THIN-LAYER PLACEMENT PROJECT SHEET

Ormefjorden and Eidangerfjorden

Background

September 2020

Location: Ormefjorden and Eidangerfjorden, Telemark

Type: Sediment Remediation

Area: 3,100 x 100 m test fields; and 1,200 x 200 m field

City: Ormefjord and Eidangerfjord

County: N/A

Main Agencies: Norwegian Climate and Pollution Agency, and Norwegian Institute for Water Research and Marine Contaminants

Country: Norway

Two species, gastropod *Hinia reticulate* (left) and polychaete Nereis sp (right) evaluated for toxicity effects from TLC. Image adapted from NIVA, 2012.

As part of the research effort to examine the effectiveness and environmental impacts of thin layer capping in the Grenlandfjords (Ormerfjord and Eidangerfjord), Schaanning and Allan (2012) evaluated biogeochemical fluxes and dioxin bioavailability in box cores collected from the Grenlandfjord field sites. In September 2009, thin layer capping with limestone, marine clay, and marine clay amended with 2-3% activated carbon (AC) was applied in Ormerfjord and Eidangerfjord. In October 2009 and Novermber 2010, Schaanning and Allen collected box-core samples from test fields and reference locations to investigate releases of chlororganic compounds into the overlying water, and uptake in two sediment-dwelling organisms.

This summary presents the findings from biogeochemical and biological investigations on sediments and sediment caps from the test fields in Eidangerfjorden and Ormefjorden following the 2009 placement of thin layer cap materials. Schaanning and Allan also assessed ecosystem functions by determination of the exchange of oxygen and nutrients between the sediments and the overlying water.

Project Description

Box-core samples transplanted from the Grenlandfjord test plots in October 2009 and November 2010 were collected with a 0.1 KC-Denmark™ box corer with transparent polycarbonate liners attached inside the steel box. The overlying water was removed through a siphon to reduce erosion of the sediment surface during transportation and handling. Artificial light and a continuous supply of fjord water from 60 m depth (Outer Oslofjord) was used to maintain an experimental environment resembling the conditions at the fjord sampling locations (including dim light, temperatures, salinities, and oxygen levels). The water overlying the sediments in each box was continuously exchanged with the fjord water to maintain high (>60%) degree of oxygen saturation. A flow of approximately 10 ml min^{-1} during biogeochemical measurements was maintained, as well as continuous stirring to ensure a well-mixed water column without visible resuspension of sediments. After completion of the biogeochemical flux measurements, aquarium pumps were replaced to ensure a well-mixed and oxygen saturated overlying water. Fluxes of oxygen and nutrient species (SiO_4, PO_4, NH_4, NO_3, and NO_2) were determined from the concentration difference between the inlet water and the overlying water in each box core.

Additionally, the uptake of dioxins were determined in two species the gastropod *Hinia reticulata* and the polychaete worm *Nereis diversicolor*.

Findings

Schaaning and Allan (2012) observed that oxygen and nitrogen nutrient fluxes were not significantly affected by capping. Anomalous fluxes of phosphate and silicate were observed in the 2009 investigation and primarily in sediments treated with the limestone material. In all box core samples collected in 2009 and in boxes from clay and AC treatments transferred in 2010, bioaccumulation and leakage of dioxins was reported to be 67% - 91% lower than at the uncapped reference fields. At the two fields treated with limestone gravel and dredged clay without activated carbon, Schaanning and Allan noted that cap efficiencies decreased to less than 46%. Schaanning and Allan (2012) concluded that a cap thicknesses of <5 cm applied in the Grenlandfjord field experiment, was adequate to obtain satisfactory cap performance with respect to biogeochemical processes. None of the fields showed significantly different fluxes of oxygen, nitrate and ammonium neither in 2009 nor in 2010. It was noted that the uptake of nitrate and nitrite are normally driven by microbial processes in the sediment and frequently correlated with the uptake of oxygen. Uptake of nitrate from water to sediment was observed in all boxes. The highest uptake occurred in 2009 in sediments containing the limestone, and the lowest uptake was reported to occur in the 2009 clay and AC treatment in Ormefjorden. Schaanning and Allan (2012) noted that the differences between fields were smaller in 2010 than in 2009, indicating normalization of nitrate fluxes after cap placement. Phosphate was reportedly released from sediment to water in both reference fields and most of the capped fields. This occurrence was attributed to its desorption and diffusion from subsurface anoxic layers, and partly from degradation of organic matter at the sediment surface. A considerable uptake of PO4 was observed in the NOAH limestone treatment in 2009, and this uptake was significantly different from the maximum release of PO4 observed in the untreated Eidangerfjord field. In 2010, small and similar release of phosphate was observed from all fields in Ormefjorden. The uptake observed shortly after cap placement was most likely chemical adsorption to the freshly mined material, but the second year results showed that this was not a long-term effect.

Bioaccumulation in *Hinia reticulata* was the only cap efficiency parameter determined both in 2009 and 2010. At the 2 reference fields, the concentrations of dioxins in this organism ranged from 3.7-6.1 pg/g wet weight. Low concentrations from 0.4 to 1.4 pg/g wet weight were observed at all capped fields in 2009 and at the clay and AC fields in 2010. These trends were similar to observations by Samuelsson et al., (2013). Schaanning and Allan (2012) demonstrated that the bioaccumulation in the gastropod increased 4 to 5 times more in caps without AC amendment during the first year after cap placement, whereas no change was observed in neither AC-amended caps nor uncapped reference sediments; suggesting that the performance of the limestone gravel and clay without AC caps declined during the first year after cap placement.

At the reference fields, the concentration of dioxins in *Nereis diversicolor* was generally higher than the concentration in *Hinia reticulate*. This difference was noted as a characteristic for the species as it may result primarily from different feeding strategies and exposure to pore water. It was documented that both organisms showed clearly higher concentrations in Eidangerfjorden compared to Ormefjorden, most likely as a result of different concentrations in the sediments, which would be consistent with the depth gradient of dioxin concentrations. Bioaccumulation ratios for dioxins and furans *in Nereis diversicolor* in the limestone field were between 1.8 and 2.7, close to 1.0 in dredged clay, and less than 0.5 in the clay and AC fields. Schaanning and Allan (2012) suggested that this outcome showed that the caps without AC had little or no effect on the dioxin

levels in the polychaetes, whereas caps with AC clearly reduced the levels of chlororganic compounds in this organism.

References

Samuelsson, G. 2013. In situ remediation of contaminated sediments using thin-layer capping. Stockholm University, Department of Ecology, Environment and Plant Sciences (DEEP), ISBN 978-91-7447-795-5; pp. 1-34.

Schaanning, M., Allan, I. 2012 Field experiment on thin-layer capping in Ormefjorden and Eidangerfjorden, Telemark Functional response and bioavailability of dioxins 2009-2011. Norwegian Institute for Water Research, Report SNO 6285-2012.

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Main Agencies:

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