The development of a remediation action plan for a contaminated fjord in Norway, hosting a biological important submerged macrophyte meadow

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Introduction: The shallow, brackish, land locked fjord Gunneklevfjorden in southern Norway, has received substantial amounts of contaminants since early 1900 and throughout most of the 19th century, due to discharges from industrial activities. The fjord is identified for remediation by national pollution authorities. Investigations and research has been carried out to develop a remediation action plan for the fjord. Major challenges are the very high concentrations of mercury and dioxins reaching deep into sediments, as well as extremely soft sediments in major parts of the fjord. Despite the heavy contamination, the fjord is hosting a large area of permanently submerged macrophytes, covering approximately 70 000 m^2. Test fishing has resulted in surprisingly vast catches within the meadow. The challenging sediment conditions, the biological diversity of the fjord and in particular the biological value of the submerged meadow should be taken into account when considering remediation actions.

Methods: A multiple of topics have been investigated to create a basis for a sustainable and adaptive management of the contaminated sediments. Studies have included sampling of water, sediment and biota for chemical analysis, as well as amendment with activated carbon in situ and in mesocosms to reveal the effects of the low-impact alternative to dredging or isolation capping. The final recommendation of a primary remedial action has been based on an evaluation of several remediation alternatives, according to the criteria primary effects, secondary effects, feasibility, costs and the chance of reaching preset remediation goals (Fig.1.).

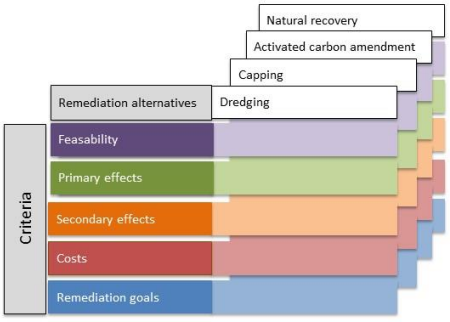

Fig. 1: Evaluation criteria for remediation alternatives in Gunneklevfjorden, Norway.

Results: Results have revealed heavily contaminated and extremely soft sediments, and calculations demonstrate that flux of mercury from sediment is the major source to present contamination of water, and potentially to uptake of contaminants into food webs. However, the transport of contaminants out of the fjord has been calculated as low, and is considered not to represent a risk of ecological effects to adjacent recipients. Further, the mercury concentration in fish is not elevated compared to nearby non-contaminated freshwater sites, probably due to a relatively low methyl mercury production within the fjord sediments, despite that there are indications of an enhanced production of methyl mercury within the meadow compared to outside the meadow.

Discussion:
Dredging or isolation capping may contribute to a remediation goal of reaching sediment concentrations below EQS, though major challenges are identified related to resuspension and spreading of particles. Alternatively, activated carbon amendment has been shown to reduce the bioavailability of both mercury and dioxins, whereas sediment concentrations will not be reduced. Still, as the first full-scale remediation site in Norway, the use of activated carbon has been recommended as the primary remediation action, aiming at reducing the bioavailability of contaminants. Activated carbon amendment does not exclude later capping if reduction in bioavailability of contaminants is not as expected. The Norwegian authorities has not yet approved the remediation plan.