Capping of contaminated seabed in Norway – lessons learned

Jens Laugesen, DNV GL, Hoevik, Norway

Espen Eek , NGI, Oslo, Norway

Jeanette Beckius and Erik Høygaard, Norwegian Environment Agency, Oslo, Norway

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Background/Objectives

- The Norwegian Environment Agency has summarized the experiences from capping of contaminated sediments with clean soil in a report that was released in June 2016.
- The work has been done by Jens Laugesen from DNV GL and Espen Eek NGI (Norwegian Geotechnical Institute).

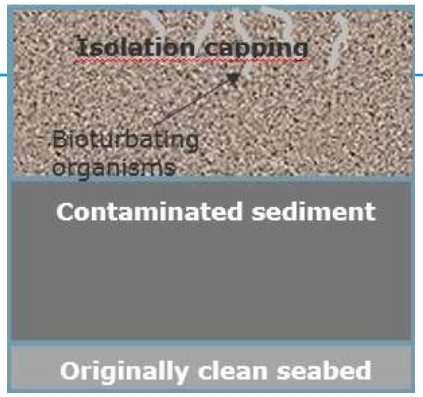
Background/Objectives

- Experiences from different capping projects in Norway over 25 years have been gathered.
- Also experiences from capping projects outside Norway have been described.
- A difference between Norway and most other countries is that basically all capping of contaminated sediments in Norway has been done in marine sediments, basically in fjord and harbour areas.
  - In other countries capping has also been done in freshwater (rivers and lakes).

Capping methods for contaminated sediments

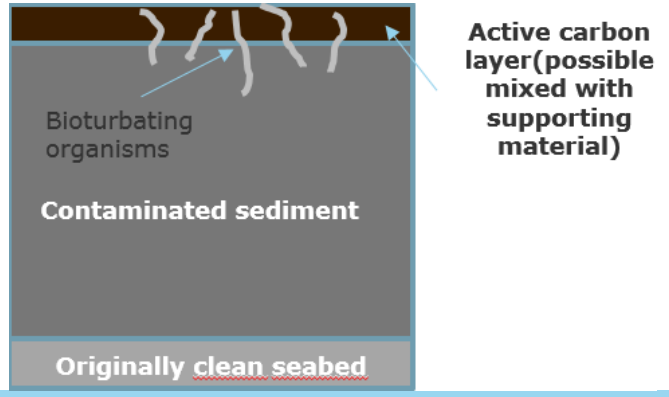
Principal types of capping methods:

- **Isolation capping with inert mineral material**
  - has to be substantially thicker than the bioturbation depth
  - typical cap thickness is 20 – 50 cm



- **Isolation capping with an active layer (active carbon)**

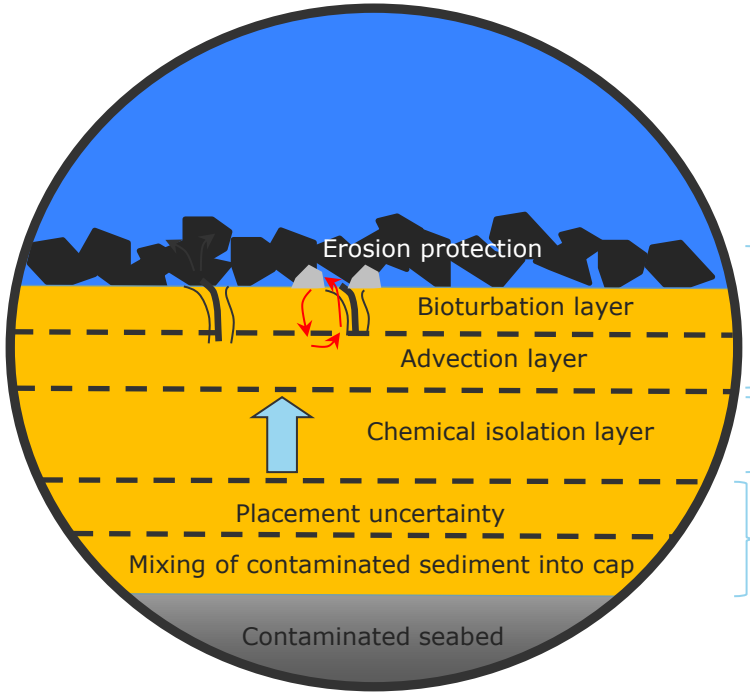
- **Thin layer capping with active material**
  - Typical cap thickness is less than 10 -15 cm



General design of an isolation cap

$h_{erosion}$
$h_{bioturbation}$
$h_{advection}$

$h_{isolation}$
$h_{uncertainty}$
h_{mix}



Part of cap where physical movements influence transport

Part of cap designed to be dominated by transport by molecular/ionic diffusion

Part of cap design for which uncertainties during placement makes its function unpredictable

Approach/Activities

- A large amount of data from capping projects that have been performed were collected.
- The focus was on finding information about:
  - which factors that affect the durability of the cap
  - how the cap functions over a longer time
  - how do different type of caps stop leaching of contaminants
  - how long does recolonization of the biota take after the cap has been placed
- Finally a summary of which factors that are the most important for a successful capping of contaminated sediments are presented in the report.

Capping projects in Norway

- In Norway the first capping project was performed in the Eitrheim Bay in Sørfjorden in 1992.

Before the Eitrheim Bay Project.

Eitrheim Bay Project 1991 - 1992:

BOLIDEN

Capping projects in Norway and in other countries

- Since then 20-30 capping projects have been performed in Norway. This projects vary from a few thousand m^2 capped seabed to about 1 km^2 (capping in Oslo harbour).

- Internationally there are a lot of capping projects that also have been performed in rivers and in freshwater (lakes). Outside Norway most of the described capping projects have been performed in USA.

Oslo harbour where about 1 km^2 has been capped. (www.dykking.no)

Example Kollevågen Bergen – Lack of stability

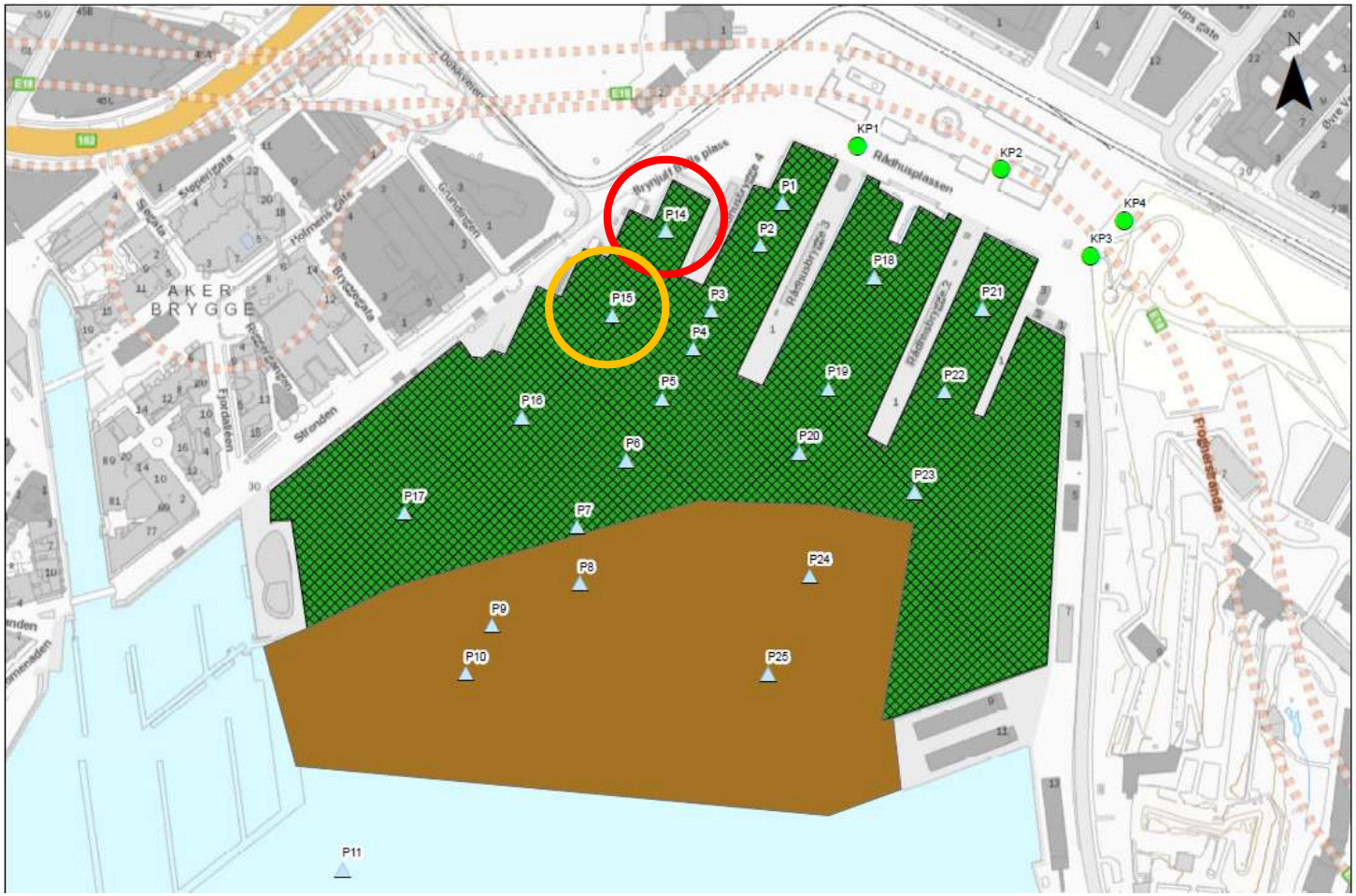
- In Kollevågen outside Bergen municipal waste was placed in the shoreline and in the sea in the period between 1930-1975.
  - In 2005 the municipal waste was covered with a 0.5 m thick layer of rock material (grain size: 0-32 mm) followed by a geotextile and a 0.3 m thick erosion protection layer (grain size: 0-64 mm).
- Investigations in 2012 and 2014 done by NGI showed that the cap was damaged and that the waste that was below sea level was exposed at several locations.
- The most probable reason for this was that the cap did not have sufficient stability with respect to erosion, slope stability and/or uneven settlements in the waste.

Exposed waste due to damaged cap at Kollevågen (NGI, 2014)

Example Oslo harbour – Erosion

- As a part of the «Clean Oslofjord» project several areas in Oslo harbour were capped (seabed 15-20 m depth, marine clay and sand).
- For handling residuals after dredging several areas in Oslo harbour were capped with crushed rock (grain size 0 – 8 mm).
- Investigations of the seabed 4 years after the capping (NGI, 2015) showed that in an inner part of the harbour where the ferries where docking all capping material was gone and pure grey clay from the former seabed could be seen.
- This was probably due the strong current caused by the propellers of local ferries that had eroded away all the capping material.
- At a point about 50 m further out from the docking area the cap was still there but contained very little of the fines, indicating that the cap had been exposed for erosion but not as strong as in the docking area itself.

Example Oslo harbour – Erosion



Red circle: Area where all cap material was gone

Yellow circle: Area where the cap still was left (but with very reduced amount of fines).

Source NGI (2015).

Example Oslo harbour – Erosion

- In this case a relatively fine-grained cap had been washed away from a smaller area where the seabed was exposed for a substantial propwash. The exposed seabed was, however, clean.
- In adjacent areas the cap is still intact.
- The example shows that a cap has to be designed to withstand propwash in areas with ship traffic. It also shows that areas just outside the areas that are most exposed for erosion (propwash) can withstand erosion even if the ships are moving over this area also.

Pipervika, Oslo harbour

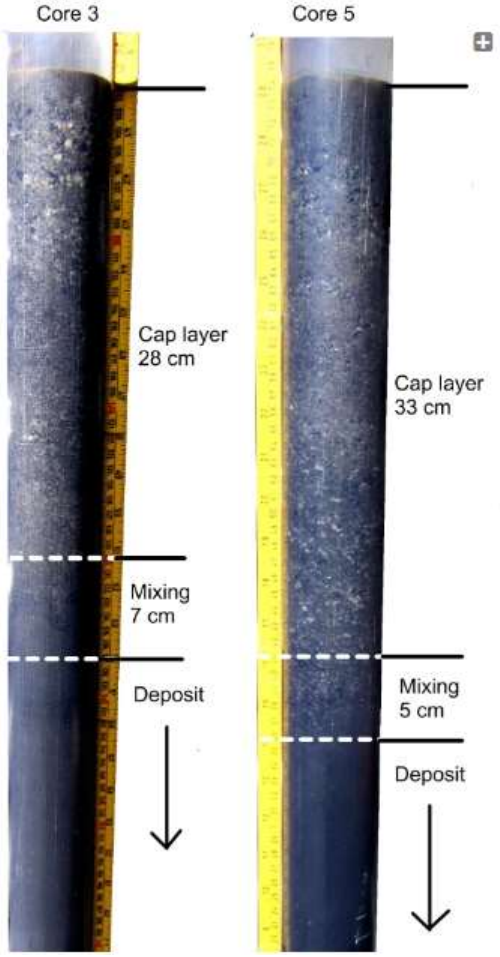
Long-term experience with capping – Eitrheim Bay

- The contaminated sediments in Eitrheim Bay were covered with a geotextile and capped with sand in 1992.
- Surveys done by divers in 1995 showed that the cap was intact and there was substantial biological activity on the surface of the cap.

- A new diver survey and sampling of sediments in 2001 showed that the surface of the cap had been recontaminated by sources on land (NIVA 2002 and 2010).
- An assessment done by DNV GL (2009) concluded that there were two probable main causes for the recontamination: accidental and regular discharges from local industries and waste disposals.
  - An assessement was done of the regular discharges (those that were included in discharge permits) which showed that they could cause substantial increase in the concentration of contaminants in the sediments (and the cap).

Long-term experience with capping – Malmøykalven, Oslo

- One of the most investigated caps is the one that is covering the deepwater disposal at Malmøykalven in the Oslo fjord close to Oslo. The requirement in the permit was a 0.4 m capping layer. As a part of the follow-up the capped area was investigated with respect to grain size distribution.
- The results showed that grain size distribution in the cap corresponded to the original cap material and thereby concluding that the cap was intact (DNV, 2012).



Samples of the cap at Malmøykalven showing the thickness of the intact cap, the mixing layer and the contaminated material. Photo: Hanne Vidgren, UiT.

Results/Lessons learned

- The lessons learned from the reviewed capping projects are mainly positive.
- This means that also several years after the capping was done the cap is still intact and functioning as intended.
- In a few projects, the cap has locally been eroded by propellers from ships. This has for example been registered when large ships are maneuvering close to quays in relatively shallow waters.
- There are also examples of poor soil conditions which have led to damages in the cap due to slope failures or large settlements.

Results/Lessons learned

- Recontamination of the seabed after capping caused by supply of new contaminated material has been found in several cases.
  - Such recontamination may be due to contamination from land, either from point sources or from diffuse sources such as runoff from contaminated land, landfills and/or from impervious surfaces via surface water.
  - Sufficient control of the diffuse sources is important to reduce the negative effect of such recontamination.
- Recontamination may also be due to the spreading from adjacent seabed where no remediation of contaminated sediments has taken place.
  - Such recontamination can be substantial if the adjacent contaminated areas are exposed to strong currents, prop wash, dredging or other operations that are done on the seabed.

Results/Lessons learned

- Finding information and data from capping projects was more challenging than expected.
- It is recommended that national and international databases are established where information from capping projects are gathered.

Photo: http://agdermarine.no

www.dnvgl.com

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