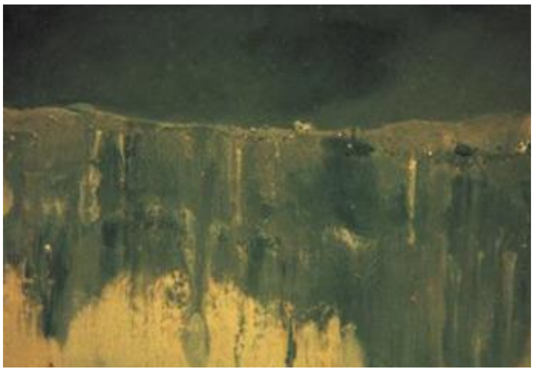
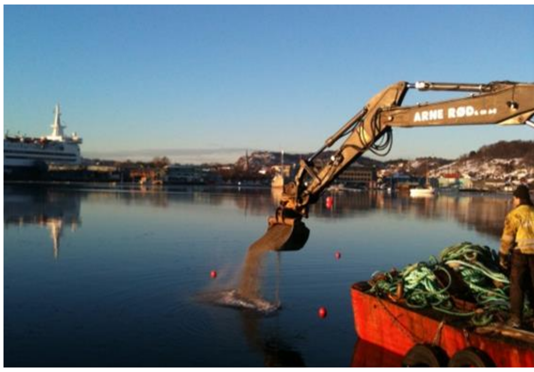
In-situ capping of contaminated sediments

In-situ capping of Sweden's fiberbank sediments: A unique challenge

Joseph Jersak, Gunnel Göransson, Yvonne Ohlsson, Lennart Larsson, Peter Flyhammar, Per Lindh





SGI Publication 30-5E **Linköping 2016**

SGI Publication 30-5E

Cite as:

Jersak, J, Göransson, G, Ohlsson, Y, Larsson, L, Flyhammar, P & Lindh, P 2016. *In-situ capping of contaminated sediments .In-situ capping of Sweden´s fiberbank sediments: A unique challenge*. SGI Publication 30-5E, Swedish Geotechnical Institute, SGI, Linköping.

Diary number: 1.1-1506-0400

Project number: 15573

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Download this publication as a PDF-document at www.swedgeo.se

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Swedish Geotechnical Institute

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In-*situ* capping of Sweden's fiberbank sediments: A unique challenge

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SGI Publication 30-5E Linköping 2016

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SGI Publication 30-2E. *In-situ* capping of contaminated sediments. Contaminated sediments in Sweden: A preliminary review.

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SGI Publication 30-7. *In-situ* övertäckning av förorenade sediment. Övergripande sammanfattning. (In Swedish)

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1. Introduction

Over many decades, Swedish pulp and paper mills discharged large volumes of processing wastewater into nearby lakes, rivers, and coastal areas. The discharges typically contained suspended fibrous material. This material, in turn, often inherently contained high concentrations of organic and/or metal contaminants, including DDTs, PCBs, PAHs, dioxins, and Hg (Hylander and Goodsite, 2006; Drott et al., 2008; Regnell et al., 2014; SGU, 2014; Skyllberg et al., 2006, 2007; Vogel, 2015; Östman and Erlander, 2008; Snowball, 2015).

The contaminated fibrous material eventually settled to the bottom in relatively localized areas. Over time, it gradually built up and created what are known as “fiberbank deposits” (Figure 1). Often adjacent to these more-or-less pure deposits of cellulose-based material are “fiber-rich sediments”. Fiber-rich sediments are composed of variable mixtures of fiberbank deposit material plus mineral-based (minerogenic) sediment material (Figure 1) (SGU, 2014; Snowball, 2016).

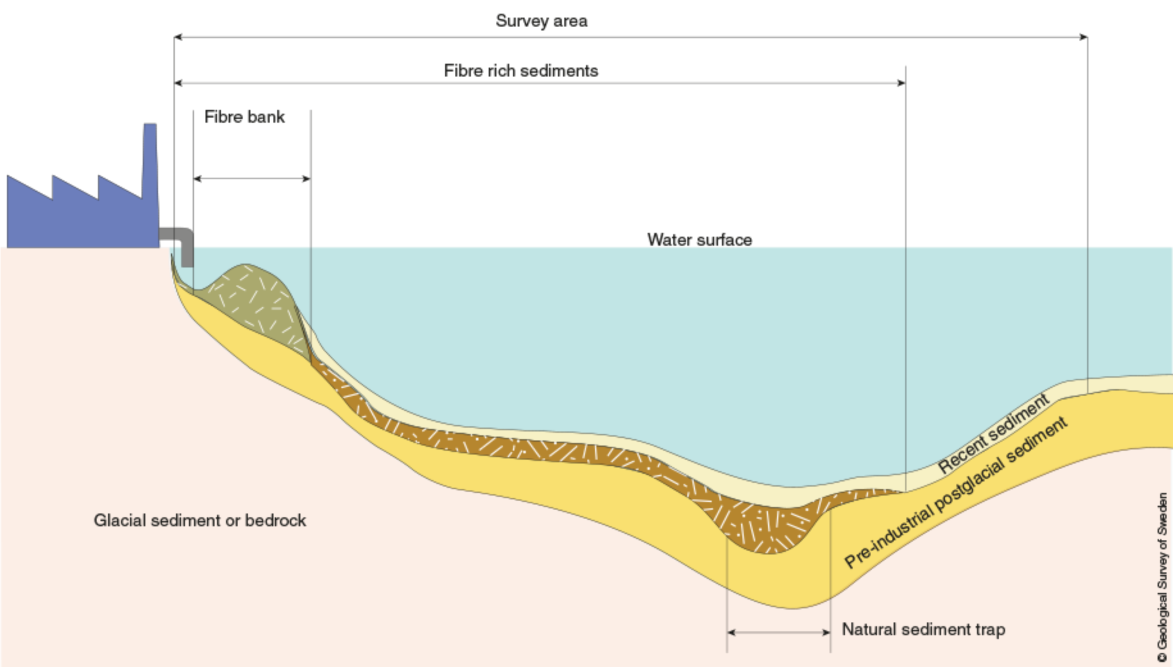

Figure 1 Conceptual illustration of a “typical” fiberbank sediment site (source SGU, 2014).

Fiberbank deposit material is often fine-grained, but can also contain coarser wood fibers and bark residuals. It is also typically very water-rich, with very low physical strength (bearing capacity) and density (Figure 2). The deposit material also typically displays high gas production and content due to extensive microbial activity. In many areas, the deposits can be up to several meters thick. (Snowball, 2016; Östman and Elander, 2008; SGU, 2014).

Figure 2 A grab sample of fiberbank sediment from the Ångermanälven estuary (source SGU).

Because of their mixed composition, fiber-rich sediments likely display characteristics in between those of pure fiberbank deposit material and "pure" minerogenic sediment. Characteristics of fiber-rich sediments also likely differ between (and within) sites due to spatial variability in deposition of new sediment, the extent of vertical mixing by benthic activity, re-distribution by waves and currents, etc. (Figure 1).

Despite their differences, fiberbank deposits and fiber-rich sediments are typically (but not always) collectively referred to herein as "fiberbank sediments".

Swedish fiberbank sediments occur mainly (but not only) in Norrland, where forest-industry activities have historically been most concentrated. Fiberbank sediments occur in at least 10 counties, and may also occur in other counties as well, where papermill operations have occurred (SGI Publication 30-2E).

2. Isolation capping of fiberbank sediments

The sediment remediation strategy of isolation capping, including conventional and active types, is described in detail in the main capping overview document to which this publication is attached.

Virtually every isolation capping project conducted to-date, worldwide, has involved contaminated minerogenic sediments (SGI Publication 30-4E). To our knowledge, only two isolation capping projects have involved fiberbank deposits and/or fiber-rich sediments, both of which were conducted in Sweden (SGI Publication 30-4E). The worldwide lack of capping projects involving fiberbank sediments is surprising since these types of sediments occur not only in Sweden, but also in other countries, including Finland (Pöykiö et al., 2008; Verta et al., 2009; Ratia, 2013; Meriläinen, 2007), Canada (Foster, 2012; Environment Canada, 2014; Fathi et al., 2013), and the U.S. (Integral, 2009; Exponent, 1999).

Given the above, all aspects of isolation sediment capping established and refined over the last few decades (conventional and active materials used, cap designs developed, approach to construction, etc.) have necessarily been directed at capping contaminated minerogenic sediments. Regardless, there are no reasons to believe – at this stage – the knowledge and experience gained from isolation capping of minerogenic sediments should not **also** apply to isolation capping of fiberbank sediments.

Furthermore, the same successes achieved in capping contaminated minerogenic sediments should also be expected when capping fiberbank sediments, for at least the following reasons:

- Successful conventional or active isolation capping has been achieved on many projects when capping minerogenic sediments contaminated by the same organic and metallic pollutants typically contaminating fiberbank sediments (SGI Publication 30-4E).
- Although minimal bearing-capacity data are available for fiberbank deposit material, available data indicate undrained shear-strength values as low as 2 kPa or lower (Östman and Elander, 2008). Shear-strength values for “soft” minerogenic sediments are similarly low. And there is abundant project experience showing such soft minerogenic sediments can be successfully capped. Capping such soft sediments can often (but not always) be accomplished without incorporating a basal geotextile component for added physical support, assuming the proper approach for cap construction is followed (see main capping overview document).

Yet, again, the simple fact remains there is extremely little international experience to-date in capping fiberbank sediments. Because of this – coupled with the unique characteristics of these highly atypical, anthropogenic sediments – there are many questions related to the efficacy of isolation capping of fiberbank sediments. Questions include, but are far from limited to, the following:

- Is isolation capping of the fiberbank deposits most challenging? That is, do fiber-rich sediments typically respond to capping-based remedies much like contaminated minerogenic sediments?
- When capping contaminated minerogenic sediments, gas ebullition – including the potentially negative effects ebullition may have on long-term cap integrity and functioning – is expected to substantially decrease after a couple years or so after cap placement. This is because the cap cuts off further inputs of labile organic matter to gas-producing microbial populations (see SGI Publication 30-1E). This may, however, not be the case when capping

fiber-rich sediments, and especially not when capping fiberbank deposits. If substantial ebullition continues over a much longer time period when capping one or both of these sediment types, what impact could this have on long-term cap integrity and overall cap effectiveness?

- Many researchers, worldwide, would likely agree Hg biogeochemistry in contaminated minerogenic sediments is challenging enough to understand and accurately predict under different conditions. Thus, understanding and predicting the same in fiberbank sediments could be substantially more challenging.
- Will isolation-cap designs incorporating active materials – for example, highly sorbent activated carbon (AC) – be even more appropriate, and necessary, when capping fiberbank sediments than when capping contaminated minerogenic sediments?
- As noted above, both fiberbank deposit material and many minerogenic sediments are soft, with low bearing capacities. But is fiberbank deposit material (and perhaps even some fiber-rich sediments) actually softer and weaker than the softest/weakest minerogenic sediments? This is currently unknown. And any general answer to this question is further complicated by the recognition obtaining accurate, *in-situ* measurements of undrained shear-strength of soft sediments is often a challenge.
- How might the uniquely fibrous nature of fiberbank sediments affect the rate and extent of their consolidation, de-watering, and bearing capacity when loaded with a cap?
- What about capping on submerged slopes, including even relatively gentle slopes? And what if slopes are inherently geotechnically unstable, even before being loaded with a cap? Investigations of submerged fiberbank deposits in Norrland indicate evidence of past sliding and slumping failures at some sites (SGU, 2014). Such observations indicate at least some fiberbank deposits are indeed inherently unstable (Wiklund, 2015).
- Many coastal fiberbank sediment sites in Sweden occur at or near present-day shoreline positions (e.g. Figure 1). How might net land uplift due to post-glacial rebound, especially in Norrland (SGU, 2014; Östman and Elander, 2008; SMHI and Naturvårdsverket, 2013/2014), affect or influence the following:
    - Erosional forces acting on a cap, including how best to design for such forces?
    - Long-term stability of inherently unstable fiberbank deposits, especially after capping?
    - Saturation and oxidation-reduction potential within the capped sediment?
    - Groundwater-surface water interactions and related dynamics?
    - Biogeochemical processes for Hg, including methylation?
- Construction of isolation caps should be accomplished using the cap-lift strategy, especially when capping soft sediments, and particularly when no basal geotextiles are included in cap design (see SGI Publication 30-1E). This method for cap construction was developed and refined through capping minerogenic sediments. Can the same cap-lift strategy also be used when capping fiberbank sediments, or does it need to be significantly modified in one or more ways?
- Abundant sunken timber occurs at some fiberbank sediment sites (e.g. Östman and Elander, 2008; Eriksson, 2014; Integral, 1999; Exponent, 2009). How might its presence influence adequately designing for as well as constructing isolation-capping remedies?

3. Thin-layer capping of fiberbank sediments

The sediment remediation strategy of thin-layer capping, including conventional and active types, is described in detail in the SGI Publication 30-1E.

Most of the above questions related to the efficacy of isolation capping of fiberbank sediments also apply to the efficacy of thin-layer capping of the same sediments. Furthermore, concerns related to geotechnical stability, ebullition, and groundwater influences as a function of whether an isolation or thin-layer capping strategy is used (see main capping overview document) should also generally apply to fiberbank sediments as well.

Regardless, there are **additional** questions that could apply specifically to thin-layer capping of fiberbank sediments, including but not limited to:

- Could the possibly much lower bearing capacity of fiberbank sediments (compared to minerogenic sediments) result in unacceptable slope stability, such that even gentle slopes (successfully capped if minerogenic sediment) cannot adequately support even thin-layer caps, regardless of how carefully the cap is constructed?
- When thin-layer capping, could the amount of gas generated in the underlying fiberbank sediment simply be too high and related cap rupturing too extensive and widespread, such that even a marginally adequate level of exposure and bioavailability reduction cannot be achieved with a thin-layer cap?
- Could the degree of Hg methylation in capped fiberbank sediment be so extensive (quantitatively, spatially, and temporally) such that even an active thin-layer cap containing large amounts of highly sorbent AC cannot provide adequate long-term reductions in contaminant exposure and bioaccumulation?

4. Summary

Currently, there are no good answers to many if not most of the above questions related to the efficacy of capping of fiberbank deposits and/or fiber-rich sediments – regardless of the capping approach used (isolation, thin-layer, conventional, active). Extensive laboratory and field (pilot-scale) research is needed to adequately answer these questions before full-scale remedial use of capping-based remedies to manage risks related to fiberbank sediments can be confidently recommended.

Further regarding risks: Sediment remediation efforts (including application of capping-based remedies) will need to be informed by and consistent with the new methodology for risk classification of fiber-rich sediments, as developed by Västernorrland's County Board. For reference, please see: Länsstyrelsen www.lansstyrelsen.se/Vasternorrland/Sv/publikationer/2016/Pages/metodik-for-riskklassning-av-fiberhaltiga-sediment.aspx.

And finally, it is clearly recognized this document offers only an initial, "point in time" general overview of **anticipated** challenges related to capping fiberbank sediments. As work progresses on this subject, many of the **actual** challenges will no-doubt be identified, clarified and addressed, but more new ones will undoubtedly arise that will also need to be addressed in turn.

5. References

For all references cited herein, please see SGI Publication 30-6E.

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