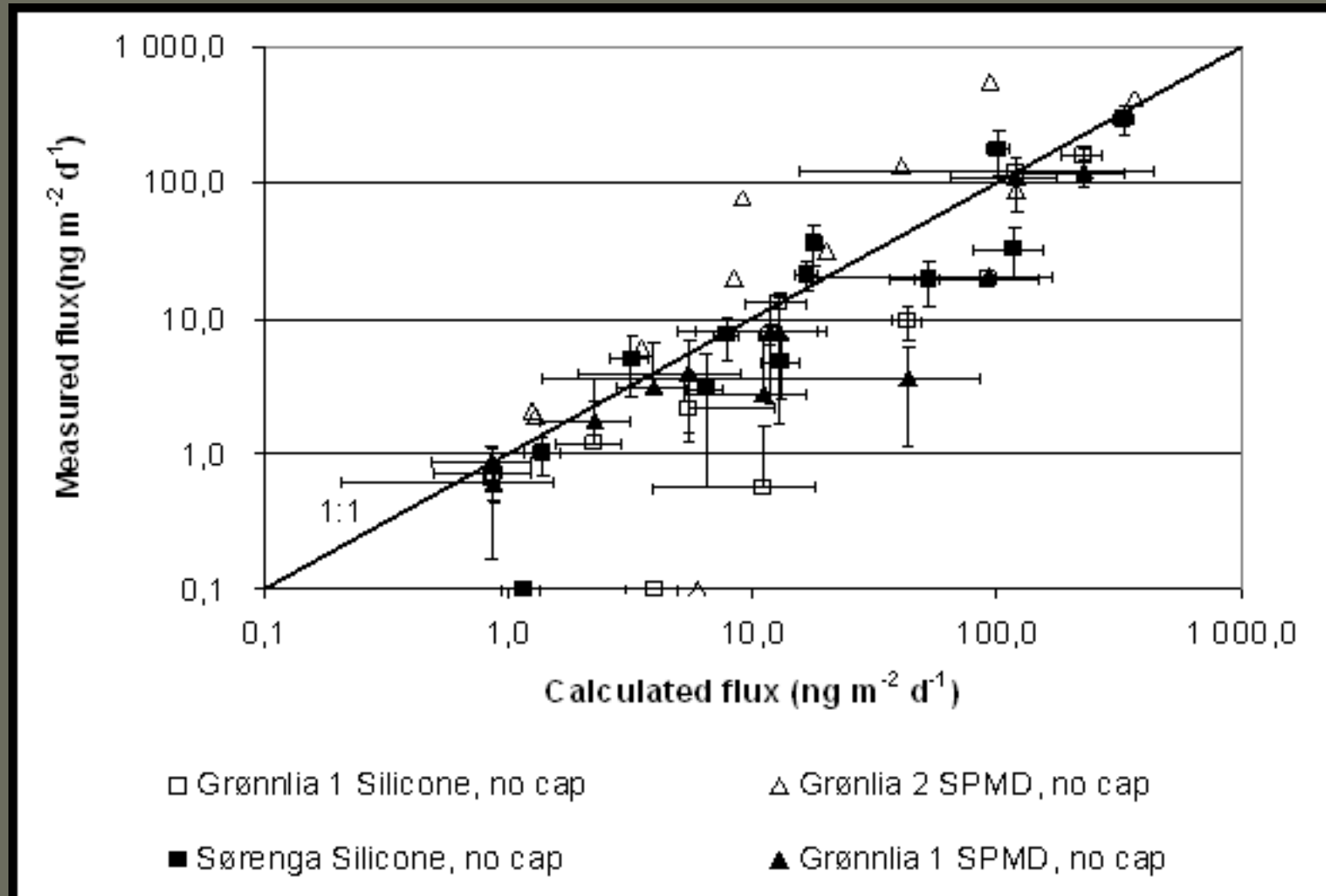
### Calculated flux:

- Diffusion coefficient: literature
- Concentration difference: passive samplers
- Thickness of the diffusive boundary layer: Gypsum dissolution rate

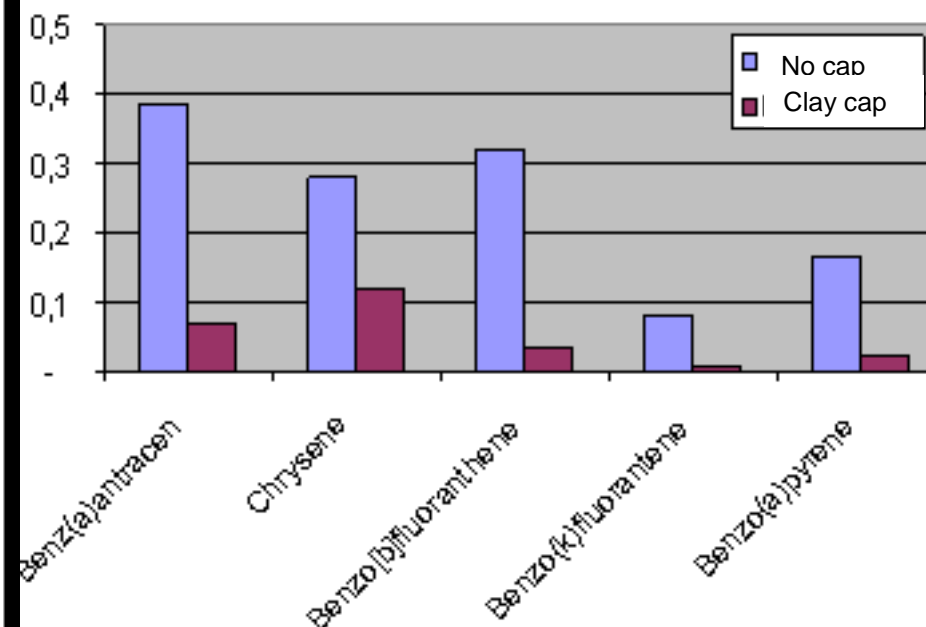
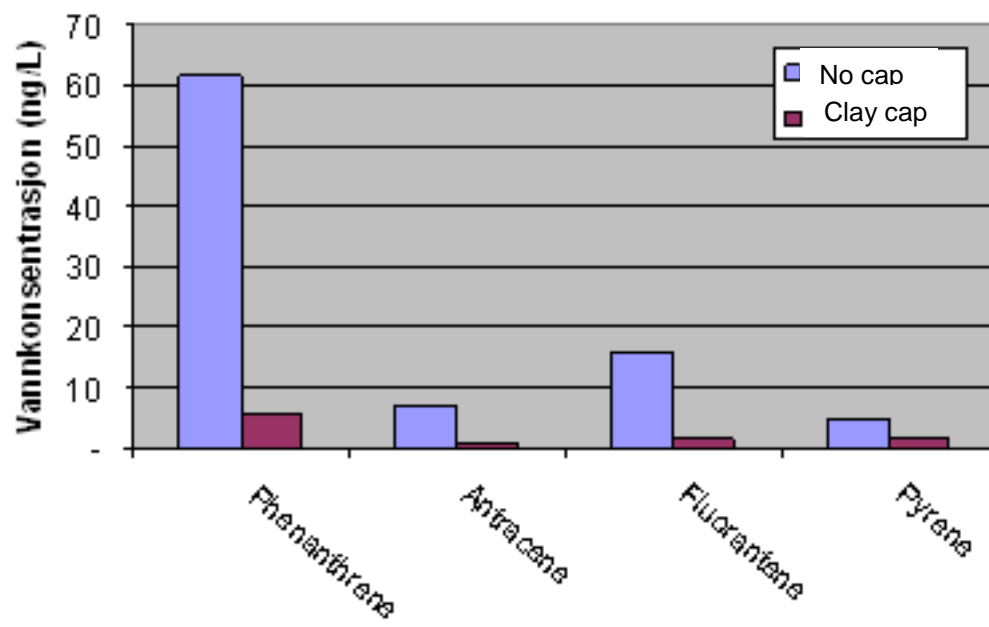
### Measured flux:

- Directly measured by in-situ benthic flux chamber

# Measured flux vs. calculated flux







# Summary of Capping efficiency measurements Oslo Harbour

Method	Effect measured on	Capping Efficiency
Microcosm test in lab, 1 cm cap	Diffusive flux	90%
Theoretical Capping efficiency, 40 cm cap, at steady state	Diffusive flux	>99.9%
Field measurements		
Flux chamber	Sediment-water flux	79 – 97%
Passive samplers in-situ	sea water concentrations	65 – 98%

## Conclusions

- PAH/PCB flux from sea bed sediments before and after capping can be measured both in lab tests and in field tests
- Theoretical Capping Efficiency (CE) of isolation caps (>20 cm thick) typically 99.9%
- Real measured CE: 70 – 95 %
- Real CE < Theoretical CE
  - Can be explained by new sediment on top of cap
  - This will usually have greater effect on the CE than flux through the cap