Solutions for contaminated sediments in the Baltic Sea region. Results of the SMOCS EU project

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Conditions of the Baltic Sea

- Baltic Sea area: 377,000 km$^2$
- Catchment area: 1.7 mln km$^2$
- Human population: 85 mln
- Average depth: 53 m
- Salinity: 1-20 PSU
- Water volume: 20,000 km$^3$
Problems with polluted sediments in the Baltic Sea

• To develop BSR (Baltic Sea Region) in a sustainable way contributing to an extended interaction and co-operation sea transport is a key issue

• Dredging of fairways and ports have to be made and several million $m^3$ of sediments have to be dredged in the coming years

• A considerable part of the dredged sediments is contaminated with non-organic and/or organic contaminants (e.g. metals, PCBs, PAHs, TBT)

• Dump of sediments in sea normally not allowed

• Land disposal most expensive

• Initial projects show large potential for innovations regarding beneficial use of treated contaminated sediments and knowledge transfer to get a BSR approach (e.g. the stabilisation/solidification method)
Decision levels relevant for management of dredged contaminated sediments

- International/global Level [e.g. IMO, PIANC]
- EU Level [e.g. EU regulation and Law, ESPO]
- BSR Level [e.g. HELCOM, BPO]
- National Level [e.g. EPA or other state authority or ministry]
- Project Level [e.g. Port or regional/local Authority]
Waste management hierarchy
SMOCS: Aims and Outputs

In the Baltic Sea Regional project SMOCS (2009-2011) the problem of sustainable management of contaminated sediments was addressed. The aim of the project was to provide support for dredging actions all around the Baltic Sea. The objective were reached through the development of guidelines for management of contaminated sediments, including sustainability assessment practices and decision support regarding the handling alternatives as well as treatment technologies.

Project in keywords:
• Management of contaminated sediments
• Beneficial use of treatment contaminated sediments
• Sustainable treatment technologies

Outputs of the project:
• Guideline comprising knowledge and practice regarding the handling alternatives for dredged sediments. It covers disposal at sea and on land including beneficial use of dredged masses
• Tool-box of how to manage dredged sediments. It includes tools for the assessment of sustainability and a decision support tool to be used in different planning and application processes
• Support on feasible treatment options including methods for capping and for beneficial use of stabilized contaminated sediments

A durable network – PortInfra - was created for management of the dredged sediments. It includes: stakeholders such as maritime organizations, contractors, consultants, R&D performers and authorities on national and trans-national level.

www.smocs.eu
www.portinfra.se
Over view of the sediment handling process

Need to dredge → Dredging → Transport → Treatment → Location

**Dredging**
- Mechanical dredgers
- Hydraulic dredgers
- Others

**Transport**
- Land
- Sea

**Treatment**
- Dewatering
- Separation
- Stabilization/solidification
- Others

**Location**

- **Beneficial use**
  - Beach nourishment and coastal protection
  - Port construction/extension
  - Land improvement
  - Habitat creation
  - Others

- **Disposal**
  - Confined sea disposal
  - Land disposal

- **Monitoring**
  - Short term
  - Long term
  - Maintenance
Controlled treatment of contaminated dredged sediments for the beneficial use

Dredging with environmental grab

Transportation

Process stabilisation

Utilisation in harbour fillings
Stabilisation methods

- mass stabilisation
  Mass stabilisation as deep mixing (Ideachip 2005). Applicable for soft soils like peat, mud and clay

- layer stabilisation
  Stabilisation in layers. Here the binder is spread on the upper surface or fed through the rotating mixing head. During the mixing process the excavator shaft is taking the mixed soil towards the excavator. The Stabilisation depth is not limited by the length of the arm (Ideachip 2005)

- column stabilisation
  On-going column stabilisation in Arabianranta. (Forsman et al., 2006)
Binder selection

Functional and effective binder admixtures

Technical acceptability

Environmental acceptability

Economic feasibility

Optimization

- Fly ashes
- Slags
- Gypsum
- Limes
- Portland cement with fly ash
- Portland cement without fly ash

Cement

Merit 5000
Development of binder recipe

Stage 1. Technical tests

• Identify appropriate binders and additives

• Laboratory tests
  – different sediments (density, water content etc.)
  – different pollutions
  – curing time
  – chemical composition of binders

<table>
<thead>
<tr>
<th>RECIPE (binders)</th>
<th>PROPORTION [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>sediment + cement + slag</td>
<td>80 + 10 + 10</td>
</tr>
<tr>
<td>sediment + fly ash + cement</td>
<td>77 + 20 + 3</td>
</tr>
<tr>
<td>sediment + cement + slag + fly ash + gypsum</td>
<td>80 + 5 + 5 + 5 + 5</td>
</tr>
<tr>
<td>sediment + middle sand + fly ash + cement</td>
<td>30 + 48.5 + 20 + 1.5</td>
</tr>
</tbody>
</table>
Development of binder recipe

Stage 2. Environmental testing
- Geotechnical properties
  - compressive strength
  - stability (frost, weathering etc.)
  - hydraulic conductivity
  - leaching

Stage 3. Final tests for construction
- Full scale testing to verify the design
Field test in Gavle Port, Sweden

New oil pier to take advantage of the new draft after dredging. Tankers up to 100,000 DWT to dock.
Field test in Gavle Port, Sweden

The quay wall was extended 350 m giving space for 500,000 m³ stabilized soil.
Field test in Gavle Port, Sweden

- cement can 100 EUR/ton
- merit can 80 EUR/ton
- fly ash can 30 EUR/ton
- the costs of the binder is 60-80% of the total cost
- not easy with the logistics according the binders
Initial appearance

Embarkment with crashed stones

Installation of scheetpile

Closing of basin
Filled of 1 m stock

Filling by stabilized sediments to the water level + 1 m

Edge beams and tension rods

Dredging of crushed stones outside the sheetwall
Overload with strengthening layer and the road base and asphalt
Monitoring – 1 year after stabilisation
Field test in Kokkola Port, Finland
Field test in Kokkola Port, Finland

12 550 m³ of soft sediments from the port area were used to the construction of new quays.

Most of the dredged sediments were contaminated by heavy metals: As, Cd, Cu, Pb, Hg, Ni, Zn and TBT.
Short history of sediment investigations

2008
Heavily contaminated by As, Cd, Cr, Cu, Pb, Ni, Zn, Hg and TBT
• sediments are unsuitable for the sea disposal (Instructions for Dredging and Depositing Dredged Materials)
In most spots Cd, Cu and Zn was above the upper limit of Vna 214/2007 (Government Decree on the Assessment of Soil Contamination and Remediation Needs)
• sediments are unsuitable for the land disposal without treatment.

2009
The whole area was contaminant free

2010
The area was contaminated by: As, Cd, Cu, Pb, Hg, Ni, Zn and TBT
Field test in Kokkola Port, Finland

<table>
<thead>
<tr>
<th></th>
<th>Binder amount in titrated samples, average [kg m(^3)]</th>
<th>Binder amount per block reported by contractor, average [kg m(^3)]</th>
<th>Compression strength, average in different ages</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Rapid-cement + fly ash</td>
<td>Fly ash</td>
<td></td>
</tr>
<tr>
<td>Ca-content, average in all quality control samples [ppm]</td>
<td>25 120</td>
<td>21 475</td>
<td></td>
</tr>
<tr>
<td>Binder amount in titrated samples, average [kg m(^3)]</td>
<td>107</td>
<td>184</td>
<td></td>
</tr>
<tr>
<td>Binder amount per block reported by contractor, average [kg m(^3)]</td>
<td>125</td>
<td>125</td>
<td></td>
</tr>
<tr>
<td>Compression strength, average in different ages</td>
<td>7 d</td>
<td>113</td>
<td>49</td>
</tr>
<tr>
<td>7 d</td>
<td>113</td>
<td>49</td>
<td></td>
</tr>
<tr>
<td>28 d</td>
<td>225</td>
<td>72</td>
<td></td>
</tr>
<tr>
<td>90 d</td>
<td>372</td>
<td>103</td>
<td></td>
</tr>
<tr>
<td>180 d</td>
<td>457</td>
<td>122</td>
<td></td>
</tr>
</tbody>
</table>

100-150 kg of binder mixture per m\(^3\) of sediments
Field test in Kokkola Port, Finland

DEEP PORT

YEAR: 2015
TOTAL capacity: 16.200.000 m.t.
New capacity: 13.100.000 m.t.
Quality control – 1 year after stabilisation

<table>
<thead>
<tr>
<th>Test method</th>
<th>Target of the test</th>
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</thead>
<tbody>
<tr>
<td>Column penetrometer test</td>
<td>Compression and shear strength of the mass stabilised sediment.</td>
</tr>
<tr>
<td></td>
<td>Uniformity and homogeneity of the mass stabilised sediment.</td>
</tr>
<tr>
<td>Plate load test</td>
<td>Modulus of the mass stabilised sediment</td>
</tr>
<tr>
<td>Test pits:</td>
<td></td>
</tr>
<tr>
<td>- penetrometer test</td>
<td>- Compression and shear strength of the mass stabilised sediment</td>
</tr>
<tr>
<td>- pocket vane test</td>
<td>- Shear strength of the mass stabilised sediment</td>
</tr>
<tr>
<td>- 1-axial compression test</td>
<td>- Compression and shear strength of the mass stabilised sediment</td>
</tr>
<tr>
<td>- Niton tests (XRF)</td>
<td>- Amount of Ca of mass stabilised sediment</td>
</tr>
</tbody>
</table>
Conclusions and recommendations

- Solidification/stabilization technology has been found as a highly applicable tool for managing contaminated sediments. It has environmental, economic and technical benefits, thus making it a truly sustainable method.

- Dredging should be performed with an environmental grab in order to avoid additional water in the in-coming dredged material.

- Dewatering should be considered.

- The amount of binders should be based on the water content of the in-coming dredged sediments to the mixing plant, however with a minimum binder amount to secure a structure of stabilized material so that the geotechnical and environmental properties can be achieved.
Conclusions and recommendations

- Quality Assurance/Quality Control (QA/QC) programme should be established

- Monitoring programme should be established including geotechnical and environmental properties of the s/s-treated sediments, the behaviour of the structure and the influence on the surroundings

- SMOCS project and the network on supporting the sustainable management of contaminated sediments in the Baltic Sea region has been most beneficial on gathering information throughout Europe.
Thank you for attention