Sweden's industrial legacy of contaminated, fibrous sediments: Properties relevant to management

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Introduction: In 2010 the Geological Survey of Sweden (SGU), by the request of the Regional Country Administrative Board of Västernorrland, began to survey selected areas of the seafloor that were suspected to be polluted by old discharges of waste from pulp and paper factories. The surveys show that deposits of organic (cellulose) rich sediments ("fiberbanks") which are contaminated by metals and persistent organic pollutants (POPs), exist at 45 sites (covering 2.6 km^2) and that a much larger area of the Swedish seafloor (~27 km^2) is affected by similarly contaminated fiber-rich sediment [1,2,3]. Two research projects are coordinated by Uppsala University; TREASURE aims to develop fiberbank characterization tools, while FIBREM aims to develop field-based instruments for estimation of fiberbank size and test in-situ remediation methods.

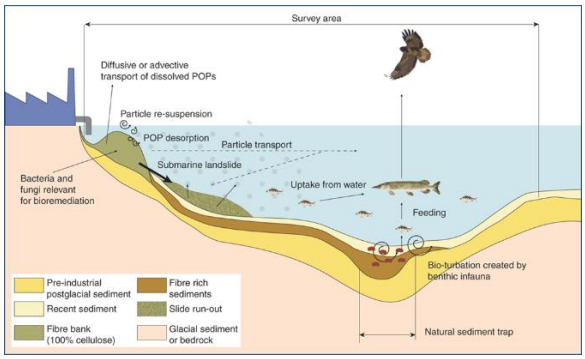

Fig 1: An overview of the processes that can lead to dispersal of contaminants from fiberbanks (SGU).

Methods: Physical properties of two fiberbanks were studied in-situ using hydroacoustic methods, free-fall penetrometers and Kullenberg piston cores. The fluxes of metals were measured in-situ using benthic landers (e.g. [4]) and through the collection of sediments and bottom water samples taken before and after induced sediment resuspension (the latter to mimic submarine landslide conditions). Laboratory studies of PCBs, DDT and HCB were conducted to assess the relationships between sorption (K_D and K_{TOC}), sediment type and compound hydrophobicity. The concentrations of POPs in the polychaete *Maranzelleria* spp. and the predatory crustacean *Saduria entomon* were also established for fiber-rich sediments. Isolating caps of crushed stone (up to 30 cm thick), proven to reduce contaminant transport from minerogenic sediment, were tested in columns (2 m tall) of reconstructed fiberbank sediment at 4°C.

Results: The fiberbanks studied are hypoxic-anoxic and produce gas (CH_4, CO_2, H_2S). They are also of very low density and strength. Metals appear to be bound to the organics, but still exist in concentrations that exceed national environmental quality standards and, when detected, are transported into the water column at rates that cannot be explained by diffusion only. POPs are bioaccumulating and biomagnifying. The high-rates of gas formation and ebullition cause pock-marks to appear on the surfaces of capped fiberbank sediment and are a likely conduit for gas facilitated contaminant transport.

Discussion: We conclude that risk classification and prioritization for remediation cannot be made solely on knowledge of contaminant concentrations in sediment. Fiberbanks are unique and comparisons between sites are difficult because sediments and contaminants differ and they can be dispersed by different mechanisms. More knowledge is needed to make science-based management decisions.

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References: [1] Apler et al. (2014) *SGU-rapport 2014:16*; [2] Norrlin et al. (2016) *SGU-rapport 2016:21*; [3] Larsson et al. (2017) *SGU Dnr: 316-907/2017*; [4] Tenberg et al. (2003) J. Exp. Mar. Biol. Ecol. **285-286**:119-142.