

The Grenland fjords, Norway – Management approach to decide upon remediation of a complex fjordsystem

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Introduction: Polluted sediments are frequently found in harbours and industrial sites, in Norway typically situated in fjords. The Grenland fjords, Telemark county, is one of 17 polluted coastal areas and harbours, prioritized by the authorities to develop a comprehensive remediation plan. The branched fjord system covers more than 30 square kilometres with depths ranging down to 100 m, facing high concentrations of dioxins and furans as well as other chlorinated organic compounds and heavy metals, mainly due to emissions from a magnesium production plant operating from 1951 to 2002. Conceptual site models developed for the fjords [1] [2] [3] predicts that without any remedial actions, 20-50 years is required before dioxin are below national benchmark values. Alternatives to natural recovery have been investigated for the last 6 years, with the size of the area and the depth of the fjords, being major challenges. The project BEST (2007-2011) has been organized by the regional authorities, with the objective to develop a basis for considering thin layer capping as a remediation strategy. Approaching the end of the project in medio 2011, the authorities are now facing new challenges in transforming scientific results into management decisions.

Methods: To be able to consider remediation a complex fjord system, the county governor recognized the need to investigate not solely the efficiency of thin layer capping, but also to build a comprehensive understanding of all aspects of remedial action. Four essential elements have been the basis for structuring subprojects, studies and tasks into four work packages (WP). The matrix of elements is in addition a visual tool, as optimizing the ratio of “green” and “red” elements will be criteria for recommending remedial action as an alternative to natural recovery.

Efficiency	Benefits
Impact	Costs

Fig. 1: Four essential elements for investigating aspects of remedial actions in the Grenland fjords, Norway.

The WP *efficiency* covers activities that enhance the understanding of how cap design controls contaminant retention, including identification and investigation of the factors influencing capping efficiency. *Impact* covers ecological consequences

of capping, in both local, regional and global perspectives. *Benefits* and *costs* are both extended to a socioeconomic perspective, and investigates the factors influencing these elements. To ensure a dynamic and adaptive project, scientists, authorities, stakeholders and NGOs have been discussing activities and results on a regular basis, leading to yearly revisions of the project. Sediment management measures have been preliminary defined, based on model predictions, and will be revised and adjusted to reality as knowledge enhance. A method for decision-making are being developed, including a multi-criteria analysis (MCA) for weighting and comparing pros and cons of remediation with the option of natural recovery, involving both authorities, scientists, stakeholders and NGOs.

Results: Substantial amounts of scientific results are produced within the project BEST and associated projects. In addition a strategy is described for structuring the factual basis needed when considering remediation of a complex fjord system. The project suggests a management approach based on scientific results for defining and deciding upon sediment management measures, as well as a method for how to reach a decision on remediation.

Discussion: Involving stakeholders, NGOs, scientists and authorities in the discussions on a regular basis in all phases of the project, has led to a common understanding of the complexity and an informal consensus of the strategy for the decision-making process. The process takes time, which might be a critical factor in some projects. Recognizing the dimensions of the project might lead to a conclusion that the approach is not relevant for smaller “hot spots”. However, many hot spots are found within a fjord system where management measures are on an ecosystem scale and not realistic to meet with limited remedial actions.

References: [1] Persson et al. (2006) *Sci Total Environ* **369**:188-202; [2] Saloranta et al. (2006) *Environ Toxicol Chem* **25**:253-264; [3] Saloranta et al. (2008) *Environ Sci Technol* **42**:200-206