Laboratory study of in-situ capping polluted fibrous sediments

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Introduction: Sweden is the third largest exporter of pulp, paper and sawn timber in the world. However, this industry has had detrimental environmental consequences. In particular, pulp and paper industries used to discharge large amounts of wood chips, bark, grit, sludge, etc. directly in aquatic environments until a national regulation in 1969. This polluted legacy is still lying on the seafloor and lake bottoms, mixing with natural sediment and potentially contaminating the food web. Today, the Swedish authorities want to find solutions to remediate these waste deposits to achieve the European Commission sustainable development goals. Taking into account the large volumes of wastes, in-situ capping – rather than removal – might be the best option, but first needs to be tested at the laboratory-scale. In-situ capping consists in applying one or several layers of clean material on top of contaminated sediments in order to prevent contaminants entering the biosphere.

Methods: The fibrous sediments were sampled in the Ångermanälven estuary in the Baltic Sea with box samplers on board the survey vessel Ocean Surveyor (Geological Survey of Sweden). Two different types of fibrous sediments were sampled; one very fine-grained and the other consisting of coarser wood particles.
The laboratory experiments were run at 4˚C to limit gas production. The sediments were redeposited in 6 transparent columns (3 columns per sediment type) with artificial seawater on top. Once stable, the sediments were capped with several layers of clean crushed stone. Total cap thicknesses were 5, 15 and 30 cm in 3 different columns. The gas production, the consolidation and other visual aspects were monitored for more than 150 days.

Results: Both fibrous sediments were able to physically support the caps. They consolidated with a relatively constant rate independent of the cap load. The coarser sediment consolidated slower than the finer-grained sediment.
Between 8 and 12 cm of water was transported from the sediment, up through caps, and into the water columns.
Pockmarks appeared at cap surfaces for both sediment types, first on the thinner cap thicknesses and later on the thicker ones. They enlarged with time.
Surfaces of the 5 and 15 cm caps over the finer-grained sediment became black-colored. These black layers appeared to thicken with time.

Discussion: The results show the importance of gas production and movement. Gas ebullition induced pockmarks at the surface of the caps and further ebullition probably caused the enlargement of the conduits over time, forming facilitated pathways.
The black layers may originate from sediment particles that have been transported by gas ebullition, through the conduits.
The transport of water from the sediment pore water to the surface shows that gas is formed in the sediment, pushing and replacing water. The sediment is slowly dewatering.

This study shows that gas production and release is extremely high in these sediments and that it influences the cap. Additional experiments are necessary to determine the impact on the transport of contaminants. Indeed, gas ebullition might facilitate the transport of some organic hydrophobic pollutants. Indirectly, it might also enhance the transport of pollutants by the migration of pore water to the water column through the conduits.