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

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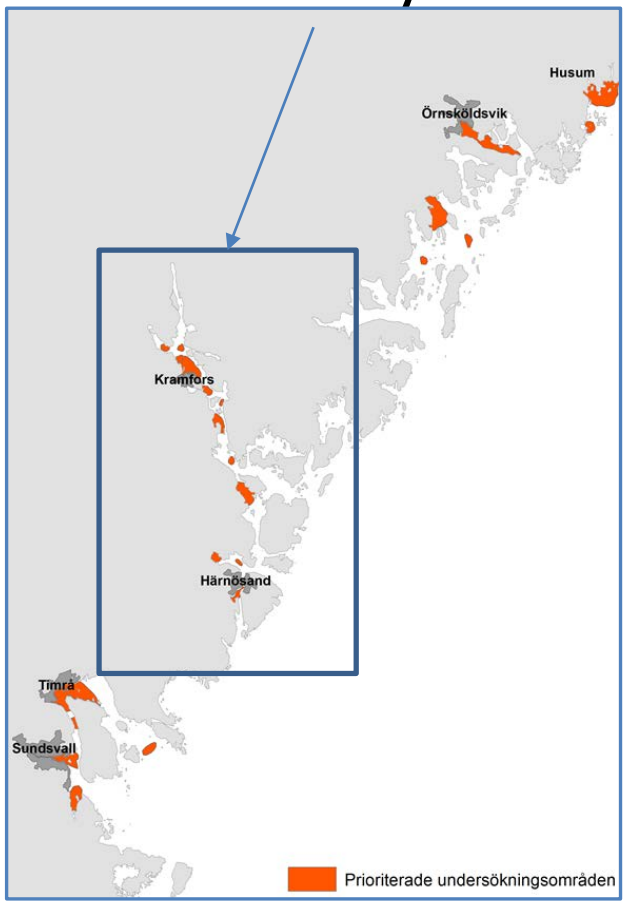
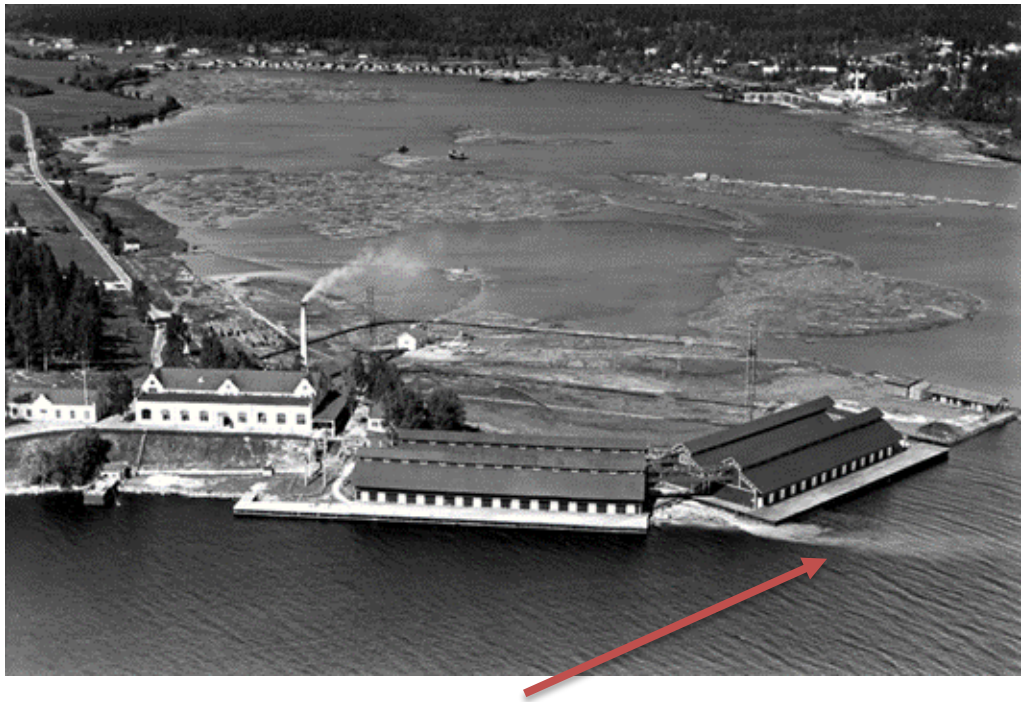
An August morning, near Kramfors in Ångermanälven (Photo taken by I. Snowball, 2015)

Sweden's paper and pulp industry in the past

Ångermanälven estuary





A plume of suspended, contaminant-laden woody materials.

100 years use of metals in processing.

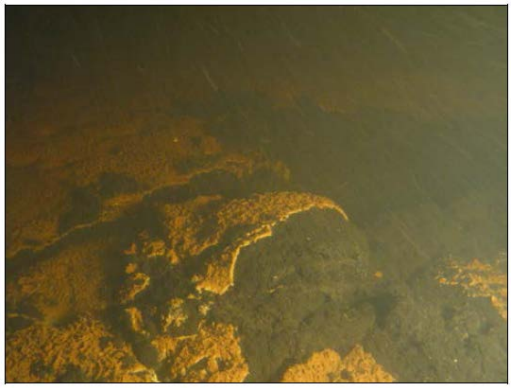
Persistent organic pollutants (e.g. PCBs, DDT) used 1930 to 1970's.

Fiberbanks and Fiber-rich sediment

SGU surveyed ~212 km^2 of seafloor along the coast of Norrland (*Apler et al. 2014, Norrlin et al. 2016, Larsson et al. 2017*)

A total area 2.6 km^2 is covered with about 45 banks of pure wood ”chips” and cellulose fibers, and some timber.

Designated as **FIBERBANKS**



High BOD
Anoxic
Sulphide oxidation by *Beggiatoa sp.*
Metals and POPs

Larger areas of the seafloor (~27 km^2) also contaminated by this waste is designated as **FIBER-RICH sediment**.

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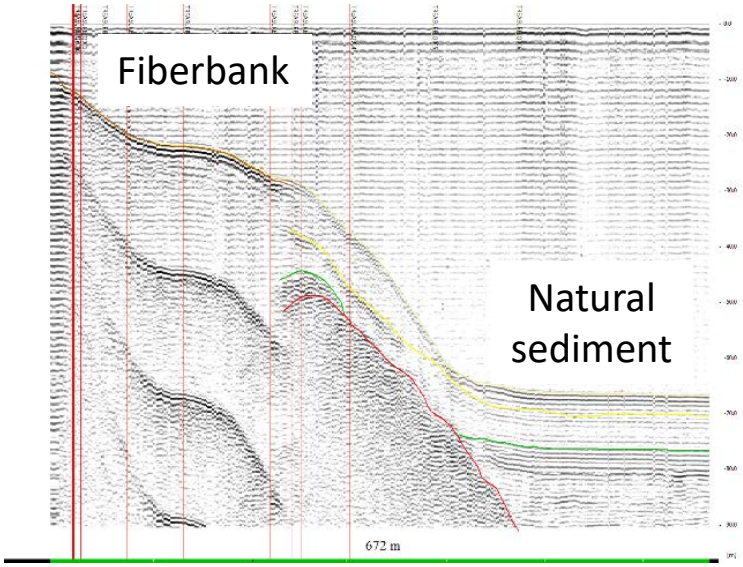
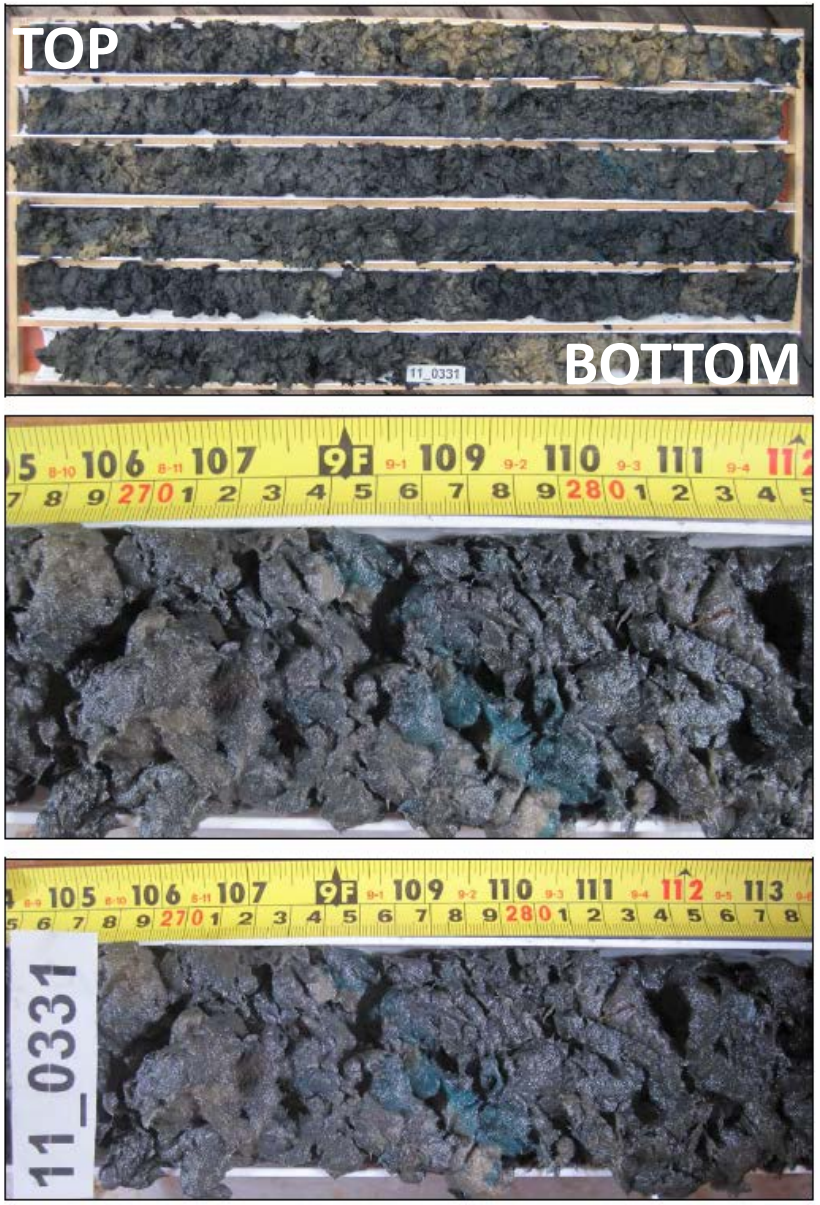
A core of typical fiberbank

One cannot “see” how thick these deposits are with normal geophysical methods (e.g. seismics) due to characteristic gas.





FIB10
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SGU
Maringeologi

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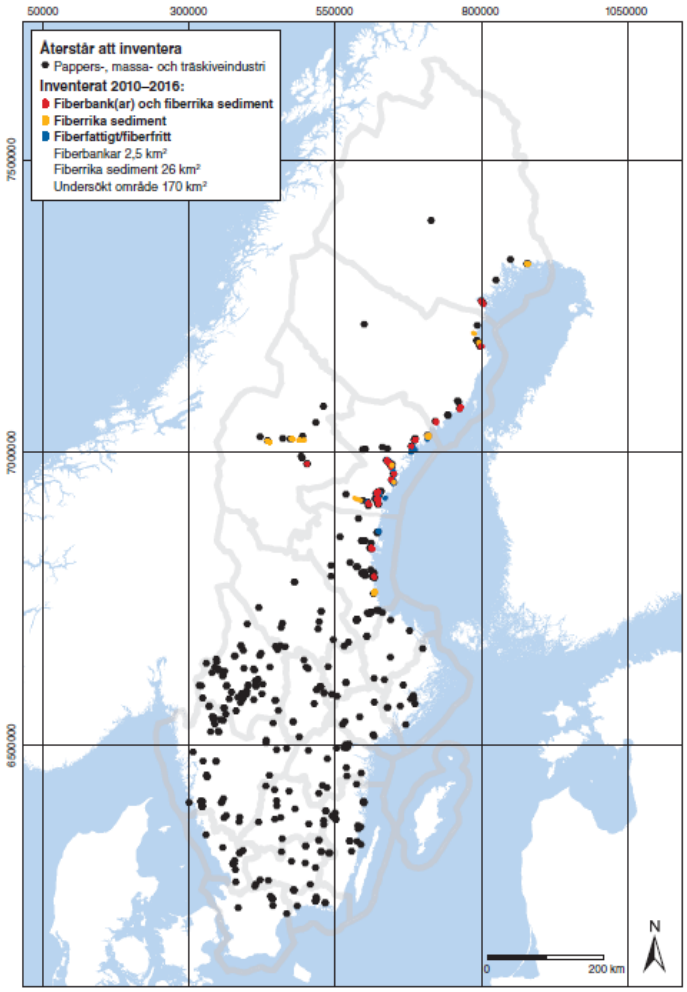
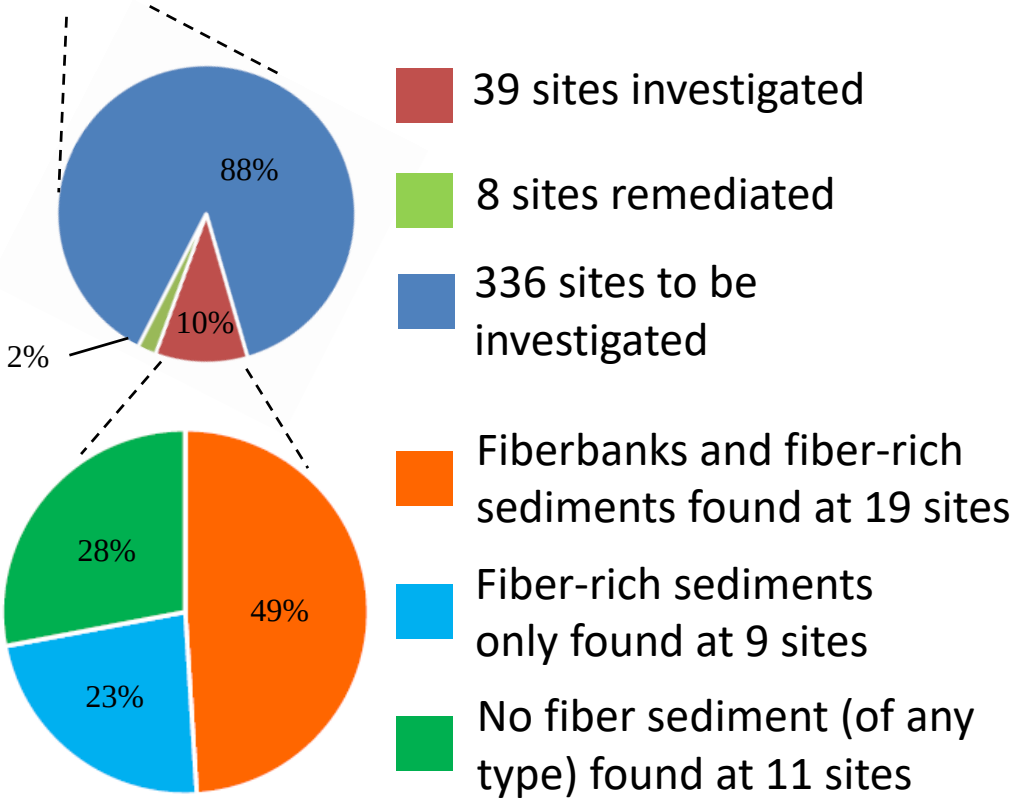
Occurence of fibrous sediments in Sweden



Source: SGU

383 known areas with potential fiber waste-generating activities



Norrlin & Josefsson, 2017

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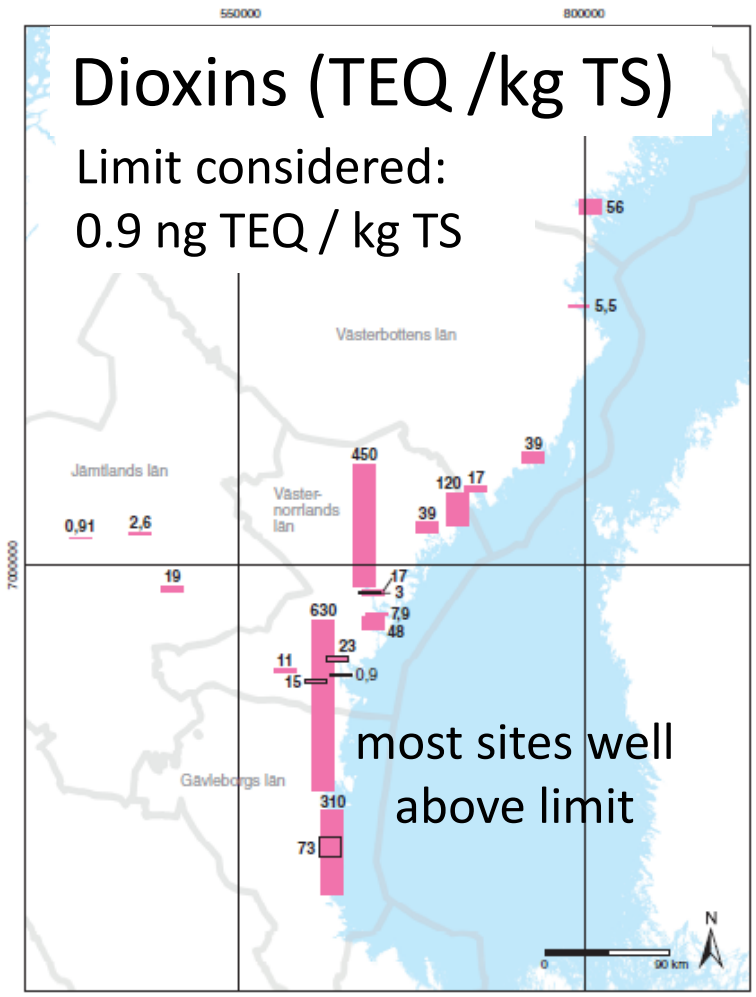
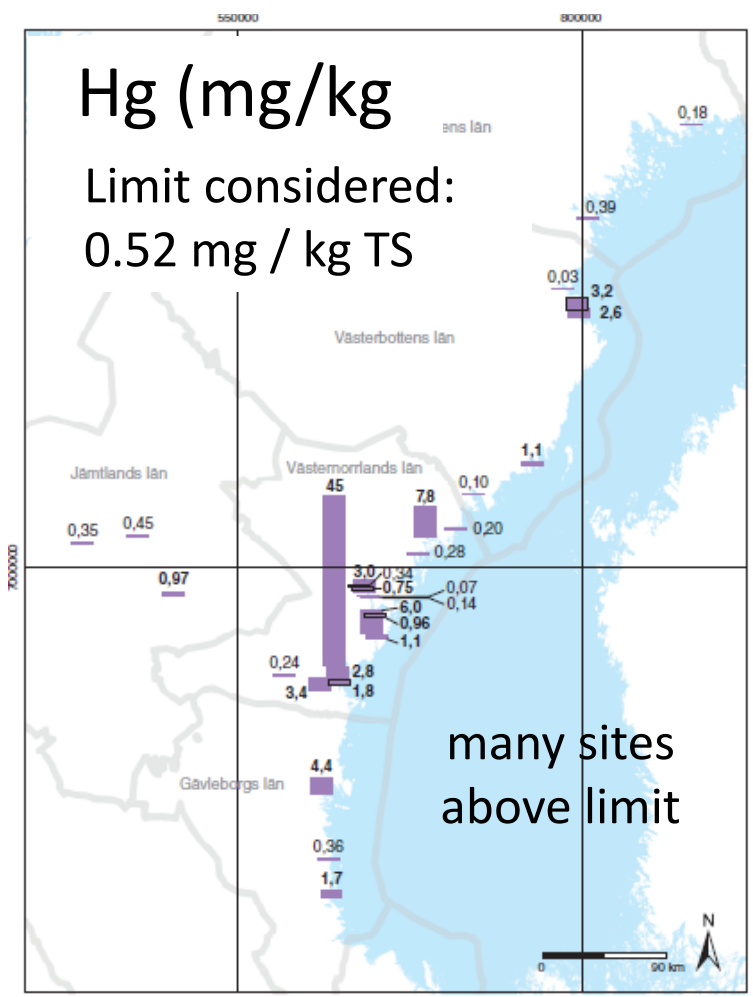
Fiberbanks are contaminated
by POPs, metals, and/or organometals

E.g.

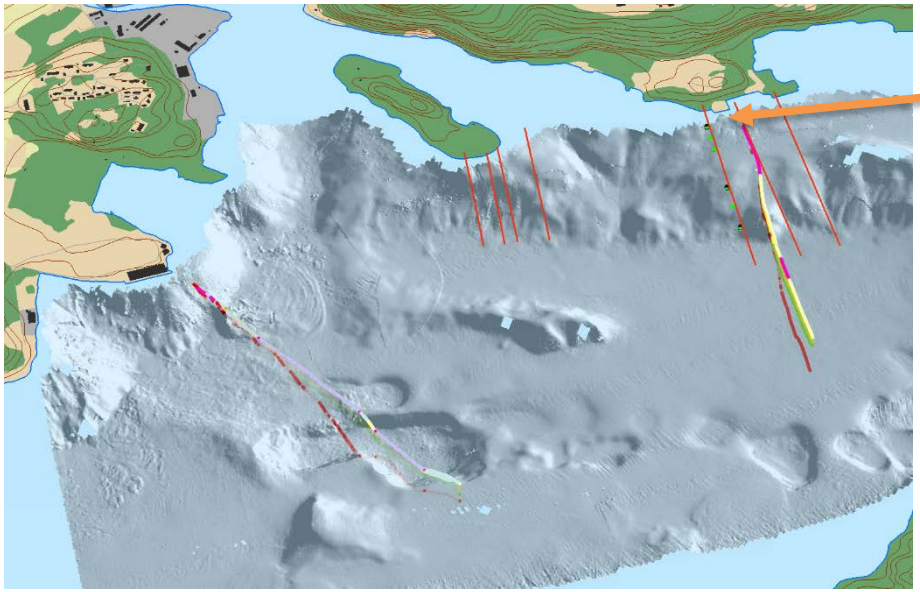


Source: SGU, 2017



Source: SGU, 2017

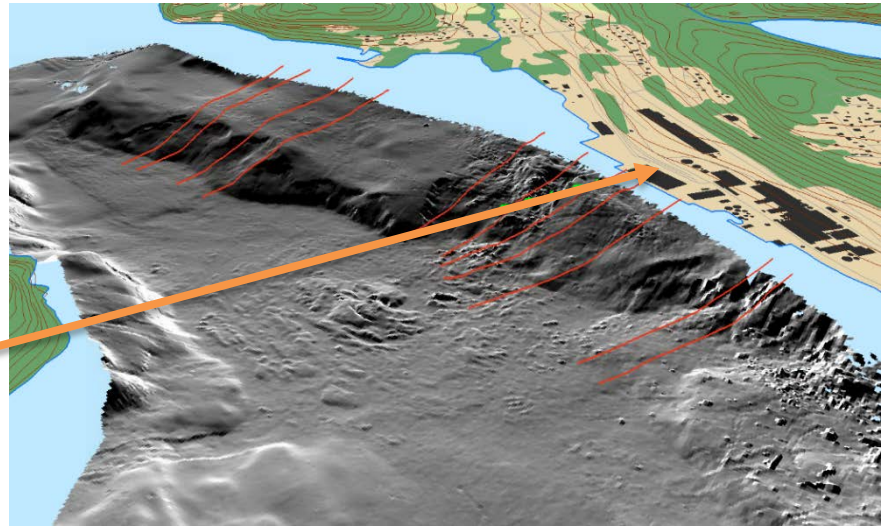
Two pilot study sites in Ångermanälven estuary



Sandviken
1928

‘3D’ Images by Jim Hedfors (SGI), using SGU data.

Väja
2015



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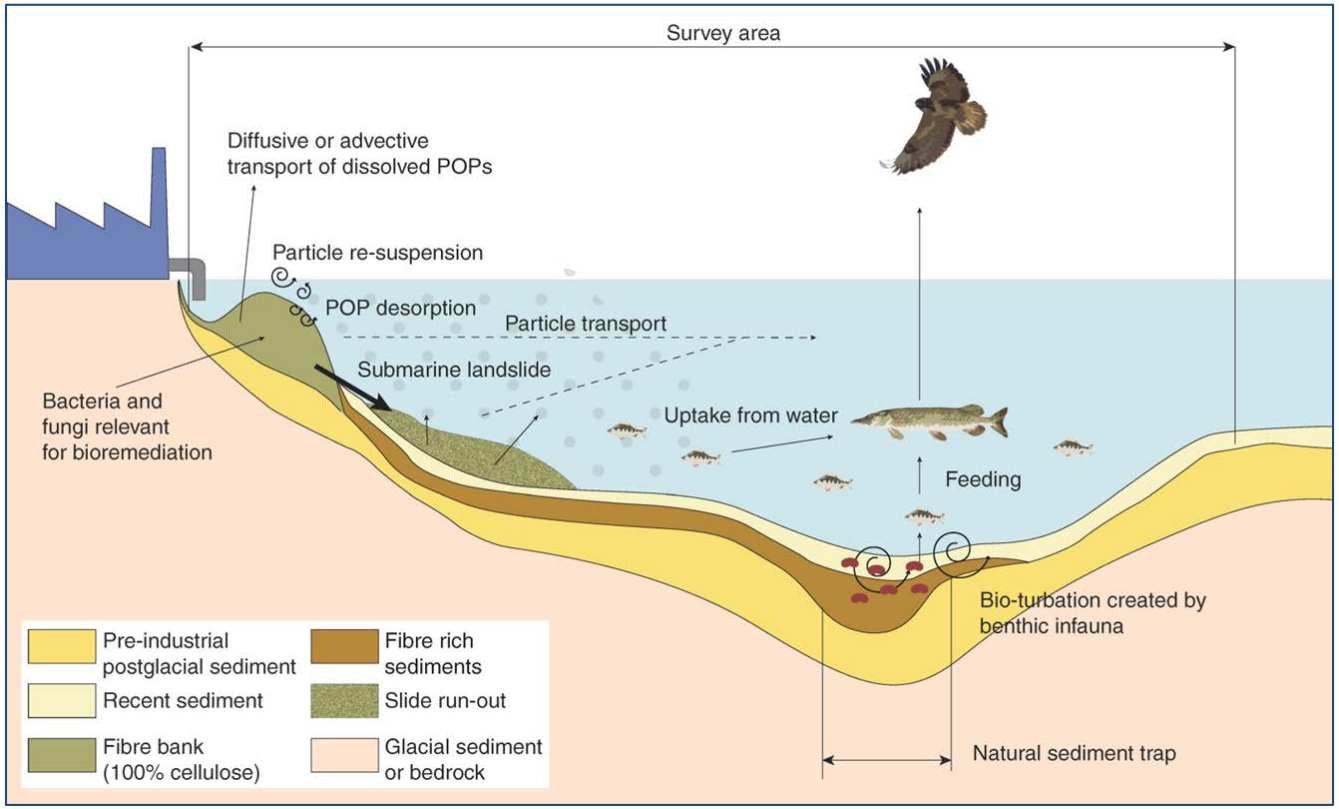
TREASURE (2015-2018)

Targeting Emerging Contaminated Sediments Along The Uplifting Northern Baltic Coast of Sweden For Remediation

Financed by the Swedish Research Council **FORMAS**, as part of the SGI TUFFO* initiative to expedite the remediation of contaminated areas.



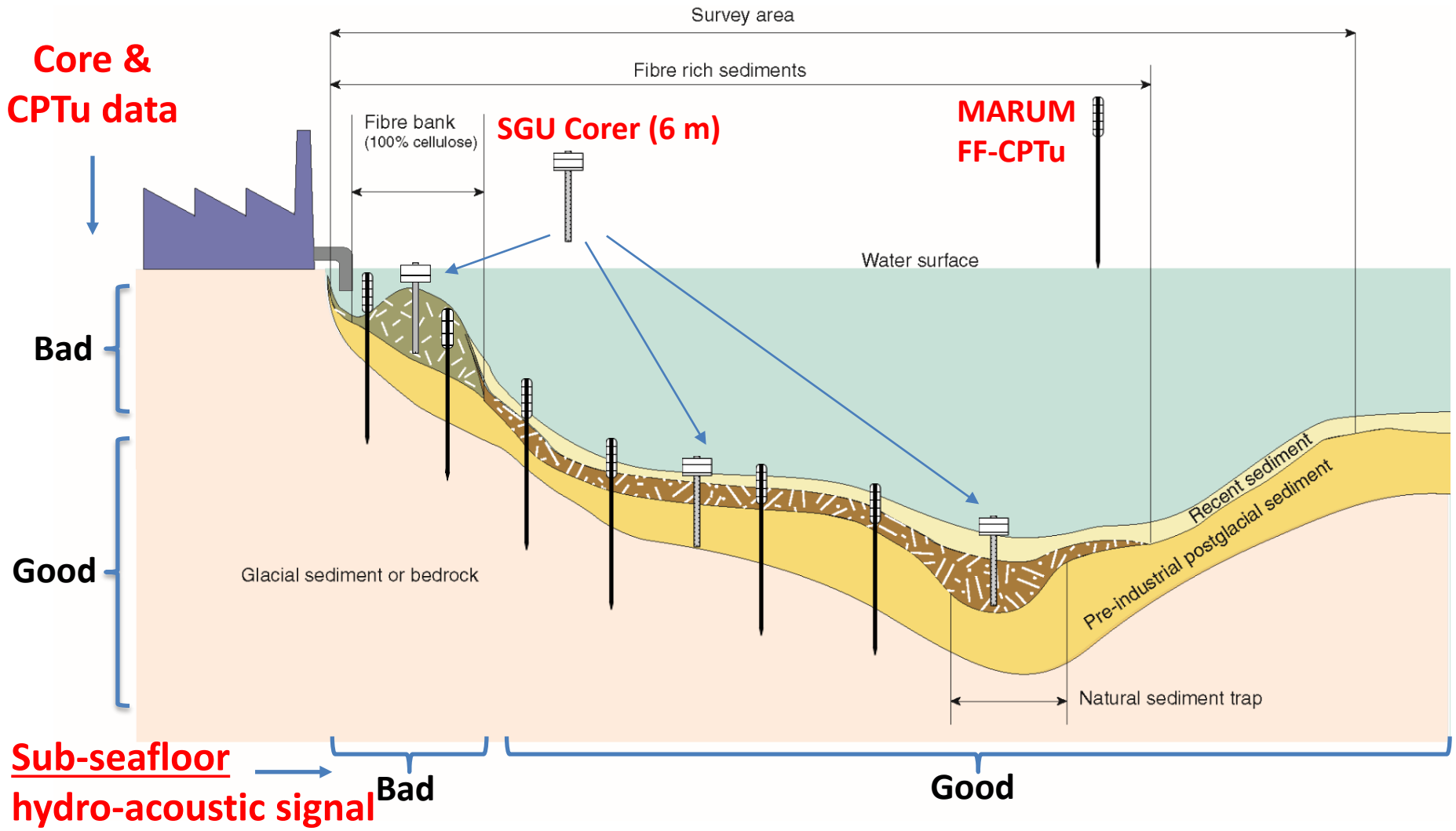
6 components

1. Coordination
2. Fieldwork
3. Geotechnical
4. Chemical/biological
5. Risk assessment
6. Recommendations for management.

*Teknikutveckling & Forskning inom Förorenade Områden

Hydro-acoustic, FF-CPTu and coring methods

Practical limitations due to low density and thick fiberbanks studied

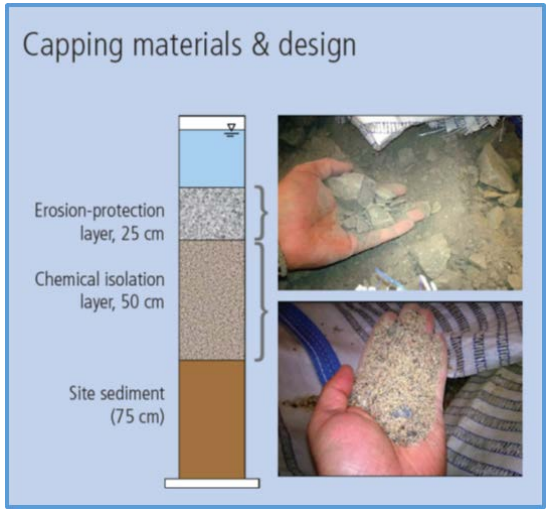


FIBREM (2017-2019)

Remediation of Sweden's fiberbank sediments: planning ahead

FIBREM is a VINNOVA funded innovation project that focuses on fiberbanks and fiber-rich sediments. It has two goals:

1. To develop cost-effective and applicable methods for characterizing fiberbanks in-situ.
2. Test the effectiveness of selected in-situ methods and techniques that were proved on minerogenic sediments, but not on fiberbanks or fiber-rich sediments.



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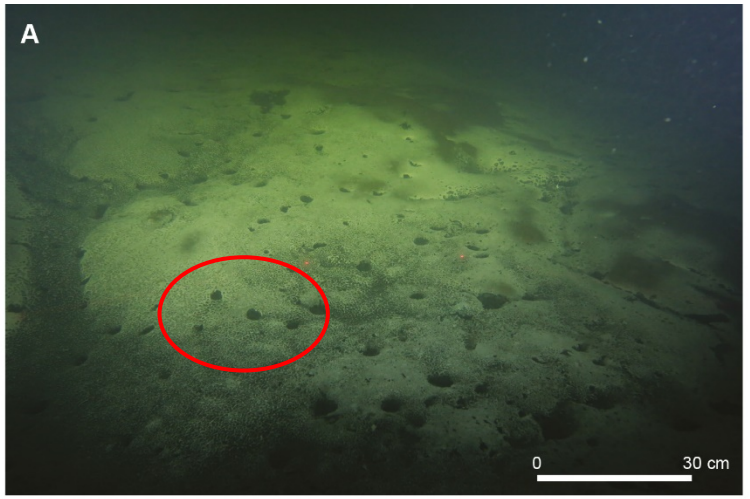
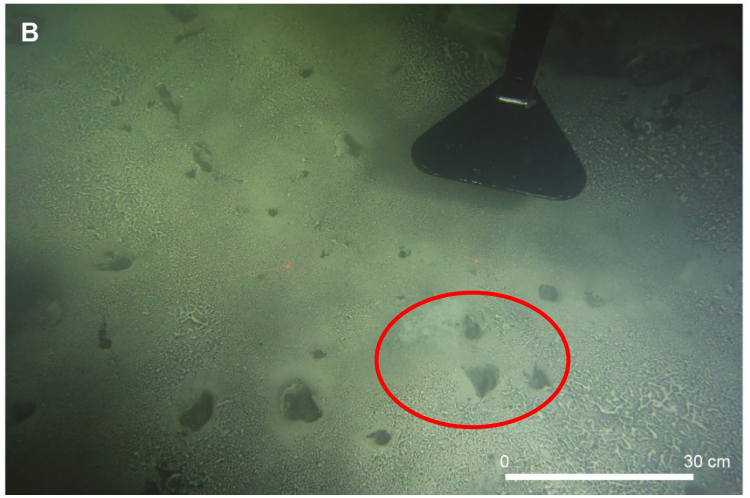
Two key features of many fiberbanks

2. pockmarks

Väja

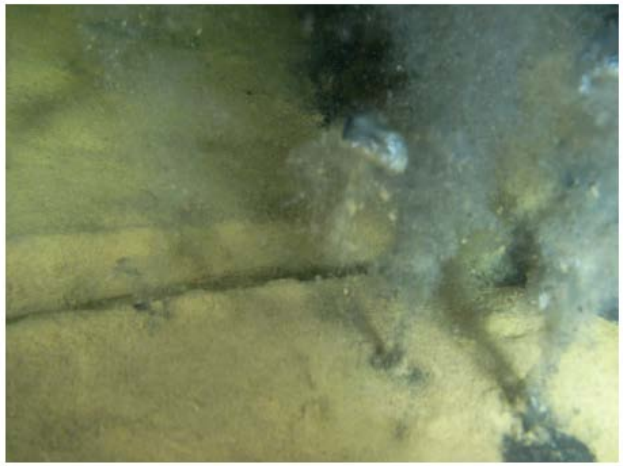




Source: SGU

1. gas

Sandviken



Pockmarks formed by gas release.

Facilitate continued gas release and perhaps porewater release.

Fiberbanks are a geotechnical challenge

Physical properties contrast with mineral-rich sediments that most geotechnical methods were designed for. Abnormal grain shapes, elastic and heterogenous.

Väja

Low dry density (500 kg m^3)
High porosity (80%)
Low shear strength (0.7-4 kPa)
Shear strength increases only marginally with reduced water content.

SGI “tipster”

Thicknesses and volumes have not been systematically estimated for all sites

But, our 2 study sites have large volumes and are thick

Q (Sandviken): **250 000 m³** fiberbank (**max 8 m thick**)
area 48 000 m²

R (Väja): **200 000 m³** fiberbank (**max 12 m thick**)
area 94 000 m²

TREASURE taught us that better methods are that needed for estimating areas and volumes. There are many sites.

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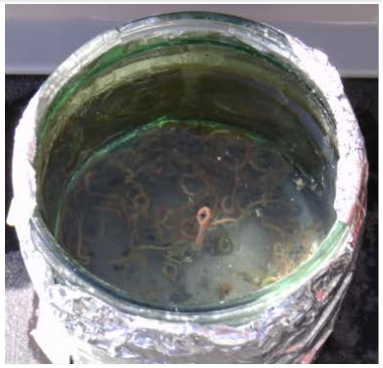
Fiber-rich sediments, biota and bioaccumulation of POPs



Benthic biota not found at fiberbanks, only bacteria.

The invasive polychaete *Marenzelleria* spp. is common in fiber-rich sediments.

The predatory crustacean *Saduria entomon* is also present.

Bioaccumulation of POPs, and evidence of biomagnification

Unpublished data removed

Benthic lander (BFC)

Benthic lander
Gothenburg University & SG)

Measured flux of metals higher than diffusion models predict from concentrations alone

Unpublished data removed

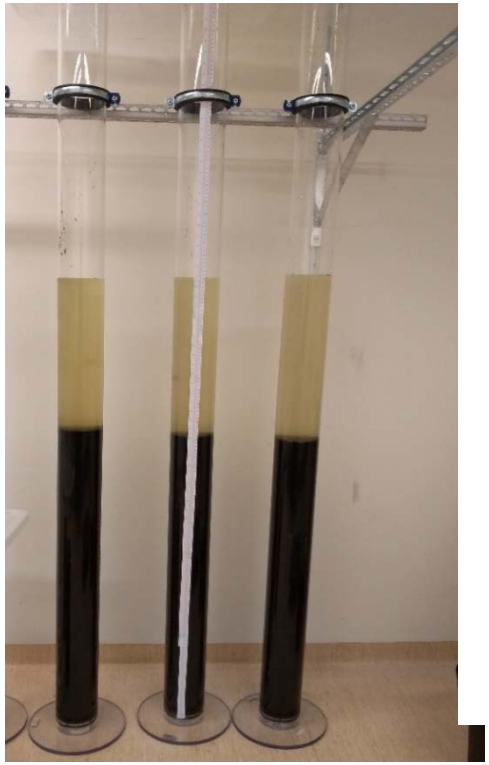
For some metals that exist in high concentrations (e.g. Pb), no fluxes were detected.

Risk assessment should not be based solely on total sediment concentrations.

Ideally complemented by flux measurements.

FIBREM

initial testing at room temperature (~ 20°C)



seawater

Väja fiberbank material

160 hrs later…

Väja fiberbank material

seawater

sediment gas build-up + de-watering + density decrease

→ ”floating sediments”

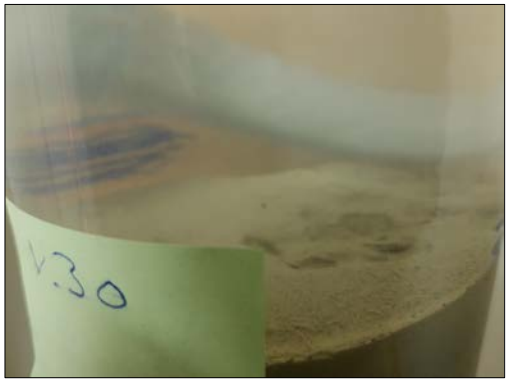
Väja - pockmarks at cap surfaces

15 cm cap

multiple pockmarks
across small areas

5 cm cap

30 cm cap



when first noted after capping

> 10 d
(after black layer)

36-39 d

31 d

Question: can gas formation facilitate contaminant transport (an advective process)?

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Crushed-stone cap surface of Väja fiberbank 15 cm cap

55 days

112 days

140 days

A black layer forms on top of Väja caps (up to 15 cm thick) but not on Sandviken caps, and thickens with time.

Answer. Yes, probably. The layer can consist of fibers that were transported through the cap during gas ebullition, and re-deposit on top of the cap.

TREASURE & FIBREM

What have we learnt so far?

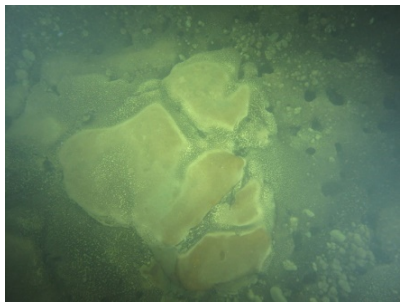
1. Low density, high organic and gas contents. Fiberbank sediments" are atypical and challenging to physically characterize.

2. Sites studied are biochemically very active: the microbial induced production of gas (~methane, carbon dioxide, hydrogen sulphide) is "enormous".

3. Fauna living in nearby fiber-rich sediments are bioaccumulating the persistant organic pollutants (POPs), including the "legacy" banned substances.

4. Metals are bound to the organics in the anoxic environment, but there is potential for release if oxidation and decomposition occurs (Apler et al. 2019).

5. Is in-situ treatment possible? The big question that remains to be answered.



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Questions?