S / S of dredging sludge containing Polycyclic Aromatic Hydrocarbons
Stabilisation / Solidification of dredging sludge containing Polycyclic Aromatic Hydrocarbons

1. Contaminated dredging sludge, aimed to be usefully applied
2. Stabilisation of PAH was required to fulfil environmental standards
3. Solidification of the sludge was required to fulfil civil engineering standards
4. Full scale verification was performed to demonstrate the feasibility of this application
5. Conclusions
1. Dredging sludge, to be usefully applied

- Large quantities of dredging sludge in the Netherlands
- Storage capacity is limited → useful application is encouraged
- The Dutch Building Materials Decree sets limits for the leaching of inorganic contaminants, and for the total content of organic contaminants
- From an environmental point of view leaching is more relevant than total content, also for organic components

- Aim of the study was to develop an S / S recipe for dredging sludge, in order to substantially decrease the leaching of Polycyclic Aromatic Hydrocarbons, and to enable useful application as road base material
1. Dredging sludge, to be usefully applied

<table>
<thead>
<tr>
<th>Parameter and unit</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Particle size $d_{50}$ [$\mu$m]</td>
<td>10</td>
</tr>
<tr>
<td>D$_{90}$ [$\mu$m]</td>
<td>60</td>
</tr>
<tr>
<td>Moisture content [wt%]</td>
<td>&gt; 80</td>
</tr>
<tr>
<td>Loss on ignition [wt%]</td>
<td>14.5</td>
</tr>
<tr>
<td>Total content of 10 PAH [mg/kg]</td>
<td>30</td>
</tr>
<tr>
<td>Total content of mineral oil [mg/kg]</td>
<td>1,300</td>
</tr>
<tr>
<td>Availability for leaching of sulphate  [mg/kg]</td>
<td>4,000</td>
</tr>
<tr>
<td>Availability for leaching of chloride [mg/kg]</td>
<td>23,000</td>
</tr>
</tbody>
</table>
2. Stabilisation of PAH, to fulfil environmental standards

- PAH cannot be bound by hydraulic binders alone
- Therefore a two-step approach was chosen:
  1. Use an additive to physico-chemically bind the PAH
  2. Build the additive (with PAH) into the cement matrix

- Two types of additives were tested:
  1. a Quaternary Ammonium Salt (QAS)
  2. an adsorbent (activated Carbon)

- Experimental method: 2.5 and 5% of additive was thoroughly mixed with the sludge, and then leached at L/S = 2 l/kg
2. Stabilisation of PAH, to fulfil environmental standards

<table>
<thead>
<tr>
<th>Exp. no.</th>
<th>Additive type</th>
<th>Additive content</th>
<th>pH of eluate</th>
<th>Leaching of PAH</th>
<th>Relative leaching of PAH</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>None</td>
<td>0 [wt%]</td>
<td>8.5 [-]</td>
<td>10.0 [μm/kg]</td>
<td>0.25</td>
</tr>
<tr>
<td>2</td>
<td>QAS</td>
<td>2.5 [wt%]</td>
<td>7.8 [-]</td>
<td>1.9 [μm/kg]</td>
<td>0.051</td>
</tr>
<tr>
<td>3</td>
<td>QAS</td>
<td>5.0 [wt%]</td>
<td>7.8 [-]</td>
<td>1.4 [μm/kg]</td>
<td>0.041</td>
</tr>
<tr>
<td>4</td>
<td>QAS + lime</td>
<td>2.5 + 5.0 [wt%]</td>
<td>12.4 [-]</td>
<td>2.8 [μm/kg]</td>
<td>0.078</td>
</tr>
<tr>
<td>5</td>
<td>Activated C</td>
<td>2.5 [wt%]</td>
<td>8.3 [-]</td>
<td>1.1 [μm/kg]</td>
<td>0.033</td>
</tr>
<tr>
<td>6</td>
<td>Activated C</td>
<td>5.0 [wt%]</td>
<td>8.4 [-]</td>
<td>1.2 [μm/kg]</td>
<td>0.035</td>
</tr>
</tbody>
</table>
3. Solidification of the sludge, to fulfil civil engineering standards

- Aim was to produce a road base material, with sufficient strength, and within the BMD limits
- From preliminary experiments, ordinary Portland cement was selected as the best hydraulic binder
- Because of the fineness of the sludge even 30% of binder was not sufficient; therefore sand was added to the sludge, to improve the particle size distribution
- The cubes (10*10*10 cm) were tested after 28 days
- Leaching from the cubes was measured in a modified tank leaching test (NEN 7345), over a period of 64 days
- Release to the soil over 100 years was calculated by modelling
3. Solidification of the sludge, to fulfil civil engineering standards

<table>
<thead>
<tr>
<th>Exp. no.</th>
<th>Sludge / sand ratio</th>
<th>Binder content [kg/kg]</th>
<th>Binder content [wt%]</th>
<th>Additive content [wt%]</th>
<th>Compressive strength [MPa]</th>
<th>PAH leaching [mg/m²]</th>
<th>Leaching [kg/kg]</th>
<th>Release [wt%]</th>
<th>Leaching [wt%]</th>
<th>Release [wt%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1 : 0</td>
<td>30</td>
<td>-</td>
<td>0.4</td>
<td>1.30</td>
<td>1.30</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>1 : 0</td>
<td>30</td>
<td>1.2</td>
<td>0.2</td>
<td>0.19</td>
<td>0.19</td>
<td>-</td>
<td>-</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>1 : 0</td>
<td>30</td>
<td>2.4</td>
<td>0.2</td>
<td>2.0</td>
<td>2.0</td>
<td>-</td>
<td>-</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>1 : 1</td>
<td>30</td>
<td>-</td>
<td>8.0</td>
<td>14.0</td>
<td>14.0</td>
<td>-</td>
<td>-</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>1 : 1</td>
<td>30</td>
<td>1.4</td>
<td>8.1</td>
<td>2.0</td>
<td>2.0</td>
<td>-</td>
<td>-</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>1 : 1</td>
<td>30</td>
<td>2.6</td>
<td>9.3</td>
<td>1.6</td>
<td>1.6</td>
<td>-</td>
<td>-</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
3. Solidification of the sludge, to fulfil civil engineering standards

![Graph showing release vs. time for different additives](graph.png)
4. Full scale demonstration

- Authorities and market players were brought together, to co-operate in a full scale demonstration project
- The project was performed in the city of Groningen, where the city canals were dredged in 2001 – 2004
- 1,200 m³ of very fine sludge were used, severely contaminated with Cu, Pb, Zn, PAH and mineral oil
- To optimise the particle size distribution, an also contaminated sewer sand was added
- Several combinations of sludge, sand, additive were tested on a laboratory scale
4. Full scale demonstration

Finally the following recipe was selected:

- Sludge / sand ratio 1 / 1 on the basis of wet material
- A very fine Portland cement (52,5R) as hydraulic binder
- A relatively low cement dosage of 17%
- No additive was used (because of the high costs, and the fact that the release of PAH and mineral oil was already below the limit values, derived by TNO)
4. Full scale demonstration

- The dredging sludge was ripened during half a year
- The ripened sludge and the sewer sand were mixed
- The cement was also added (in-plant)
- Trucks drove the 2,800 tons of mixture to the road construction site
- The road base was build up in two separate layers, a lower layer of 25 cm and a top layer of 15 cm
- The mixture was levelled (with a grader) and compacted (with a road roller)
- The layers were carved to prevent uncontrolled crack formation
4. Full scale demonstration
4. Full scale demonstration
5. Conclusions

- Activated carbon is capable to physico-chemically bind the PAH in such a way that the PAH-leaching is reduced by a factor of 10
- It is possible to stabilise / solidify a mixture or dredging sludge and sewer sand in such a way that the leaching of PAH is minimised
- The S/S product fulfils the criteria (environmental as well as civil engineering) for an application as road construction material

The full-scale demonstration project learned that:
- the sludge must be dewatered and ripened until the water content is below 30%
- in case of a very fine sludge, a coarser material must be added
- the fineness, salt content, organic matter content and degree of contamination determine the recipe for S / S
- the properties of the full scale road base very well corresponded with the predictions, based on the lab scale tests