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Miljø- og Fødevareministeriet
Kystdirektoratet

DTU

Contaminants in harbor sediment: how to track the sources and how to degrade the contaminants?

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Overall content of the talk

How to track the sources?

- lessons learned from ”Clean Harbor 2025” in Esbjerg Harbor, Denmark
- reduce the cost of handling contaminated sediment

How to degrade the contaminants?

- master study based on plant growth in harbor sediment from Esbjerg Harbor

Future initiatives

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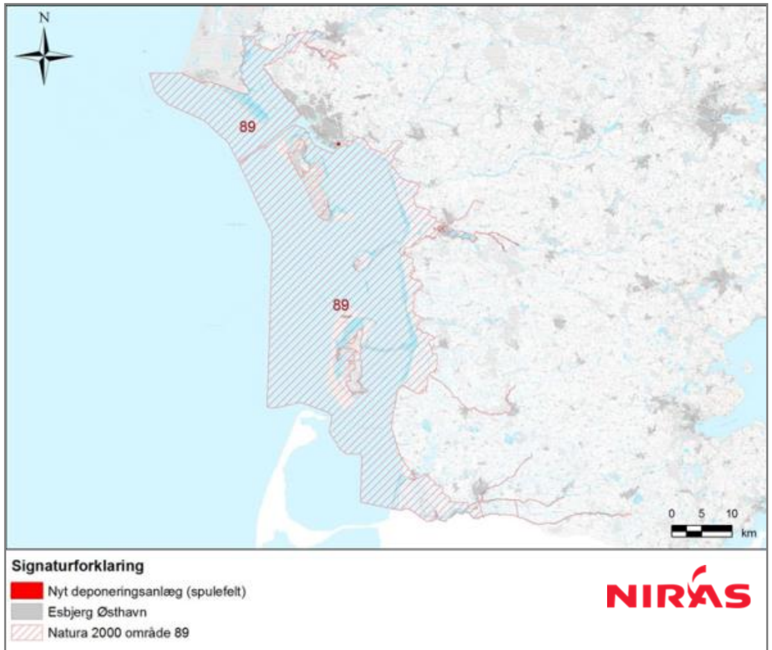
Esbjerg Harbor

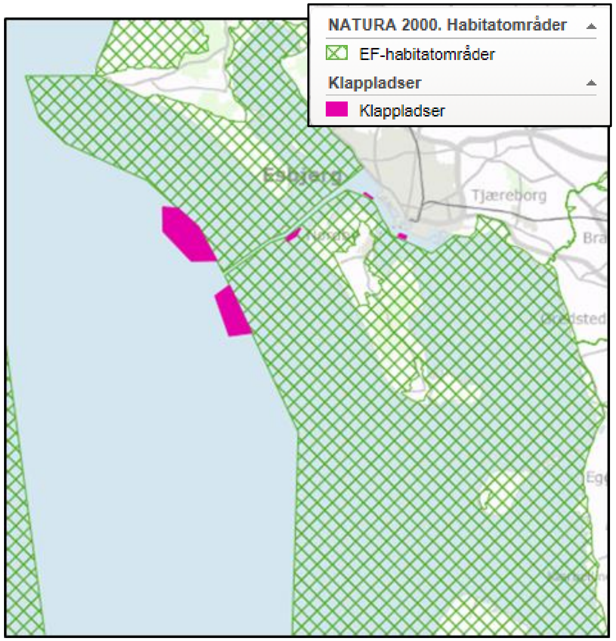
- One of the biggest industry harbors in DK
- Situated in the Wadden Sea, which is a Natura 2000 area.
- Sedimentation rate: a few cm to 0,5 m per year
- 1 – 2 mio m^3 sediment is dredged every year from harbor and fairway
- The Danish Coastal Authority maintains the water depth in the harbor
- NIRAS is responsible for environmental evaluations of drying basins, confined disposal facility (spulefelt), dredging and dumping (2015 - 2018)

(www.portesbjerg.com)



Clean Harbor 2025

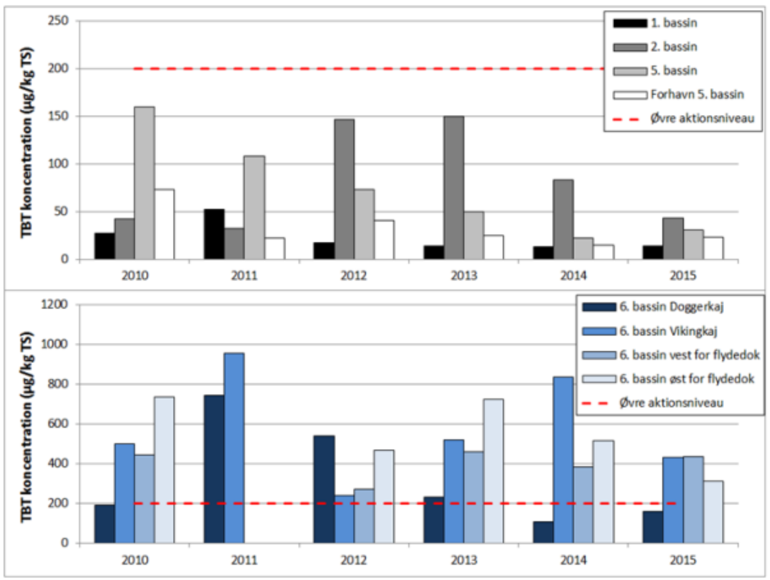
- After 2025, the sediment must be clean enough to be dumped in the Wadden Sea
- The Danish Coastal Authority, the Municipality of Esbjerg, the Port of Esbjerg and the Danish Environmental Protection Agency have agreed to make a *Source Tracking Committee*
- Efficient source tracking is crucial to be able to stop future input of contaminants
- NIRAS is responsible for analyses and methodology of source tracking



(www.miljoegis.mim.dk)

Source tracking

Description of timetrends in basins based on a few mixed samples



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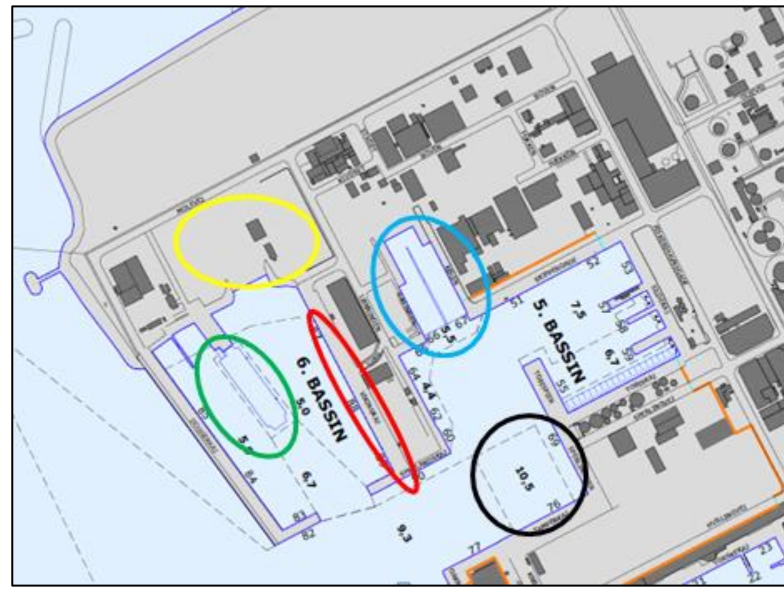
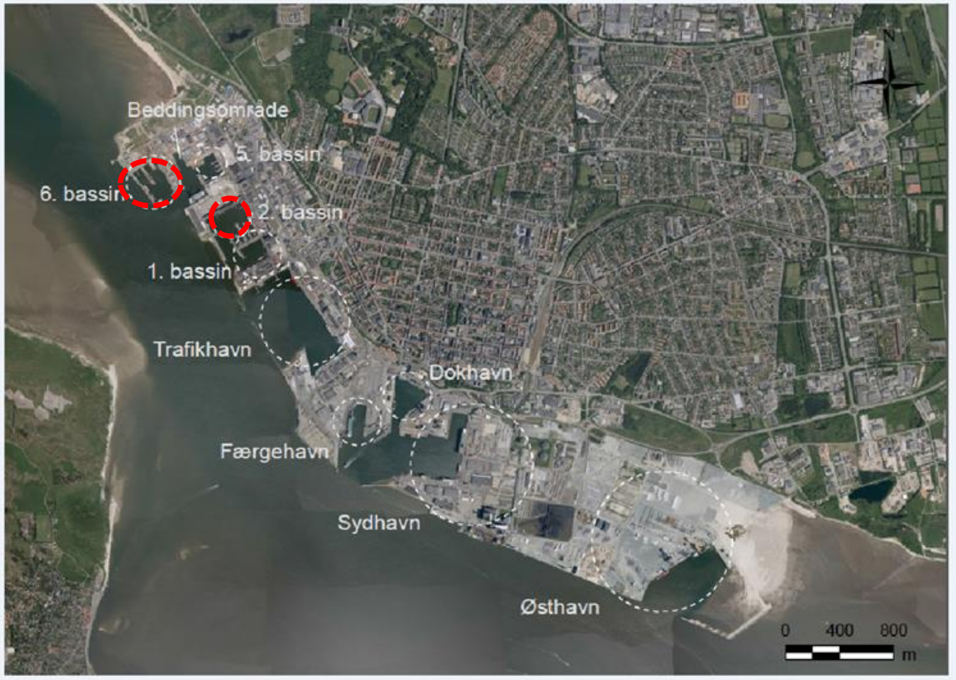
Mixture of activities/companies → area differentiation



Two types of source tracking



Pre-dredging source tracking

(Basin 2)

Currently leisure boats, previously fishing boats.

Detailed sampling grid (horizontal and vertical) (TBT analyses)

Post-dredging source tracking

(Basin 6)

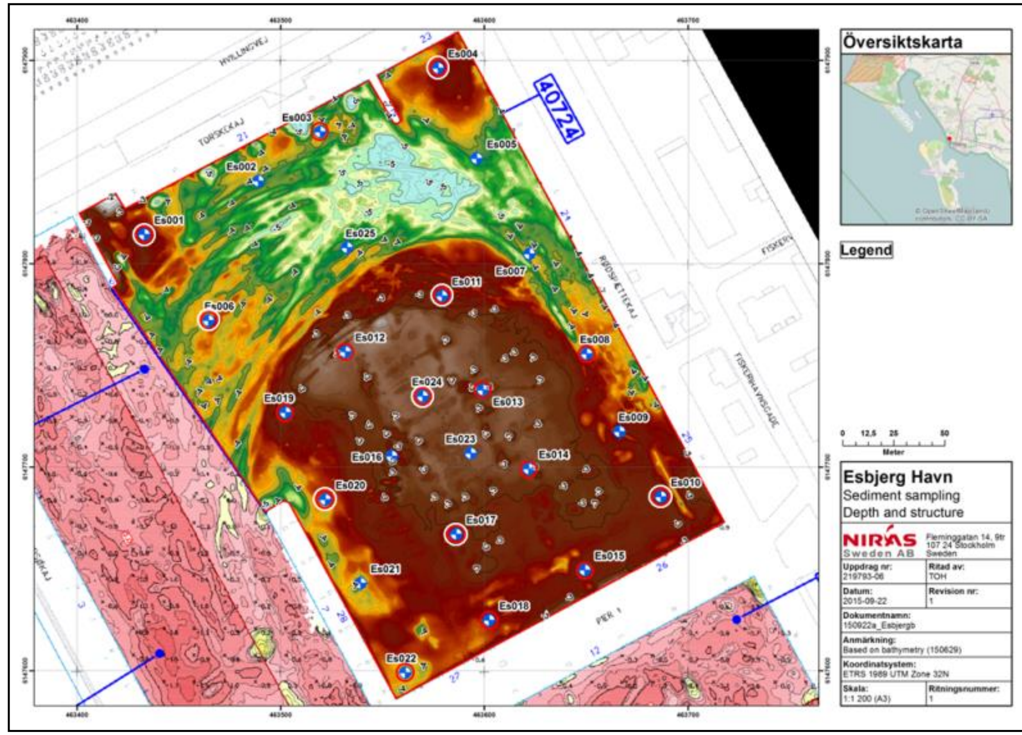
Repair and decommissioning of ships

Less detailed analysis of the basin (TBT analyses)

Pre-dredging source tracking (Basin 2)

Sampling grid (24 stations)

Sampling (max 1,6 m cores)



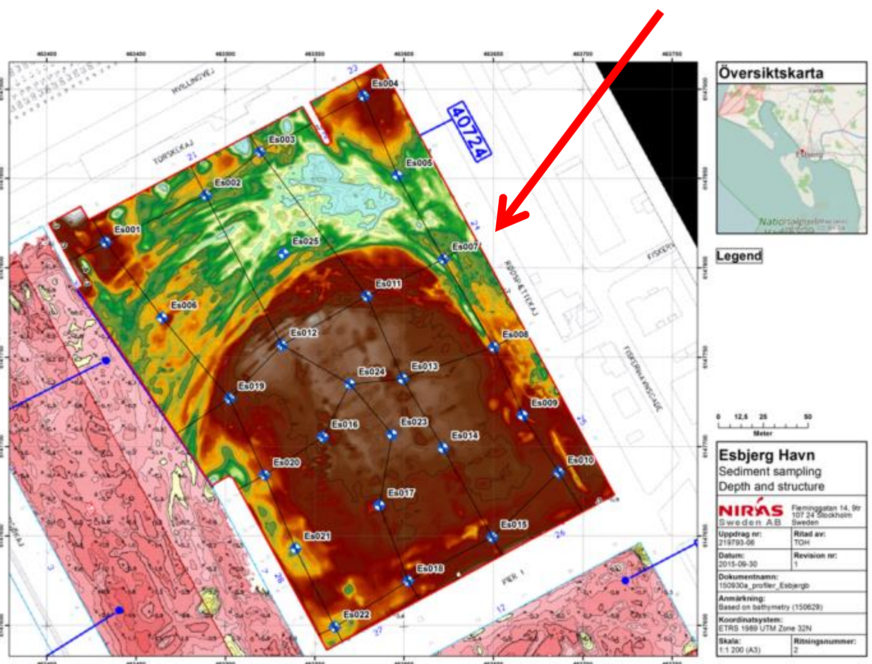
Pre-dredging source tracking (Basin 2)

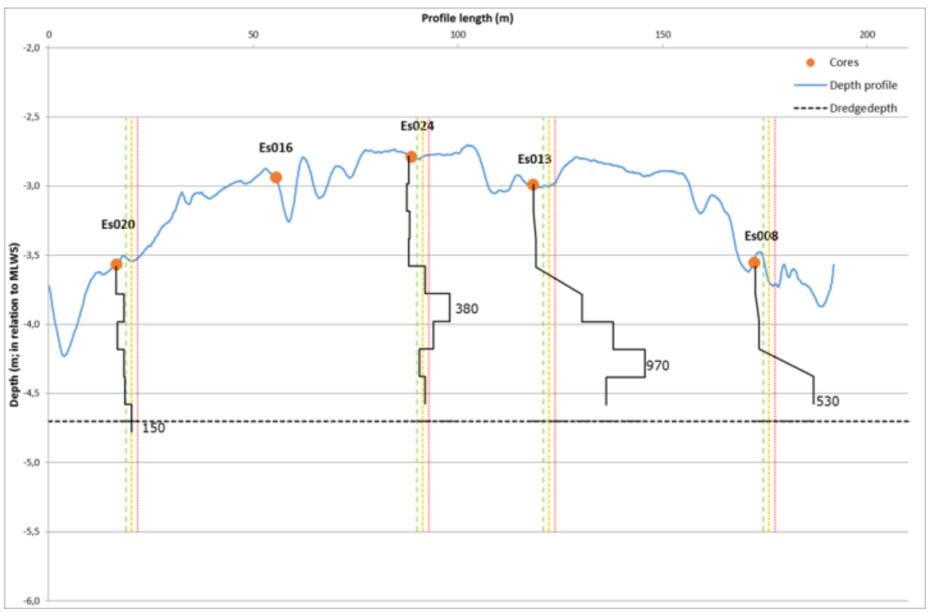
Descriptive statistics (*n* = 99)

- average = 225 µg TBT/kg DW (tørstof)

- median = 110 µg TBT/kg DW

→ Extreme values → indication of hotspots

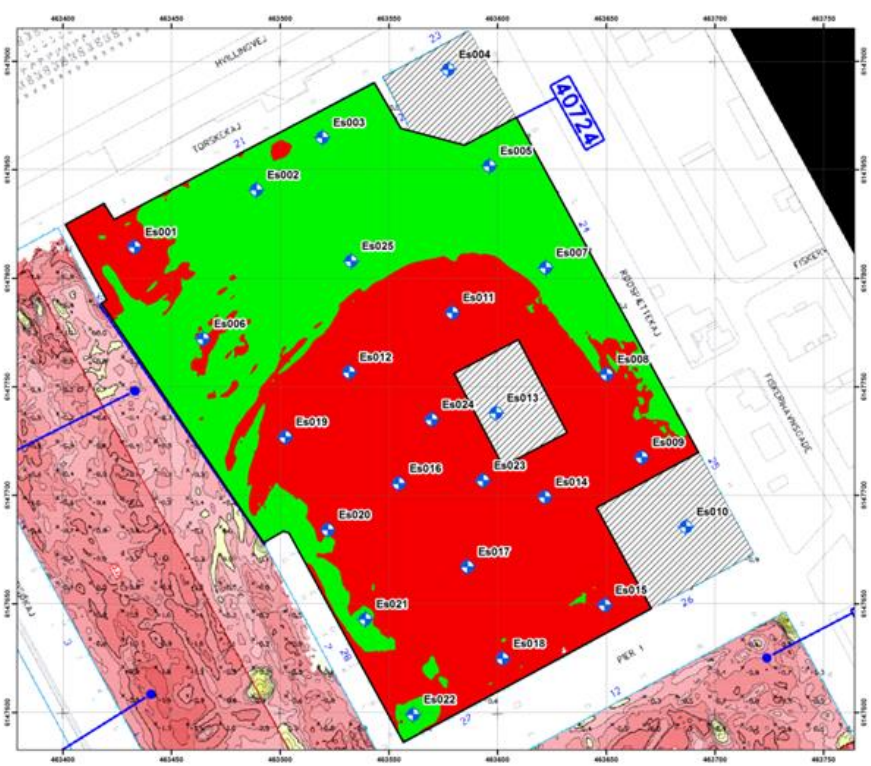




Pre-dredging source tracking (Basin 2)

Potential hotspots

Sedimentation area for fine material (between bridges) – no locale sources



Differentiation of sediment → economic optimization of sediment handling

Old museum ship possibly with old TBT-paint?

Post-dredging source tracking (Basin 6)

- Yearly monitoring indicated high levels of TBT in Basin 6
- Dredging of sediment for land-based recycling project (stabilization of 175.000 t sediment)
- Analyses were performed by the company to secure compliance with their legal guidelines for contaminant levels (RGS Nordic)
- They kindly provided us with the contaminant-data

Post-dredging source tracking (Basin 6)

Daily sampling and analyses of dredged material (1-27 mixed samples)

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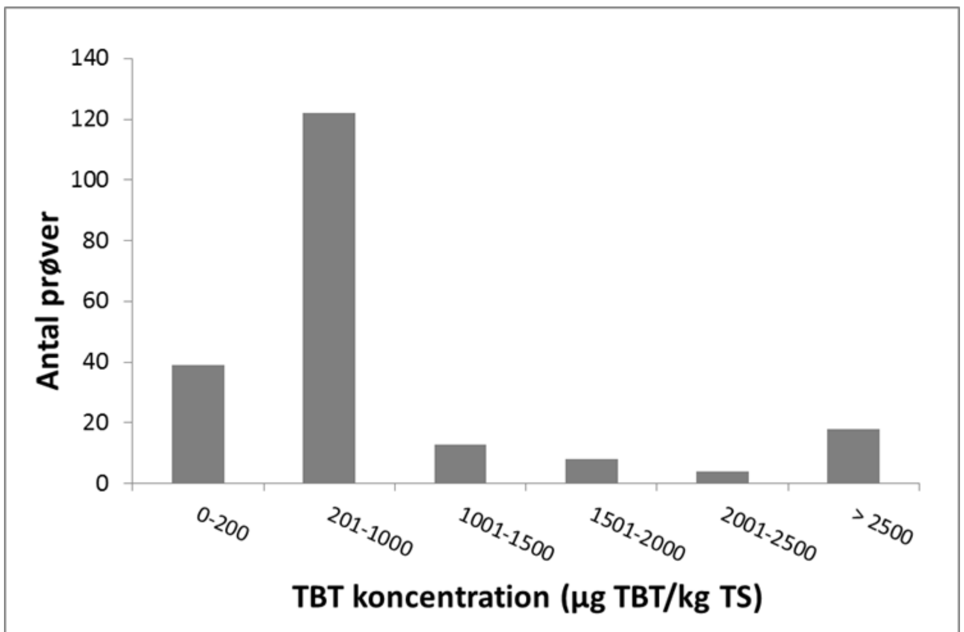

TBT content from 49 to 12.688 µg/kg DW (*n* = 204 samples)

Average = 933 µg TBT/kg DW
Median = 488 µg TBT/kg DW
→ Extreme values → potential hotspots

Post-dredging source tracking (Basin 6)

Daily sampling and analyses of dredged material (1-27 mixed samples)


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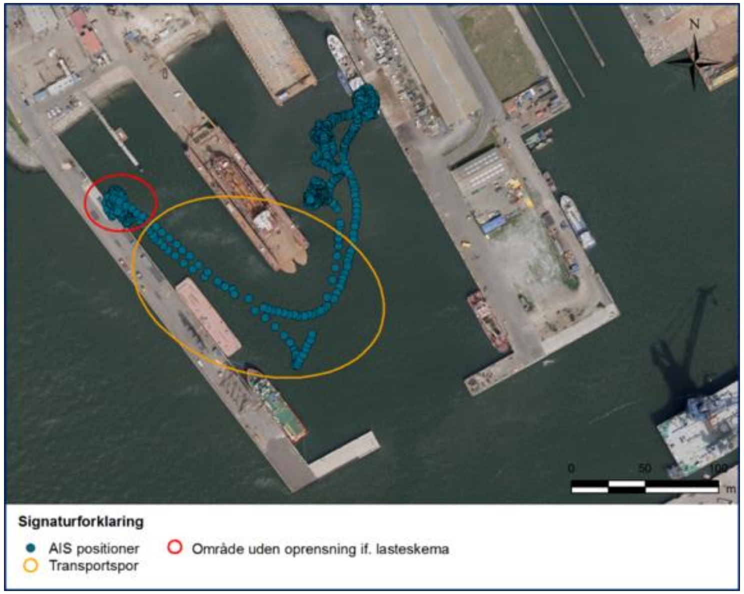
Daily tracking of dredging ship (Toste)



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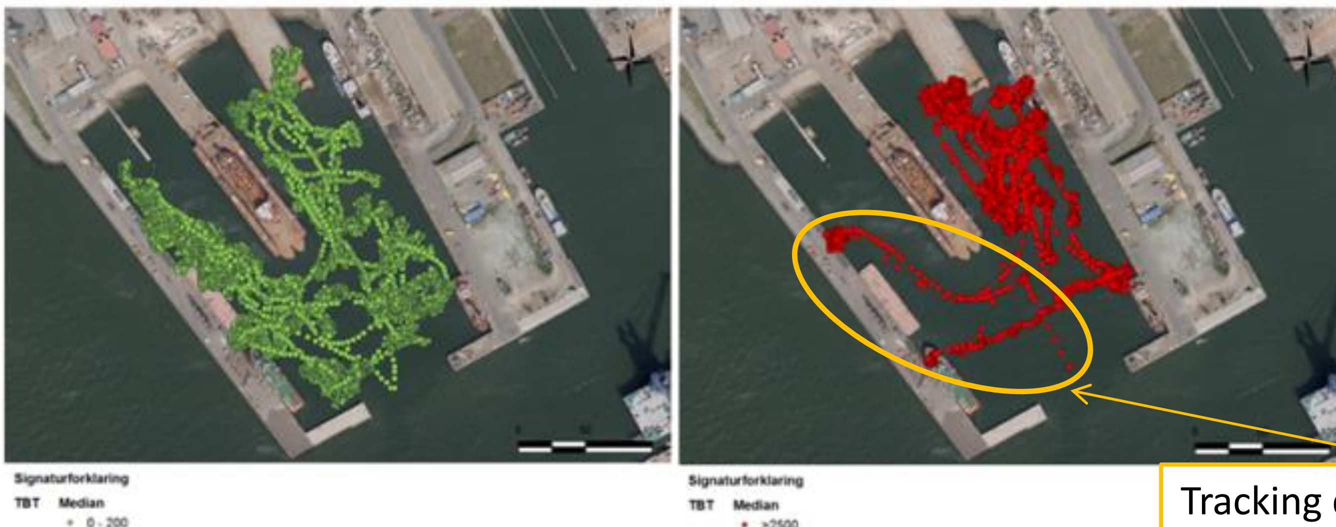
Post-dredging source tracking (Basin 6)

Combining the GPS data from Toste with TBT-data from RGS Nordic
→ less precise, but still useful source tracking



Tracking during transport has not been removed

The highest values based on daily medians are located between the floating dock and Vikingkaj. Activities at the floating dock includes sandblasting, and activities on Vikingkaj includes decommissioning of ships.

Master study on phytoremediation of harbor sediment by Albertha Greve, DTU

Currently, no BAT exists for confined disposal facilities (CDF, spulefelt)

- *Is there a potential for phytoremediation of contaminated harbor sediment by plants?*

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Can plants germinate and grow in sediment from Esbjerg Harbor?

- 22 plant species were tested for germination
- 12 plant species were tested for growth in salinity 35 and 10 ‰ (26 days, 22-25 °C)

Planter		
1	**Byg**	***Hordeum "Odyssey vårbyg"***
2	**Havre**	***Avena sativa "Gry havre"***
3	**Raps**	***Brassica napus "Quartz raps"***
4	Sennep	*Sinapis alba var. ASTA*
5	**Majs**	***Zea mays***
6	**Kålroe**	***Brassica napus***
7	**Grønkål**	***Brassica oleracea acephala***
8	Foderroe	*Beta vulgaris ssp.*
9	**Glaskål**	***Brassica oleracea***
10	Rødbede	*Beta vulgaris var. conditiva Alef*
11	**Mangold**	***Beta vulgaris var. vulgaris***

Planter		
12	**Foderkål**	***Brassica oleracea***
13	**Græsmix**	
14	Have-mælde	*Atriplex hortensis*
15	Alm. Strandkål	*Crambe maritima*
16	**Vildkål**	***Brassica oleracea***
17	Tæt hindebæger	*Limonium vulgare*
18	Tagrør	*Phragmites australis*
19	Dunhammer	*Typha latifolia*
20	Alm. Salturt	*Salicornia europaea*
21	Spansk salturt	*Sarcocornia fruticosa*
22	**Strandsvingel**	***Festuca arundinacea***

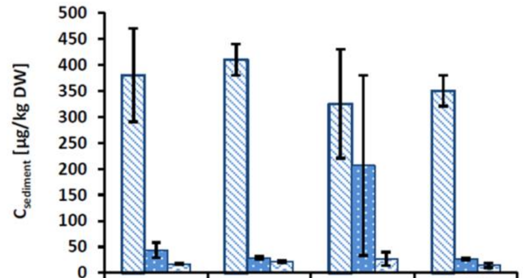
Results:

- Only 1 species germinated and survived (kveller/salturt, *Salicornia europaea*), but no species grew in salinity 35 ‰
- 6 species had 100 % germination and survival in salinity 10 ‰ (barley, rape, turnip, 3 species of cabbage)

The salinity and not the concentration of TBT is the most important factor for germination and growth of plants.

Is there a potential for phytoremediation of contaminated harbor sediment by plants?

- 2 species were used: barley and cabbage (vildkål)
- TBT, DBT and MBT were measured in the soil before and after plant growth. The results show no significant degradation of TBT, DBT or MBT.



	Natural	Washed	Barley	Wild cabbage
Tributyltin	380	410	325	350
Dibutyltin	44	29	207	27
Monobutyltin	17	22	27	15

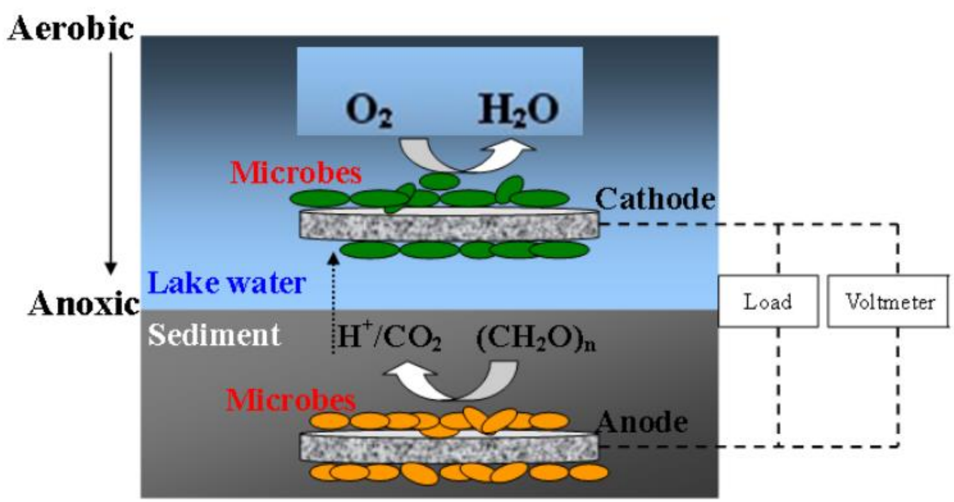
- However, the older plants showed higher degradation of TBT. This indicates that larger roots/rhizosphere facilitate microbial degradation.

Phytoremediation was not found with the selected species, but indications were found that older plants with larger roots facilitated microbial degradation

What is the next step?

Plants are essential for the oxygen dynamics, but it is a **slow process**. Instead of relying on plants, we now test bioelectrodes, in order to oxidise sediments, methane, oil residues and TBT.

Collaboration between NIRAS, DTU and Aarhus University + Miljøstyrelsen and Danish Coastal Authority.



Principle of a microbial fuel cell (Zhang and Angelidaki 2012).

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Highlights

- Efficient source tracking can potentially differentiate contaminated areas from clean areas, and minimize the cost of handling.
- Source tracking can be done before *and* after dredging.
- New initiative using bioelectrodes in contaminated marine sediment will (hopefully) be applicable to reduce contaminant loading (more to come…)