Capping sediment

Water quality improvement through capping the sediment with sand and additives

Client

Deltares, in cooperation with the regional water authorities “Schieland en de Krimpenerwaard” and Waternet, carried out this project within the Water Framework Directive Innovation Programme funded by the Dutch Ministry of Infrastructure and the Environment.

Reducing the internal phosphate load in Lake Bergse Plassen, the Netherlands

Algal growth, a lack of vegetation and a high turbidity are often the result of a high phosphate level. After dealing with the external sources, the naturally occurring phosphate deposit in the soil can still hinder water quality improvement. Capping the sediment with sand in combination with the addition of aluminium hydroxide can, in this case, reduce the internal phosphorus loading significantly.

Extensive growth of algae caused by eutrophication in Lake Bergse Plassen

The Regional water authority Schieland en de Krimpenerwaard District is responsible for Lake Bergse Plassen in Rotterdam.

Aerial picture of Lake Bergse Plassen located in the urban area of Rotterdam

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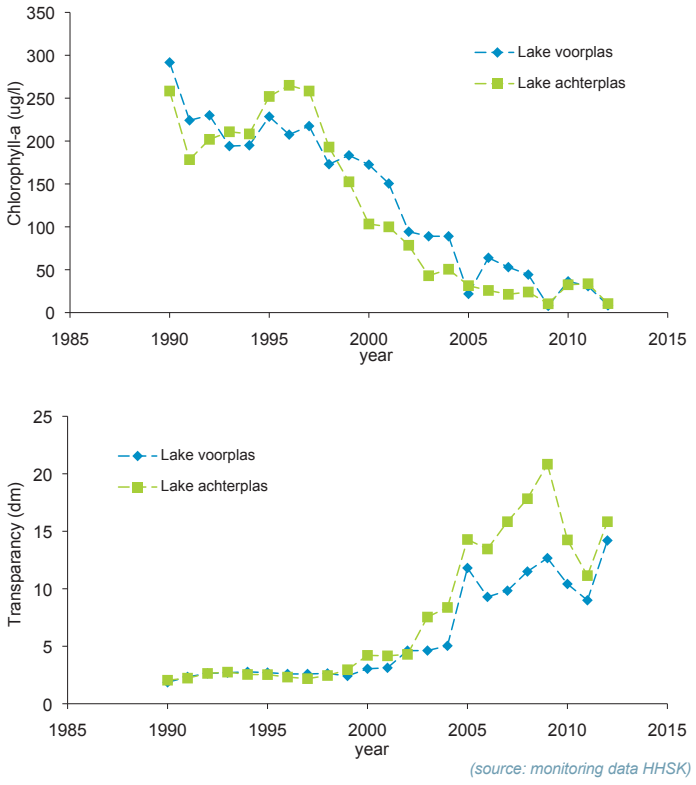
In the past, Lake Bergse Plassen became highly eutrophic as a result of untreated discharges, WWTP effluents, inlet of eutrophic water and mineralisation of the peat soil. Every summer, this resulted in extensive algal growth, causing inconvenience for the people living in the neighbourhood and recreationists. In the nineties, the Water Board sharply reduced the external nutrient sources. In addition, Lake Bergse Achterplas was partly dredged and capped with 30 cm of sand in 2002. Both measures resulted in an increased transparency of the water in Lake Bergse Achterplas.



The progress of transparency and chlorophyll-a contraction in Lake Bergse Plassen

The transparency in Lake Bergse Voorplas did not improve as much as it did in Lake Bergse Achterplas. The Water Board therefore decided to cap Lake Bergse Voorplas as well. It was uncertain whether the sand layer would have enough binding capacity to prevent the phosphorus flux from the soil for a longer period of time. This especially applied to the area near the Rotte River where seepage occurred. Based on literature studies, laboratory experiments and field work, Deltares examined how adding a phosphate binding substance to a sand layer would affect the soil phosphorus flux. This study was carried out in the framework of the Water Framework Directive.

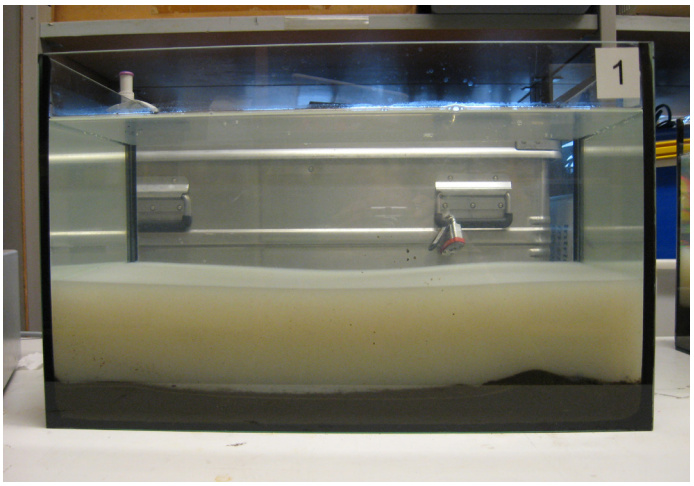
Selecting phosphate binding substances

Based on international literature and adsorption experiments, we selected the additives of five substances. It turned out that aluminium and iron hydroxides, and also Phoslock, were capable of binding the most P per g material. The binding capacity of lime and sand appeared to be low. For capping Lake Bergse Plassen, we chose Poly Aluminium Chloride (PAC) as a phosphate binding substance. PAC is transformed into aluminium hydroxide around neutral pH. It is a naturally occurring soil substance found in all parts of the world. The main advantages of this substance are its high phosphate binding capacity, its non- toxicity at the neutral pH level that occurs in the sediment and that it is not redox sensitive in contrast to iron hydroxides. The latter advantage was important because the substance was to be applied under the sand layer and should therefore be stable also under anaerobe conditions. In addition, PAC can be obtained in large quantities and is relatively cheap.

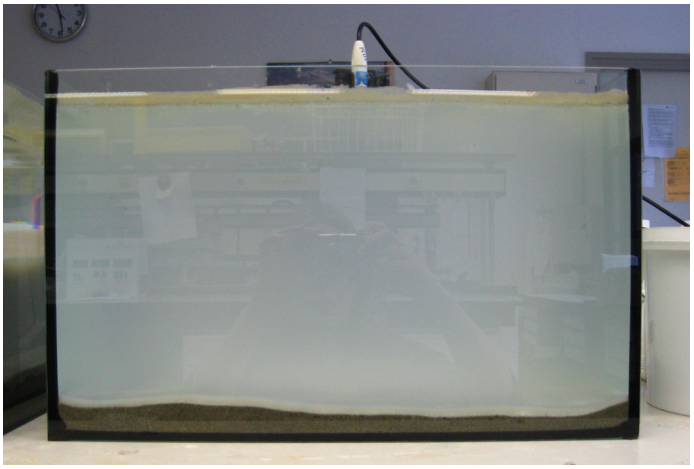
Laboratory experiments as preparation for and support of the execution

After selecting PAC as the phosphate binding substance, Deltares studied the following aspects as a preparation for and support of the field experiment.

- Determination of the side-effects of PAC on the pH level, the chloride content and dissolved aluminium concentrations. The experiments showed that the pH and the chloride content would remain well below the standard set for Lake Bergse Plassen. At the current neutral pH level of the sediment, no dissolved aluminium was measured and toxic effects could thus be excluded.
- Physical aspects of adding PAC. Will there be a nice layer of aluminium hydroxide that can properly be capped with sand? The experiment showed that a 7 cm thick layer of loose aluminium hydroxide flocks was created if PAC and NaOH

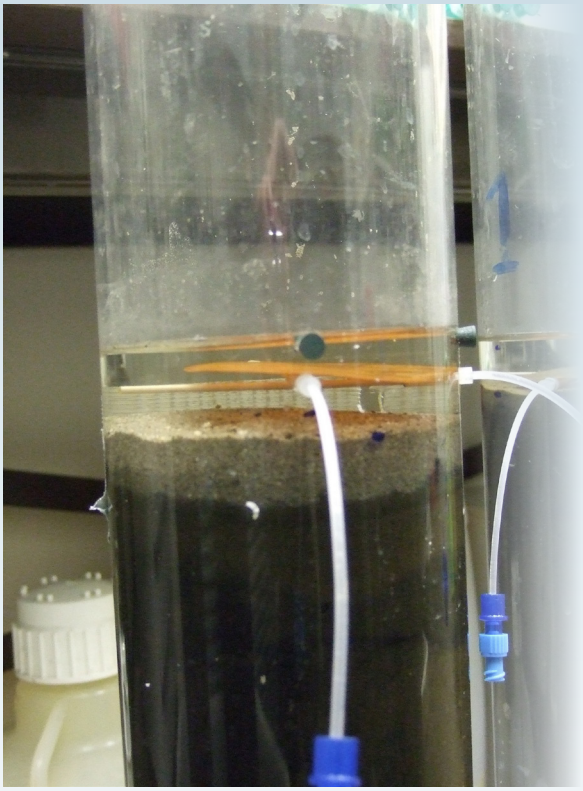


Addition of aluminium hydroxide: top: mixing of PAC and caustic soda in water, bottom: mixing of concentrated PAC and caustic soda and then added to the water.



were added to the water separately. The sand fell right through it. More compact flocks that could be capped easier were obtained by first mixing concentrated PAC with NaOH and then adding the mixture to the water.

- Further study into the phosphate binding capacity of PAC. This was previously done with batch experiments. Both types of experiments showed that the sand to be used had its own phosphate binding and decelerating capacity, however, combining sand and PAC resulted in a far more efficient and prolonged prevention of internal phosphorus loading.



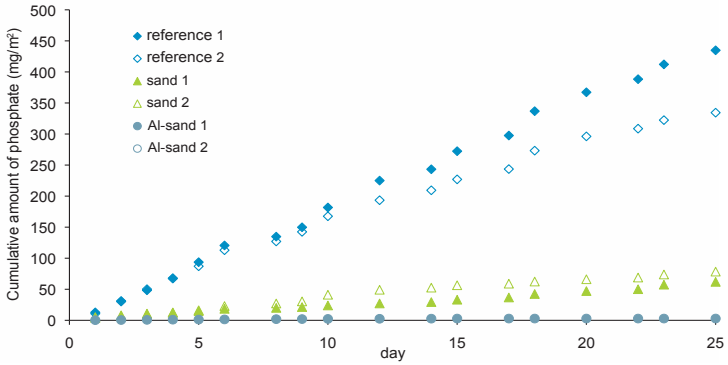
Diffusion in an undisturbed sediment column where diffused phosphate is adsorbed to small pieces of iron oxide paper to keep the P-concentration in the surface water low. The iron papers are refreshed daily.

Explanation of the legend:

reference = not capped

sand = capped with sand

Al-sand = capped with PAC and sand



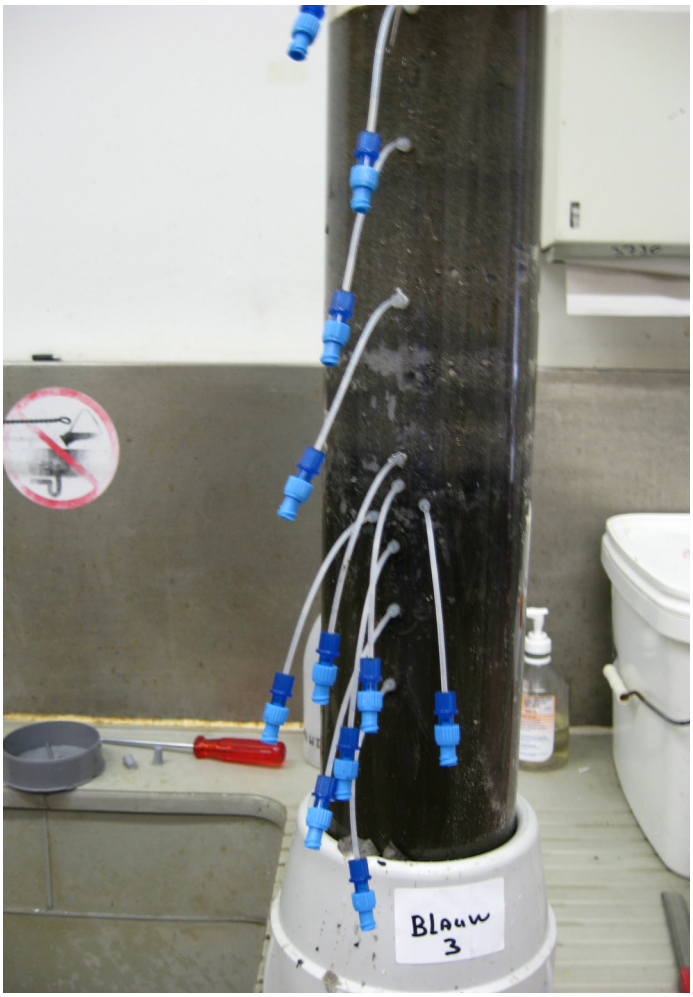
Work carried out by contractor De Vries & Van de Wiel

Based on the laboratory experiments, it was concluded that the production of aluminium hydroxide from PAC and NaOH should be done in a concentrated form. Therefore, a mixer was used to produce a yoghurt-like substance that was pumped to a dosing vessel with a high-pressure tube. After dosing and settling of the aluminium hydroxide, the sediment was capped with sand. The sand was applied to the sediment of Lake Bergse Voorplas in several thin layers up to a thickness of 20 cm.

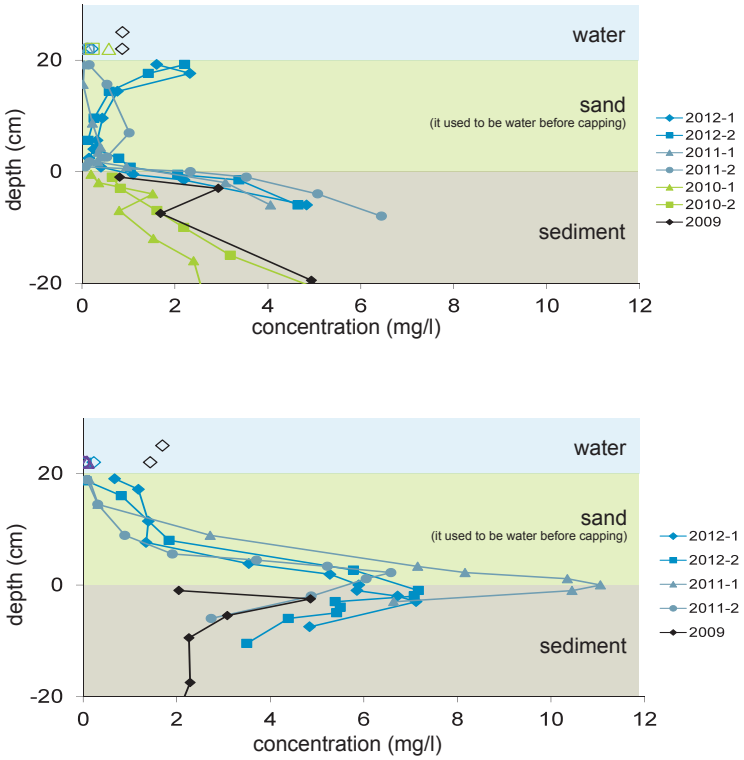
Monitoring

The Schieland en de Krimpenerwaard District Water Board monitored the water quality before, during and after the capping. They also monitor the ecology, water plants, phytoplankton, macro fauna and fish long-term. During the work, a low ortho-P concentration was measured.

Deltares monitored the development of the sediment by sampling of the undisturbed sediment columns. We made a pore water profile by drilling small holes at various depths and pushing a Rhizon pore water sampler horizontally into the column. We then cut the column into slices to determine the total content. Clear differences were observed in the pore water profiles of Lake Bergse Voorplas in the parts capped with the combination of PAC and sand and the parts capped



with sand only. For the combination of PAC and sand, the P concentrations in the pore water after capping (2011/2012) clearly showed a sharp reduction at the interface sediment/sand whereas capping with only sand showed a substantial increase. In 2012, both columns taken in the PAC/sand area showed an increased P concentration in the pore water of the top layer. It is not yet clear whether this is a trend. In addition, it was noticed that the iron/phosphorus ratio in the pore water of the sediment sharply increased. This effect occurred more prominently in the PAC/sand treatment than in the sand treatment and was mainly caused by the strongly increased Fe concentrations in the pore water of the sediment.



Pore water profile for P in sediment columns of Lake Bergse Voorplas in the part with PAC (top) and without PAC (bottom). The zero-line represents, before capping (2009) the sediment/water interface and after capping (2011/2012) the sediment/sand interface. The open symbols represent measurements in the water column.

Conclusions

- Capping with a combination of sand and aluminium hydroxide (consistent of PAC and NaOH) is possible on field scale, provided that aluminium hydroxide flocks are being made before dosing.
- Laboratory experiments (columns experiments) showed that the P flux of the sediment decreases when applying a sand layer and, when applying a PAC and sand combination almost reduces to 0.
- The Fe/P ratio in the pore water of the top layer is much higher in the new sand layer, especially when PAC has been added.
- The P concentrations in the pore water on the sediment/sand interface are much lower if PAC is added before the sand capping procedure.

More information

If you want more information about sand capping possibilities and or additives, please send an e-mail to:

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Aerial picture of the River Vecht near Hinderdam

Reducing the heavy metals and PAH load in the River Vecht, Utrecht

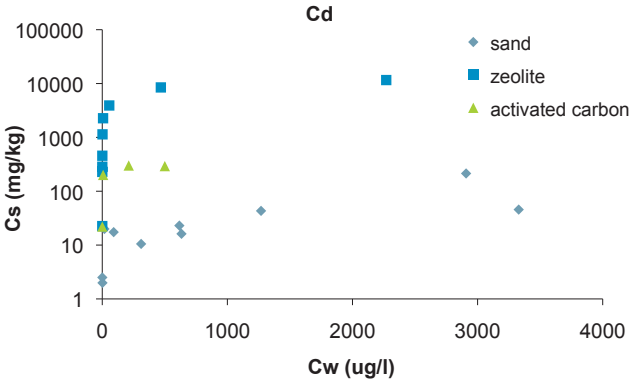
Sediment pollution with heavy metals and PAHs

The Regional Water Authority “Amstel, Gooi and Vecht” manages the River Vecht in Utrecht, The Netherlands. For a long time, the water quality of the River Vecht remained poor because of WWTP effluents and discharges from companies. Even though all discharges now comply with the current regulations, the water quality remains moderate and does not comply with the standards of the Water Framework Directive. After extended research, it has thus been decided to remediate the River Vecht. The current river bed is generally too shallow to be capped with a thick layer of sand. We therefore examined if mixing additives through the sand would make it possible to reduce the thickness of the sand layer.

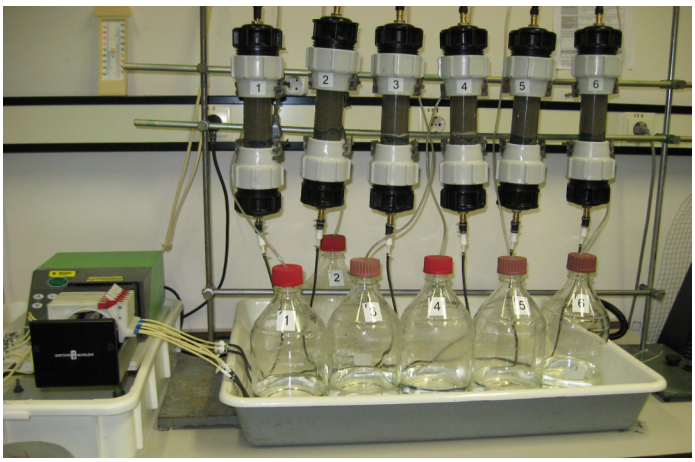
The Water Framework Directive Innovation Project consisted of a literature search and laboratory research. We have examined the synthetic zeolites to bind heavy metals and activated carbon to bind PAH.

Zeolite

Synthetic zeolite (Doucil A4) was tested to bind a mix of heavy metals with a pH between 6.5 and 8. The pH and concentrations used have been based on the pore water concentrations of sediment in the River Vecht. The experiment showed that zeolite binds heavy metals well and can be applied under the sand properly.



Binding Cd to sand, zeolite and activated carbon. Cs is the concentration bounds, while Cw is the concentration in water



The column experiments carried out with sand and zeolite showed that the sand itself also has a rather good binding capacity for heavy metals. The adsorption capacity is a factor of 100-1000 less than the capacity of zeolite. However, as a common material for capping, sand will be applied in much larger quantities compared to an additive such as zeolite. The sand of the top layer itself can thus contribute significantly to the reduction of the internal heavy metal loading from the sediment.

Activated carbon

For PAH, activated carbon was tested as an additive. This was done for a PAH mix in concentrations based on the concentrations of sediment in the River Vecht. The mix varied from small PAH's like phenantrene and antracene to larger PAH's such as indeno pyrene and benzo(ghi)perylene. The experiment showed that activated carbon has a very high binding capacity for PAH with adsorption coefficients (log K_d) varying from 7.5 to 12. Because of the excellent binding capacity of activated carbon for the various kinds of PAH, it can well be applied in a top layer to reduce the internal PAH loading of the sediment. Relatively little activated carbon is needed in this process. It turned out that activated carbon also has a good binding capacity for the mix of heavy metals, as studied for zeolite. The binding capacity of activated carbon for heavy metals is only a factor of 10 less compared to zeolite.

Conclusions

- Capping with a combination of sand and zeolite or activated carbon is technically possible on field scale.
- Laboratory experiments showed that the flux decreases significantly by zeolite/activated carbon.
- Application of additives is especially useful when a thick sand layer is impossible because of insufficient depth or high costs.

More information

If you want more information about sand capping possibilities and/or additives, you can send an e-mail to:
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