Appendix 5 – Pilot experiments, field report

Biochar based capping of polluted sediment

Biokolbaserad reaktiv barriär för täckning av förorenade sediment

Luleå tekniska universitet

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1. Backgound

Luleå University of Technology (LTU), together with the Norwegian Geotechnical Institute (NGI) and Skellefteå municipality, is carrying out a pilot project funded by the Swedish Geological Survey (SGU) within the framework of the Governments mission *Contaminated Sediments (förorenade sediment)*. The pilot project regards the use of a biochar-based reactive barrier to cover contaminated sea sediments.

As part of the project, a pilot field experiment was carried out to cover a small area of sediment with a mixture of biochar (as reactive agent), bentonite (as the structural material) and salt (to facilitate the sedimentation of the material). The experiment was executed in the bay of Bureå outside an old industrial area, where Bure Träslip operated a wood grinding industry from 1928 until 1992. Wood pulp impregnated with the impregnation agent *Pulpasan,* containing methylmercury, has been transported into the Bay, and the sediment has also been contaminated with different PAH due to the trafficking of the bay during the time in which Bure Träslip was active. The sediment also contains high concentrations of trace elements.

Prior to the pilot project, a notification of remedial action (avhjälpandeåtgärd) was made (Reference 2021,636, decision date 2021-03-11) and an application for water activities (Diarnr. 2021.928, decision date 2021-03-11) was sent to *Sämhällsbyggnadsnämnden*.

This report will present the field work that was performed in the bay of Bureå between 7th of June to 9th of June. The field work considered the covering of the polluted sea bottom sediment in order to reduce diffusion of pollutants from the sediment to the sea water. The covering was limited to a specific area called *Testområde* (test area), see Figure 1, within the 3x3 orange cells of the grid. The outer part of the grid was used for turbidity tests.

On the 15th of May, eight diffusion chambers had been placed in the sea sediment within the test area (Testområdet) and the reference area (Referensområdet), see Figure 1. At the time of the field work in June, these samplers had been on the sea floor for three weeks.

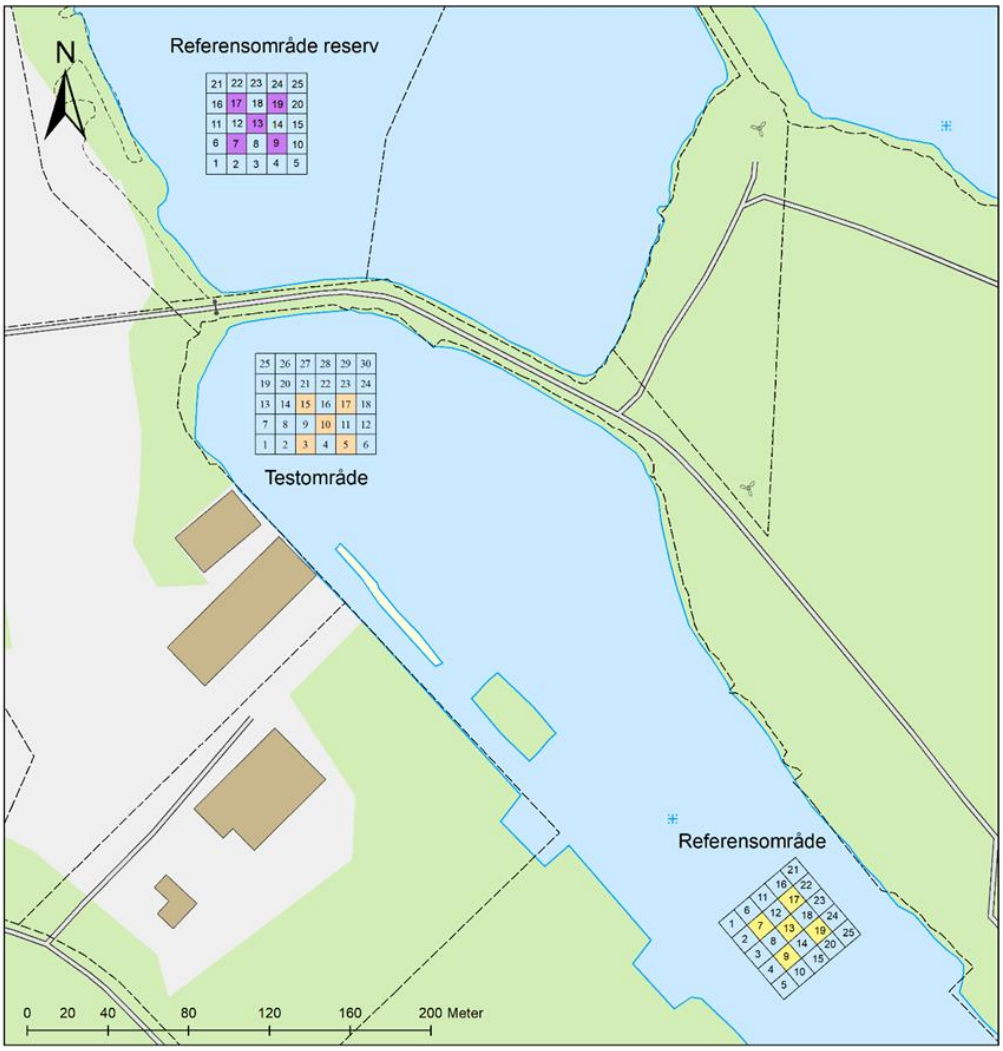

Figure 1 *Map of the Bureå bay with the three sampling locations: The reference area (yellow grid), the test area (orange grid), and the backup area (purple grid) (Ramboll, 2021).*

2. Method

The field work that was executed for 3 days included:

- Day 1: Preparations and site visit, collecting of 4 diffusion chambers in the test area (for evaluation of background values/contamination situation), and turbidity measurements,
- Day 2: Covering with 2 loads of biochar mixture and turbidity measurements,
- Day 3: Covering with 2 loads of biochar mixture, turbidity measurements and slam tests of the sediment.

The outer boundaries of the test area had been marked with anchored floats which served as navigation marks for the covering test. Additional two anchored floats had been placed in the area, one at a 40-meters distance and another at 80-meters distance from the test site. Two boats had been rented from the Bureå harbour (Bureå båtklubb), one smaller boat and one floating dock that was

monitored with a motor. The floating dock was used during the covering to monitor the tube that was used to distribute the biochar mixture, see Figure 2.

Figure 2 *The floating dock was used to monitor the tube that spread the biochar mixture. Anchored floats marked the outer boundaries of the area (Maurice, 2021)*

2.1 Field tests

2.1.1 Covering test and biochar mixture

The recipe for the biochar mixture had been pre-determined in the soil mechanics lab at LTU. The biochar mixture was mixed at the Swerock station outside of Skellefteå and transported by a cement truck to the test site. The mixing ratios of the biochar mixture had been predetermined in the laboratory, and each individual load of mixture consisted approximately of:

- 20 kg salt,
- 300 kg biochar,
- 1,2 tons bentonite,
- 9 m^3 water.

The goal was to add approximately 3 kg/m^2 of biochar mixture, to ensure a covering layer of at least 1.6 kg/m^2 , which is the amount that has been used in laboratory experiments that's been executed by NGI.

2.1.2 Diffusion chambers for sediment sampling

4 out of the 8 diffusion chambers were planned to be collected, and these were located in the test area. The 4 samplers placed in the reference area was to be left for another week and collected on the 17th of June. A thin membrane that adsorbs organic pollutants was attached to the samplers. The organic membranes were later to be sent for analysis at Eurofins, Germany.

2.1.3 Turbidity tests

Turbidity tests were planned to be performed within the test area and at a distance of 40- and 80-meters from the covering site. Water samples for turbidity measurements were collected with a Ruttner sampler. The turbidity was measured at 0.5 meters depth and 1.5 meters depth. The aim with these tests were to observe how fast the biochar mixture settles and if it affects the turbidity in the water at a 40- and 80 meters distance from the test site. A field turbidity instrument was used, and the measured unit was FNU. A calibration curve of FNU and corresponding mg/l had been calculated in the soil mechanics lab at LTU. Figure 7 in appendix shows the turbidity instrument that was used during the field sampling.

2.2 Field work – pilot capping

The following sections Monday 2021-06-07 to Wednesday 2021-06-09 will describe the fieldwork that was performed during the covering test in Bureå.

2.2.1 Monday 2021-06-07

Arrival at Bureå harbour 12.30 am. Weather conditions were 20 degrees Celsius, sunny, and relatively windless. The aim with Monday's field work was to collect the 4 diffusion chambers that had been placed in test area for 3 weeks. A small boat was used for transportation to the test area, and a GPS was used to navigate around the site. The visibility depth in the test area was measured to 2.3 meters with a Secchi disc, and the water temperature was 16 degrees Celsius.

A GoPro camera was used for filming the diffusion chambers under the water before collecting them. Figure 3shows the diffusion chambers, and Figure 4 shows the membranes that were detached from the samplers and collected in aluminium jars for later analysis. One blank test was performed by attaching a membrane to a diffusion chamber and lowering it down to the sea floor, and then picking it up again and collecting the membrane.

Figure 3 Diffusion chamber

Figure 4 The adsorbing membranes attached to the samplers (Flodin, 2021).

The turbidity was measured within the test area and at 80 meters distance. At last, the outer boundaries of the test area were marked with anchored floats. Anchored floats were also placed at 40- and 80- meters distance from the test area.

2.2.2 **Tuesday 2021-06-08**

Arrival at Bureå harbour at 07.45 am. Weather conditions were 20 degrees Celsius, sunny, and relatively windless. The day started with transportation of the small boat and floating dock from the Bureå harbour to the test site.

A crane lorry from Swerock had arrived at the test site and was used for pumping the biochar mixture to the covering site. A long tube was mounted to the crane lorry and the floating dock was used for dragging the tube from land out to the test site, see Figure 5a. The floating anchors visible in Figure 5a marks the north-east boundary of the test area.

The cement truck from Swerock arrived with the first biochar load (load nr. 1) around 11.00 am, and the first covering test started around 11.30 am and was performed during approximately 25 minutes. Figure 5 shows how the mixture was spread in the water with the tube from the floating dock. The floating dock was navigated with a motor within the test area during the pumping of the biochar mixture. The mixture was observed to have a quite fluid texture.

Figure 5 *A tube was mounted to the crane lorry to transport the biochar mixture to the test area (a) and the biochar-mixture was spread in the water from the floating dock (b) (Flodin, 2021).*

When the fist load of biochar mixture had been distributed, the cement truck went back to the Swerock station to mix and get the next load (load nr. 2). This was quite time consuming and load nr. 2 arrived in Bureå at 14.00 pm, and shortly after the covering proceeded. To increase the thickness of

the biochar mixture, less water had been added to this load. Figure 8 in the appendix shows the cement truck that arrived at the site with the mixture. Since the mixture had a thicker texture now, it took some more time to pump the mixture through the tube. But the covering went well and all of the mixture had been distributed in the area by 14.45 pm.

Turbidity was measured during the covering at 3 different sites within the test area at 0.5 meters depth. The turbidity was then measured again at 0.5- and 1.5 meters depth one hour after the covering test had ended.

2.2.3 **Wednesday 2021-06-09**

Arrival at Bureå harbour at 08.00 am. Weather conditions were 20 degrees Celsius, sunny, and relatively windless. The floating dock was transported from the harbour, and the first covering started at 08.30 am. The same mixing ratio had been used for this load (nr. 3) as for load nr. 2 the day before. Some problems arose in connection with dry lumps occurring in the mixture that was clogging the grill in the crane lorry (where the mixture was pumped from the cement truck to the lorry). This issue resulted with that it took longer time to spread the mixture in the test area. This problem occurred most likely due to that the dry substances had been added to the cement truck before the water was added, resulting in dry lumps forming in the mixture. Even though this problem was time consuming, load nr. 3 could successfully be spread in the test area eventually.

Figure 6. The mixture was spread in the water through the tube mounted on the crane lorry

Load nr. 4 arrived at Bureå around 12.00 am, and the covering started at 12.30. For this load the water had first been added to the cement truck, and then the dry substances were added. This load had a slightly thicker texture than load n. 3 since the remaining bentonite and biochar had been added to the mixture. The covering was successful and went quite fast. shows how the biochar mixture was spread in the water.

Turbidity was measured within the test area in the morning before the first covering (load nr. 3) was performed. The turbidity was measured again at 14.00 pm at 40- and 80 meters distance.

3. Results form the pilot experiment

Table 1 shows the results from the turbidity measurements. The turbidity was measured in FNU unit. Table 2 gives FNU-values and corresponding suspended material in mg/l.

The turbidity measured the day before the cover tests shows a background average FNU value of 3.5 (100 mg/l). Compared with guideline values in report 5050 (2000) by The Swedish Environmental Protection Agency, the water condition with 3.5 FNU units is classified as substantially turbid. At 80-meter distance from the test area, an average turbidity was measured to 1.5 FNU units. During the covering on June 8th the turbidity was measured to 32, 43, and 53 FNU units within the test area at 0.5 m depth. 1 hour after the covering, the turbidity was measured to range between 3 – 6 FNU at 0.5- and 1.5-meter depth within the test area, and 2 – 7 FNU at 40-meter, and 4 FNU at 80-meter distance. On June 9th the turbidity was measured at 40- and 80-meters distance to range between 5 – 8 FNU at 0.5- and 1.5-meters depth.

Table 1. Results from turbidity measurements given in mg/l suspended material.

Date	**Comment**	**Test area - turbidity**		**40 meter - turbidity**		**80 meter - turbidity**	
		0.5 m depth	1.5 m depth	0.5 m depth	1.5 m depth	0.5 m depth	1.5 m depth
June 7th		2	5			2	1
June 8th	During covering	32					
June 8th	During covering	43					
June 8th	During covering	53					
June 8th	13.30 pm, 1 hour after covering	6	3	2	7	4	4
June 8th	14.00 pm	3	6				
June 9th	08.00 am	5	2				
June 9th	14.00, after last covering			5	6	5	8

Table 2. FNU units and corresponding suspended material in mg/l.

Turbidity	
FNU	**mg/l**
1	97.5
2	98
3	100
4	101
5	102
6	103.5
7	104
8	106
32	134
43	146.5
53	158.5

4. Discussion and conclusion

A total of 4 loads à 12 tons of biochar mixture was spread in the test area. The field experiment was successfully executed and lasted for about 30-45 minutes at each performed covering. It is estimated that the biochar mixture was more or less evenly distributed in the test area. There may be a slightly thicker layer of mixture in the north-east part of the area, and this would be due to that on Tuesday the tube from the crane lorry was too short to be able to reach the whole test area with the floating dock. On Wednesday an extra piece of tube was mounted on the tube, and the whole area could be reached.

What was most time-consuming with the field trial was the actual mixing of the material that was performed at Swerock's station in Skellefteå. There was a long wait between the loads as we only had access to one cement truck that would transport and mix materials. To use two smaller concrete trucks instead of a large concrete truck would have increased the production rate and it would then have been possible to shorten the time between the coverings.

The water samples taken within and around the test area showed low turbidity values at both 0.5- and 1.5-meters depth. The turbidity values were increased in connection with the covering (FNU values between 32-53), where the mixture was pumped out, but had decreased to the background values (FNU values between 2-5) when the turbidity was measured again after 1 hour. Outside the test area, 10 meters outside and at control points, 80 meters from the area, no distinct changes in turbidity were detected. This indicates that the biochar mixture settled rapidly which was also desirable.

The conclusion from this field experiment is that the covering was successfully performed, and the biochar mixture settled relatively rapid after it had been pumped into the water, which was established with the turbidity tests. The collaboration with Swerock was smooth with good communication.

A new sampling campaign is planned to be performed in Bureå in August and September 2021 to see how the biochar mixture has settled on the sediment, and what effect it has had on the spread of pollution in short term. Diffusion chambers will be placed in the test- and reference area, and sediment cores will be collected for analysis.

5. References

Swedish EPA, 2000. *Lakes and watercourses*. Report 5050. Stockholm: Swedish Environmental Protection Agency Customer Services.

Appendix A

Images from the field work

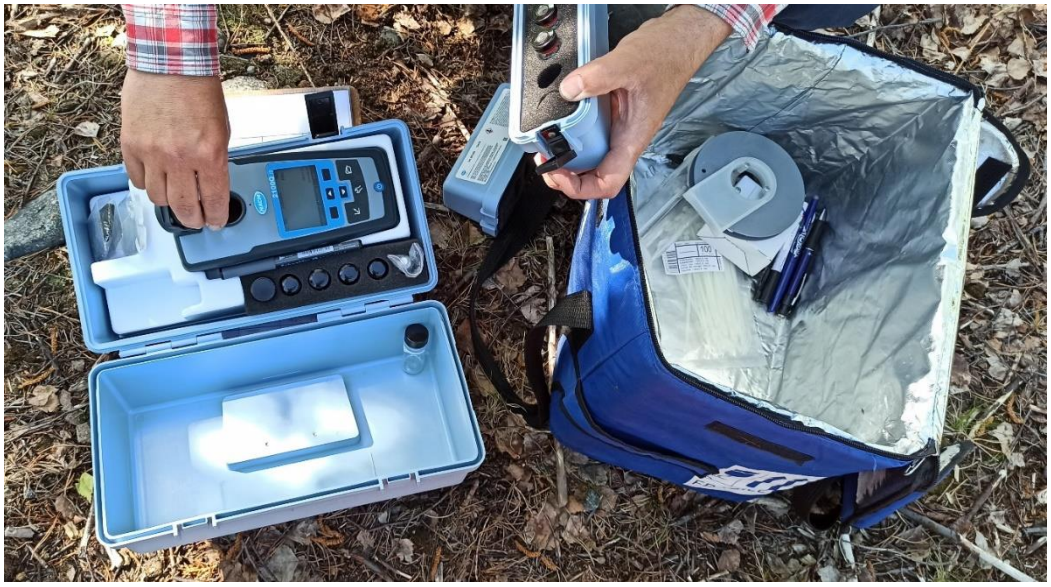

Figure 7. The turbidity instrument that was used in the field (Flodin, 2021).

Figure 8. The cement truck that arrived to Bureå with the biochar-mixture (Flodin, 2021).