Flotation chemicals and biological observations in sediment at the sea deposit site in Frænfjorden

Hilde C. Trannum & Carlos Escudero

Senior Research Scientists, NIVA

Outline

- Introduction
- Chemical characteristics
- Biological characteristics
  - Epifauna/infauna
  - Structure/function
- Research highlights

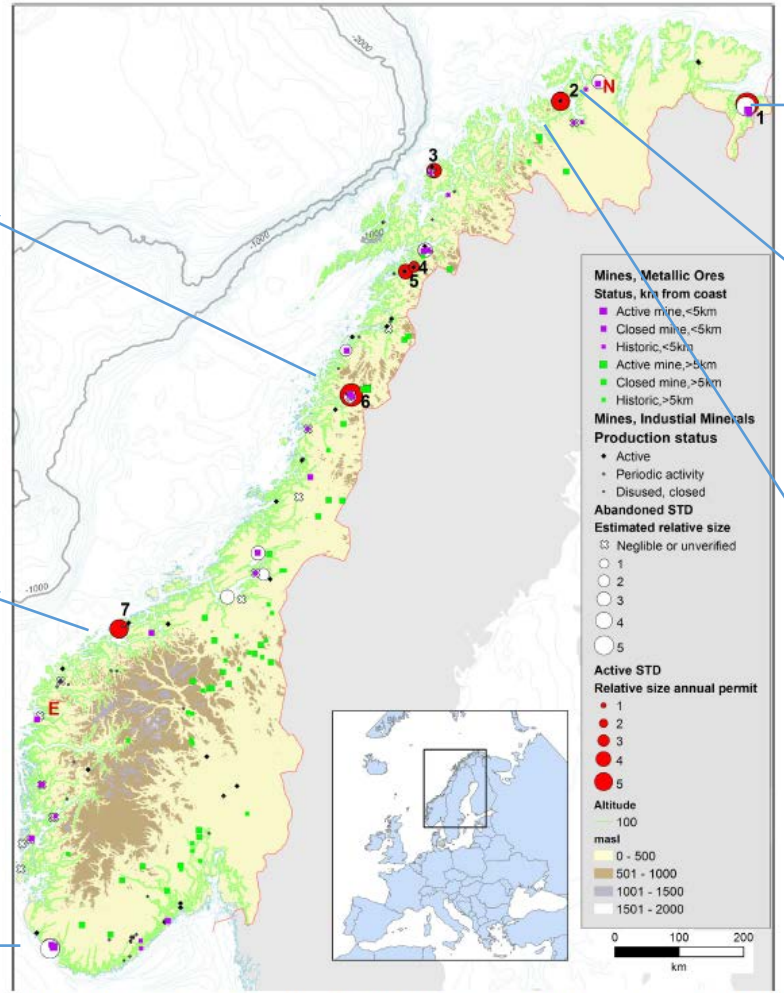
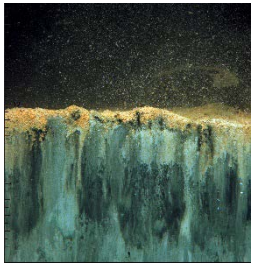
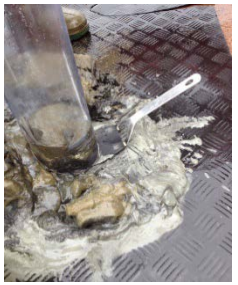


Fig. 5. Map showing the distribution of Norwegian mines in relation to the coast, their status (active/inactive) and the distribution of current (red circles) and abandoned (open circles) STDs. The numbers refer to the STDs reported in Table 1. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)



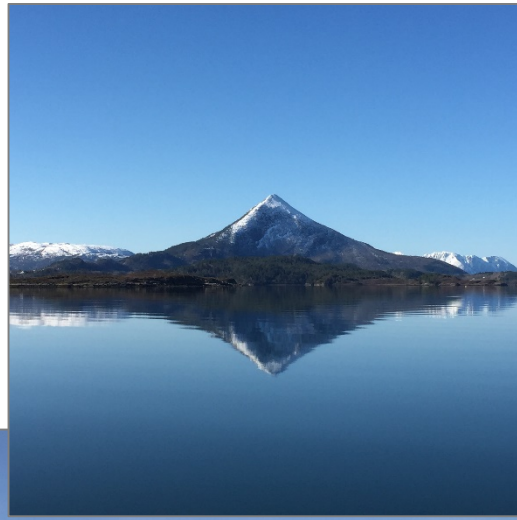


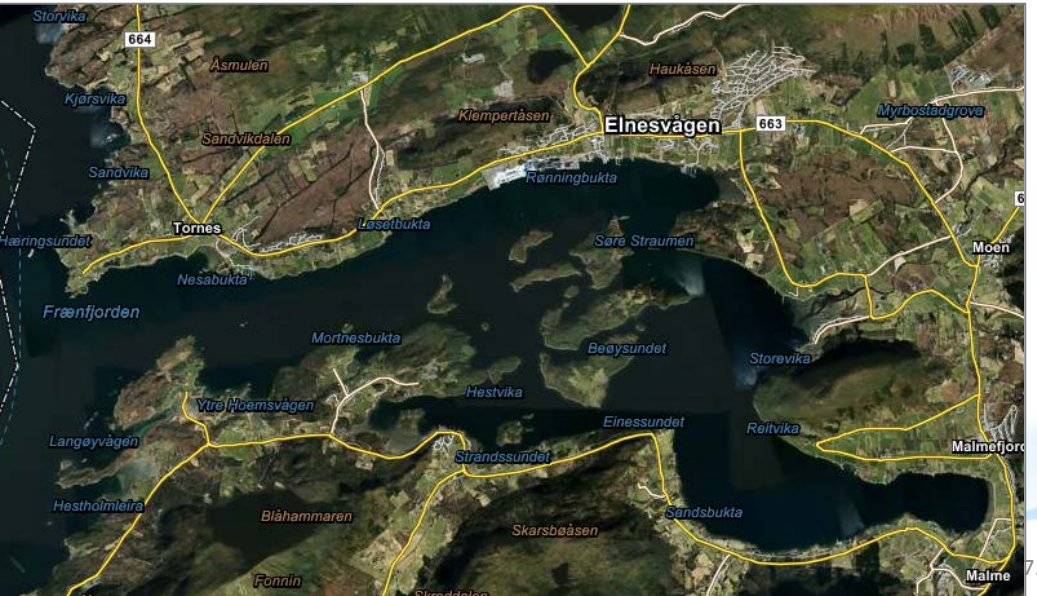
Figur 18 Fotografi av bunnen og bunnvegetasjonen (stivt kjerringhår) på 11 m dyp på stasjon B3, som var dekket av hvitt, flat "støv" fra utslippet.

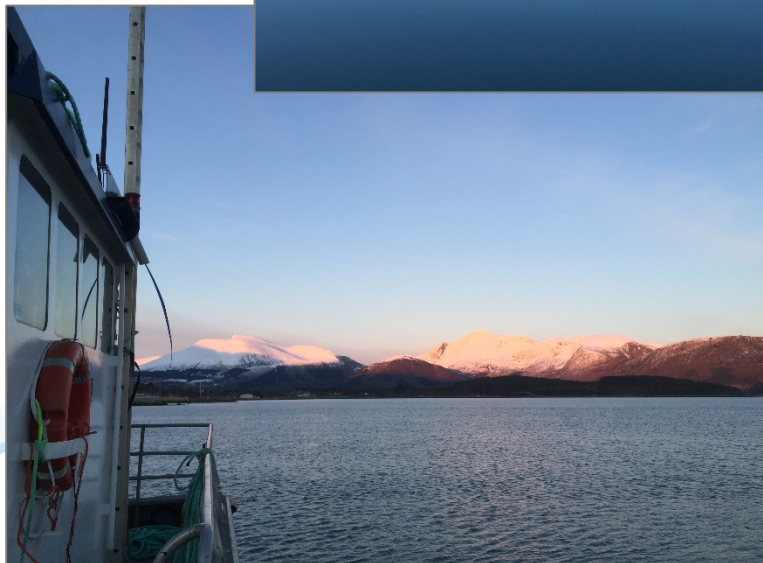
Ramirez-Llodra et al., 2015. Marine Pollution Bulletin 97: 13-35.

Frænfjorden

- Møre og Romsdal county
- 12 km long with a maximum depth of around 70 m
- Tidal range about 2 m and the fjord is well flushed
- Recipient for Omya Hustadmarmor AS, discharge from Tine meierier, municipal water and runoff from agriculture



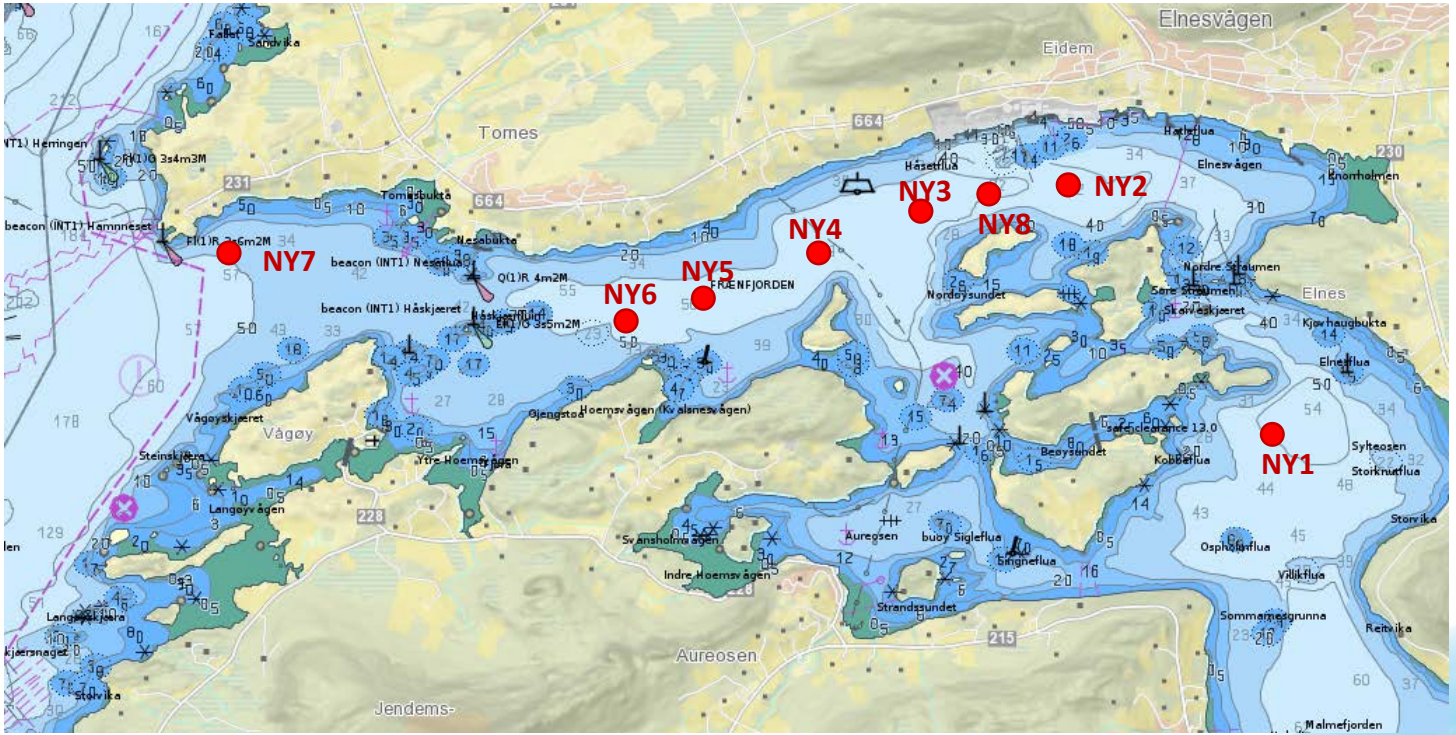




Frænfjorden sea deposit

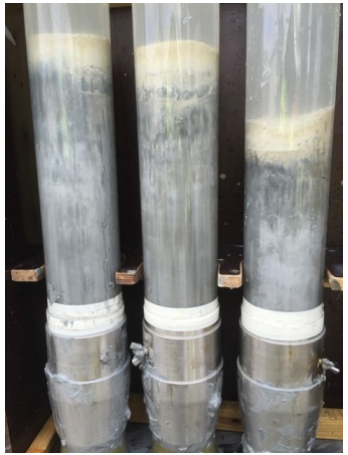
- Sea deposit from 1982
- ~ 300 k tons/year in the last years
- The discharge takes place at 20 m depth, and the tailings are deposited in a basin at 40-70 m depth
- As a result of the discharge, the depth of the fjord in certain areas has gradually decreased by up to 25 m from the original depth
- Tailings:
  - 40–50 % calcium carbonate
  - Fine grained: ~ 97% < 63 µm, 30% < 4 µm
  - No elevated levels of metals
  - Process chemicals; flocculation chemicals (anionic polyacrylamide) and cationic flotation chemicals
- Sediment close to the discharge > 99% fine fraction (< 63 µm)

Frænfjorden sediment chemistry stations



Frænfjorden chemistry sampling

Gemini cores



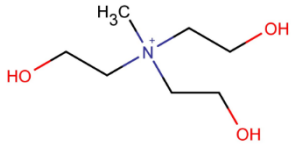
Sampling depth: four fractions

1. 0-1 cm
2. 1-3 cm
3. 3-5 cm
4. 5-10 cm

Suspected substances in the tailings from Hustadsmarmor

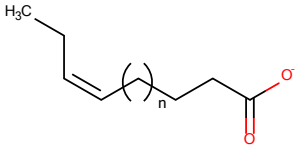
- Flotation reagent FLOT2015 employed in Hustadsmarmor.
- Cationic tensioactive, family of Esterquats
- Mixture of different chemical structures

Hydrolysis



tris(2-hydroxyethyl)(methyl)azanium

+



QAC core; final expected product of the degradation of the flotation chemical

Fatty acid. Environmentally non-relevant

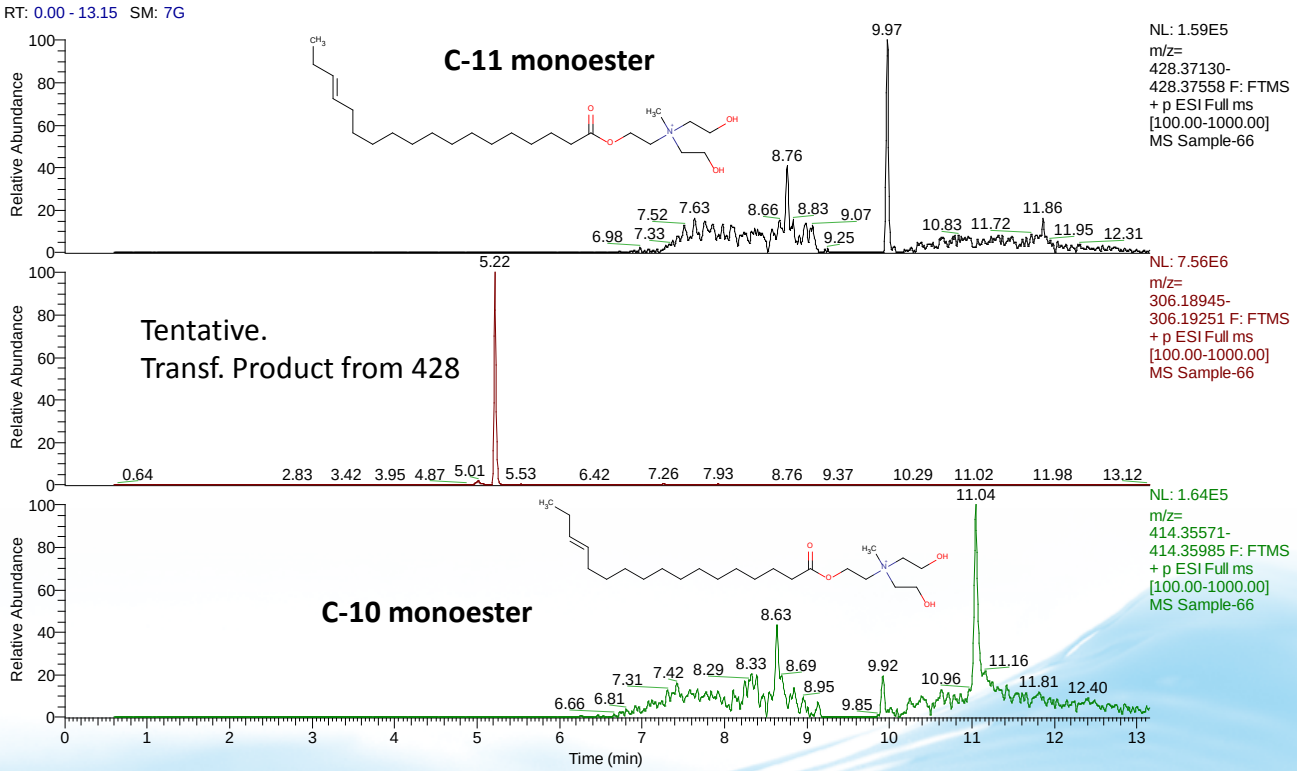
Sediments and pore water from Frænfjorden analyzed for:

- Identification of the different components of the raw material (including the QAC core).
- Identification and Quantification of the QAC core (standard available).
- Screening to tentatively identify the presence of transformation products

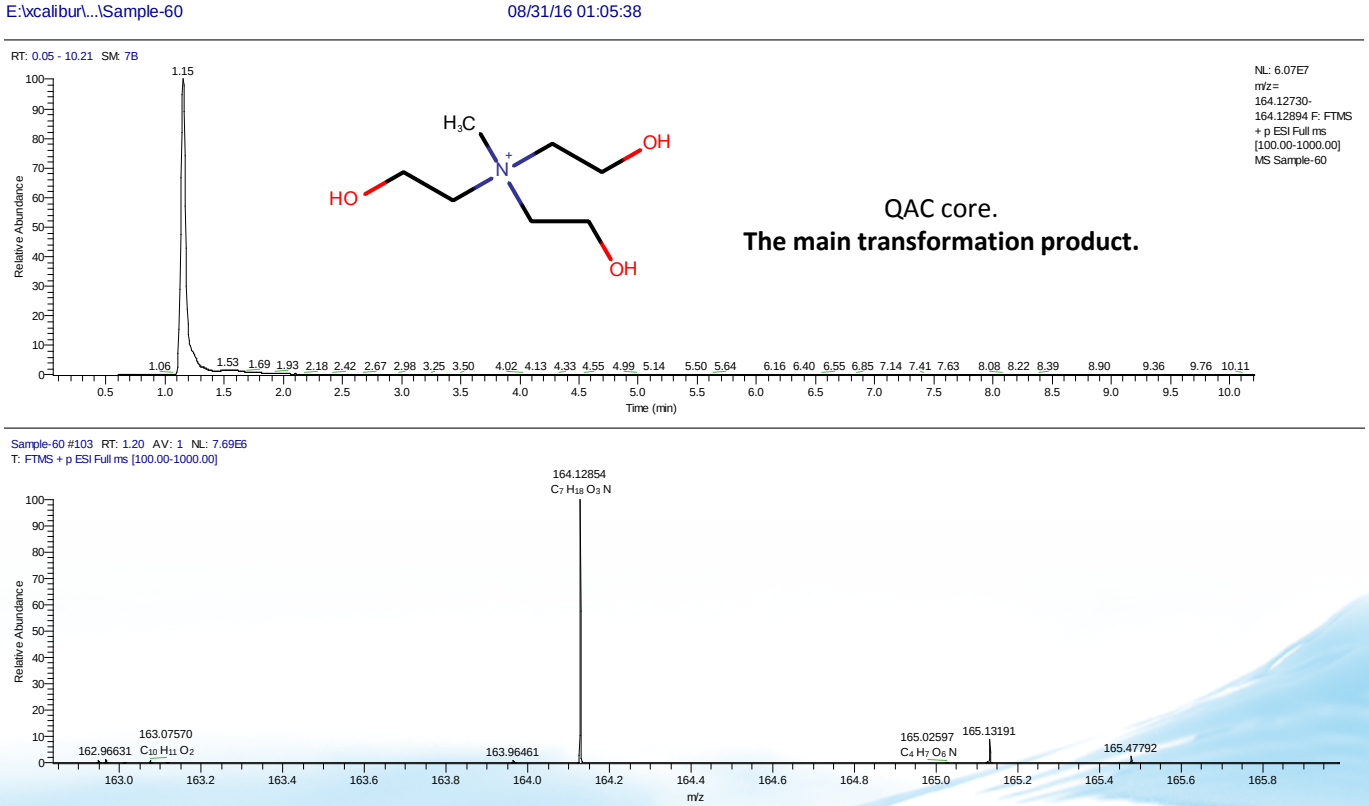
The analyses were performed at the Institute for Energy Technoloy (IFE) using Ultra High Performance Liquid Chromatography coupled to High Resolution Mass Spectrometry (UPLC-HRMS; Orbitrap).

Screening of the raw chemical and transformation products in sediments

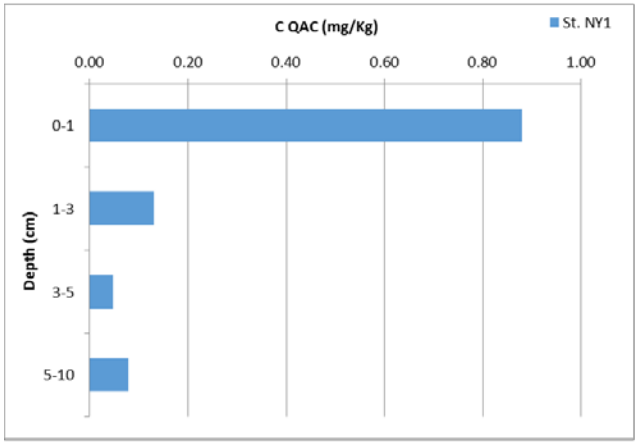
We have tentatively identified so far:

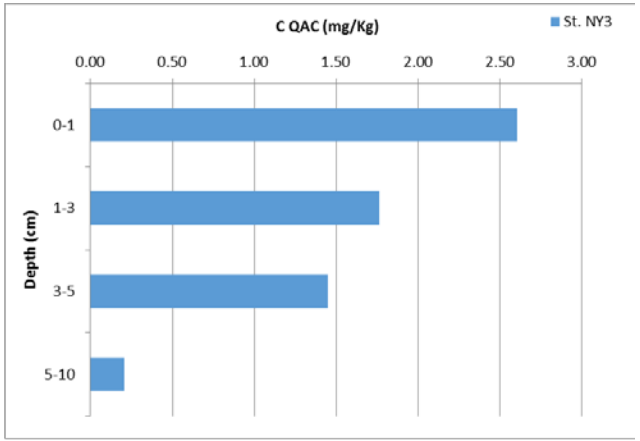


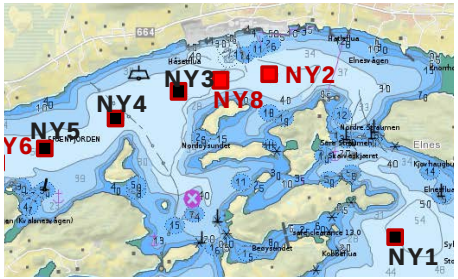
Screening of the raw chemical and transformation products in Frænfjorden

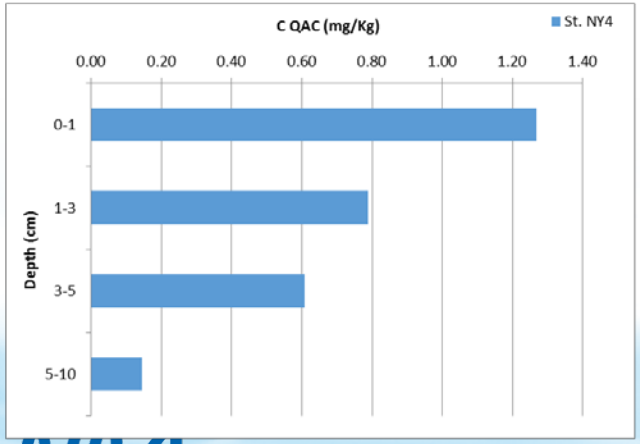


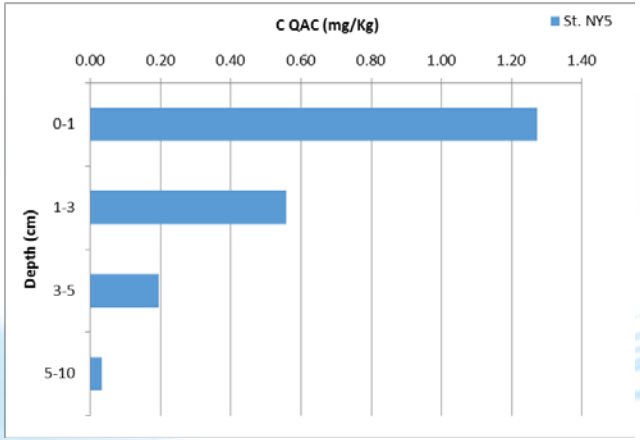
QAC profile in sediments from the fjord: distance from the pipe and depth



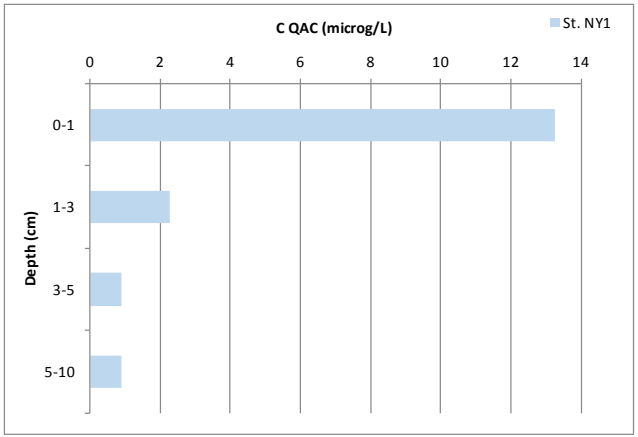


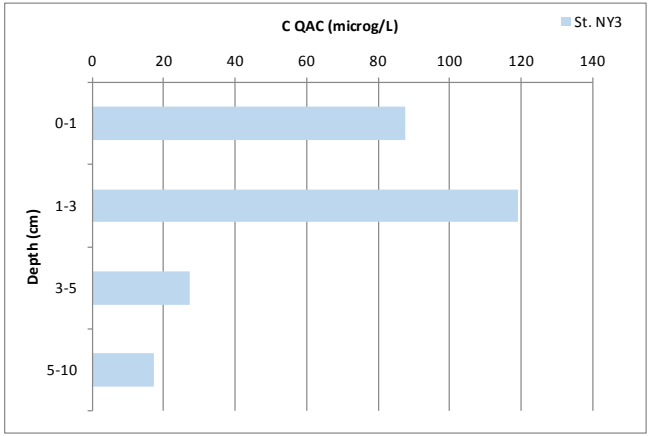


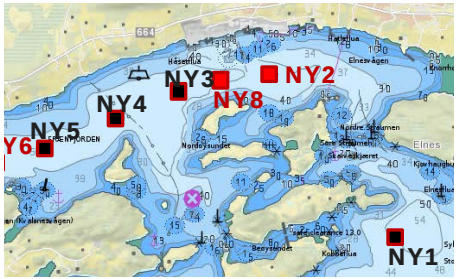


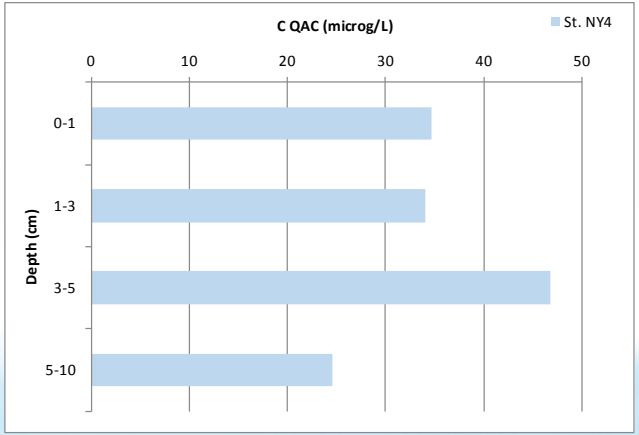


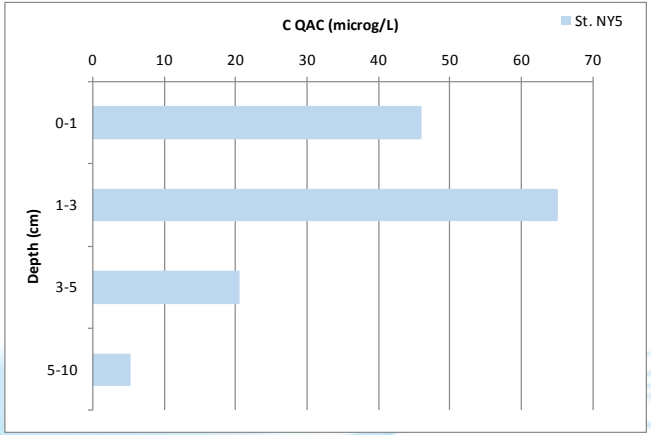
QAC profile in sediment porewater: distance from the pipe and depth











Research highlights: chemistry

- The cationic tensioactive FLOT2015 undergoes hydrolytic degradation once discharged into the fjord.

- The products of the likely degradation route (QAC and fatty acids) are considered as non-toxic and with low bioaccumulation potential. However, there is still presence of tensioactive in living organisms exposed to the tailings (mussels and sea cucumbers).

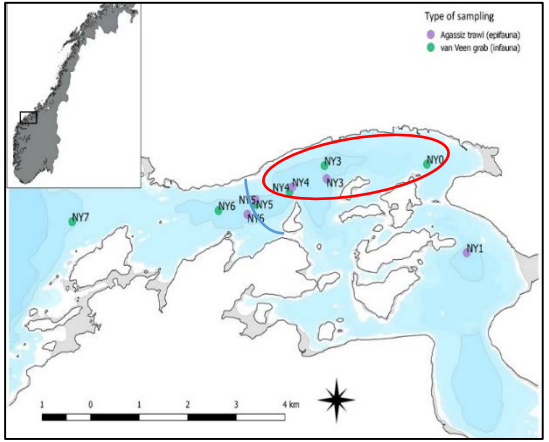
- A fraction of the product remains adsorbed to the particles of the tailing and another dissolves into the surrounding water

- In overall, FLOT2015 can be considered as an evolution of the industrial tensioactives following a concept of “Benign by design”. The product has been chemically designed with “water-sensitive” bonds with the objective of fading out in the water environment with relatively low long-term impact.

Frænfjorden: State of benthic communities *in situ*

Infauna

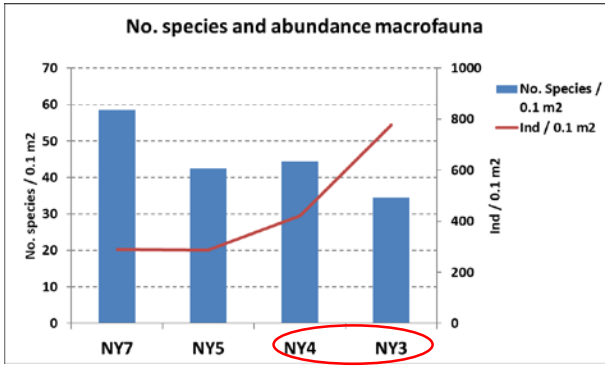
Epifauna

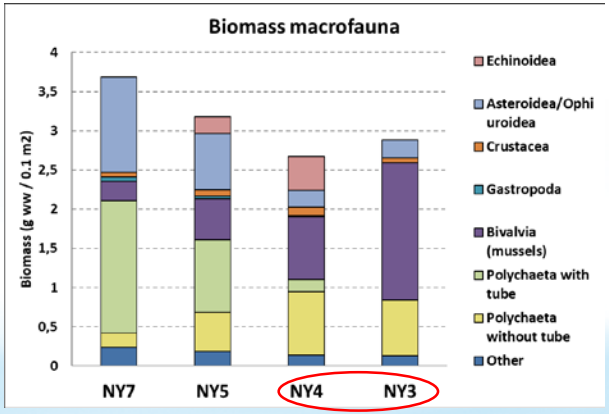


Infauna-data 2013-2016 (DNV & NIVA)
Epifauna 2016 (NIVA)

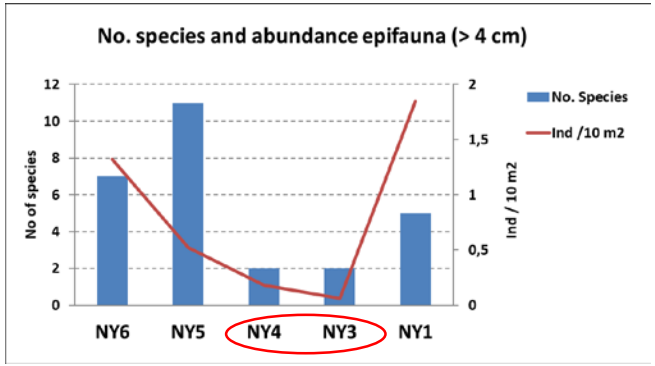
Benthic univariate responses

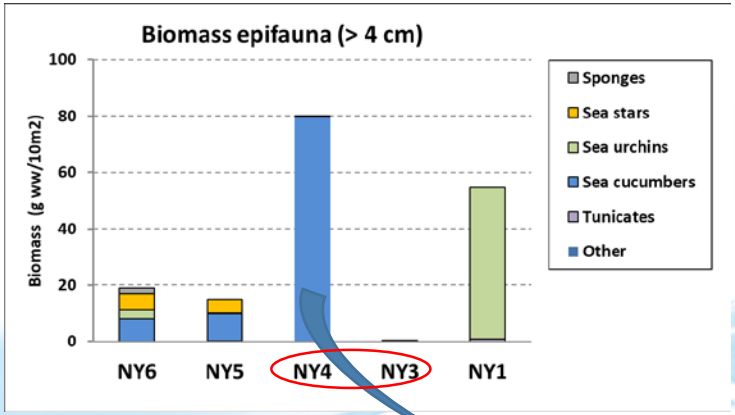
Infauna

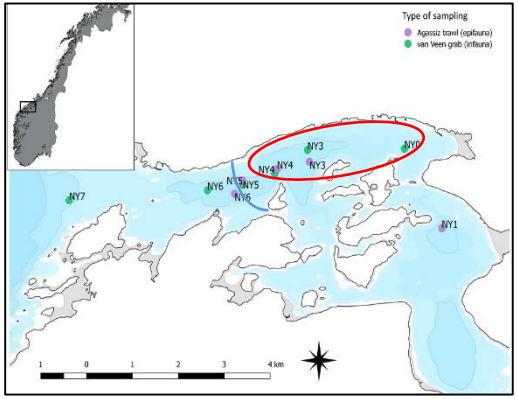




Epifauna

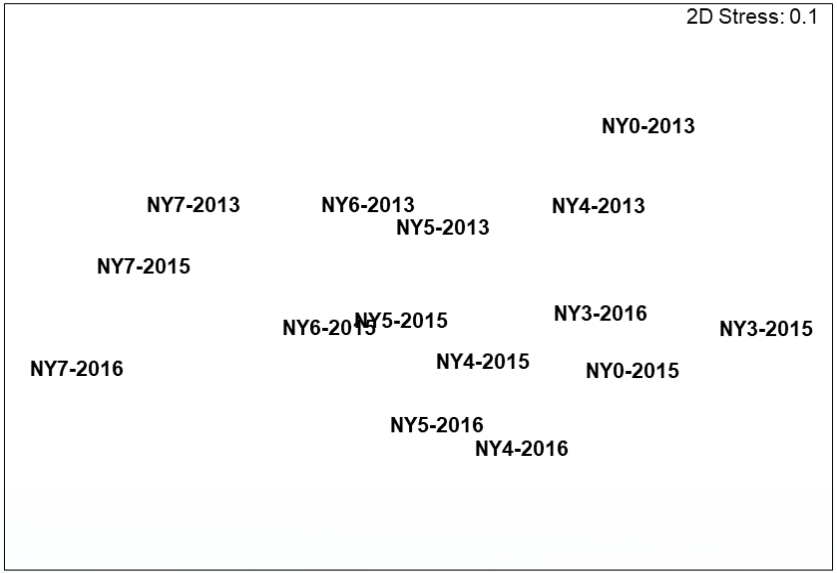






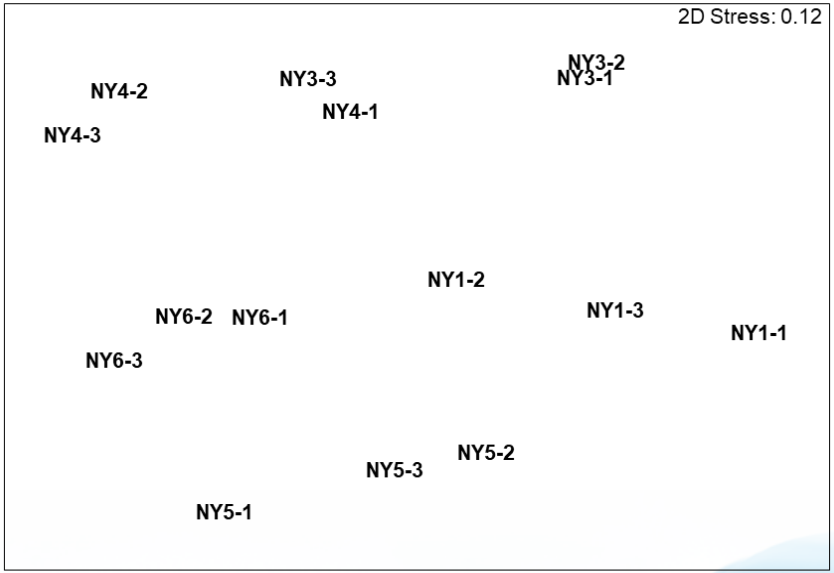
Multivariate pattern

Infauna



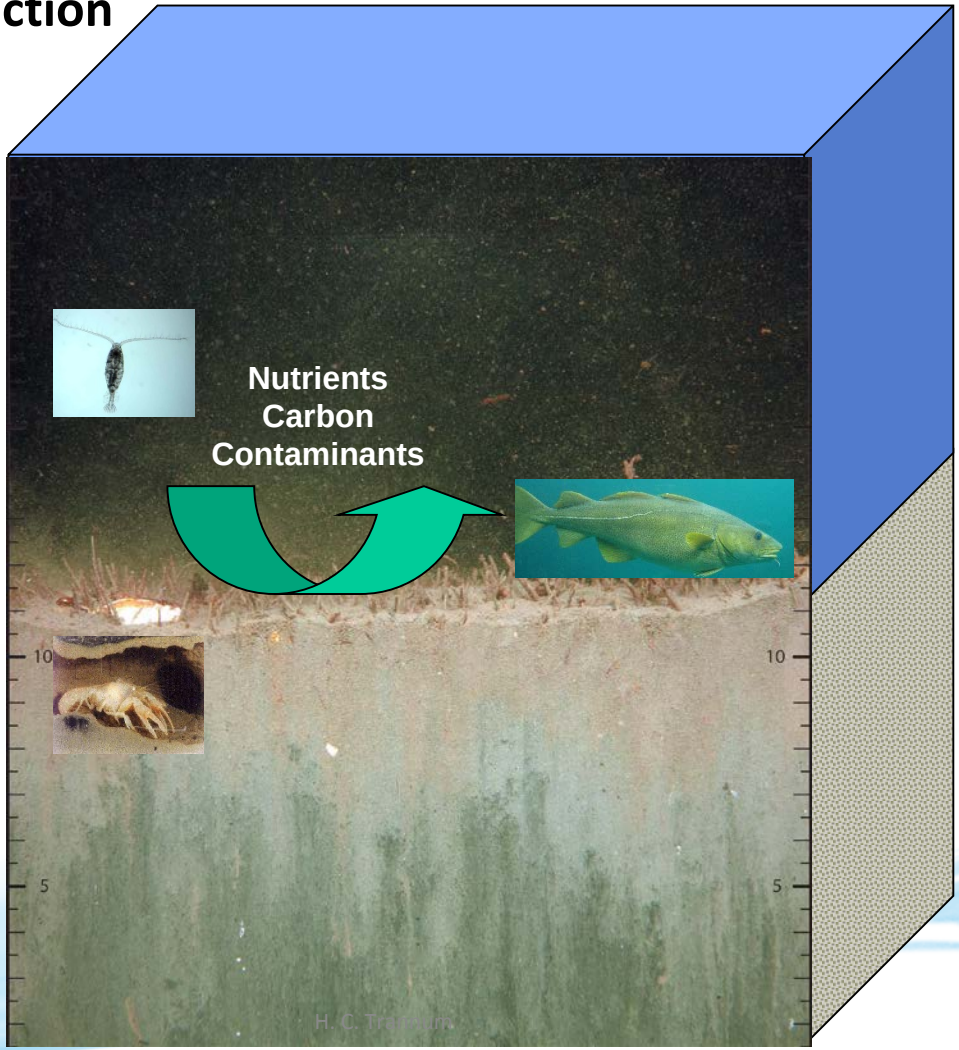
Tailings gradient

Epifauna



Tailings gradient

From structure to function



Traits-analysis: rationale

What the species **do** rather than the taxonomic identity

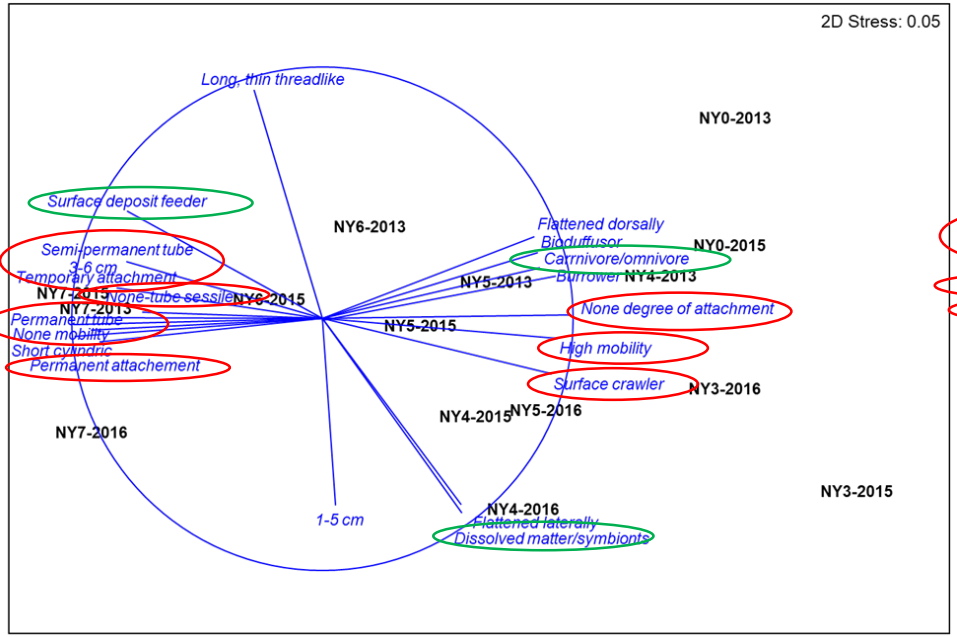
- Traits analysis describe ecosystem functions
- Describe the diversity of functions in species assemblages (“functional diversity”)

Functional attributes

- **Feeding**
- **Size and shape**
- **Activity**
  - **Life habitat/position**
  - **Mobility**
  - **Faecal deposition**
  - **Sediment reworking**
- **Reproduction**
  - **Larvae type**
  - **Reproduction technique**
  - **Reproduction period**

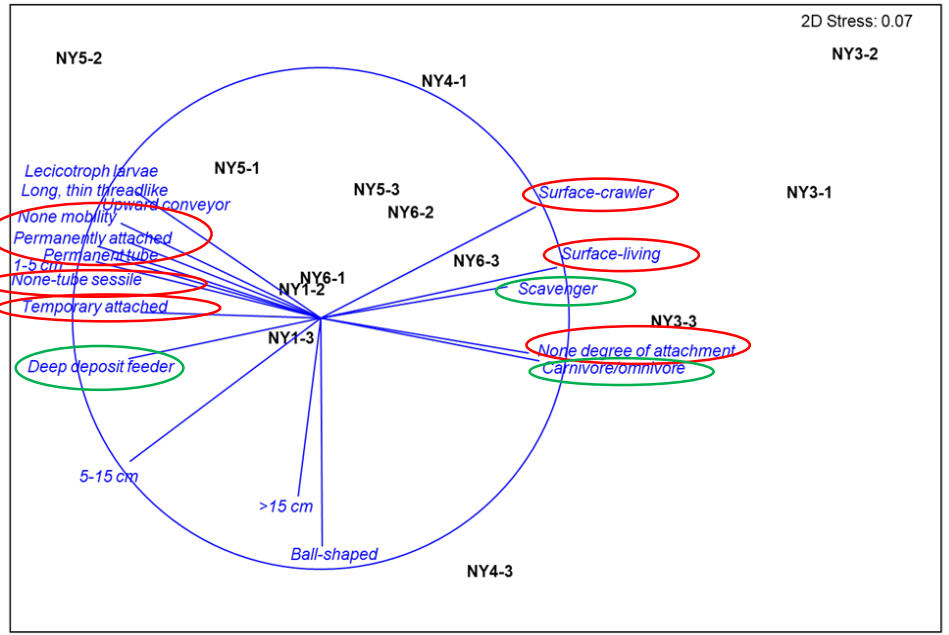
Functional responses

Infauna



Tailings gradient

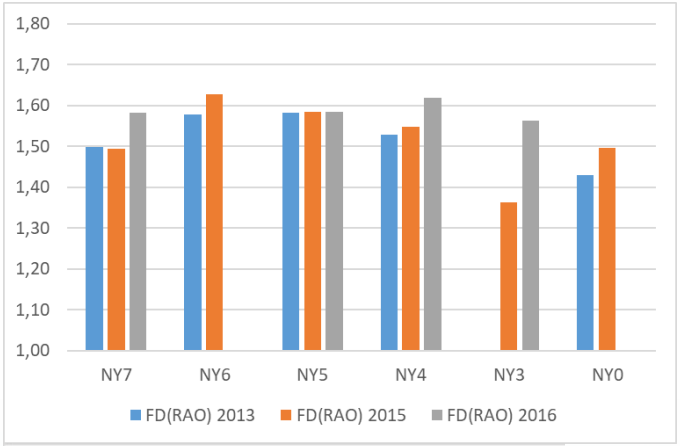
Epifauna



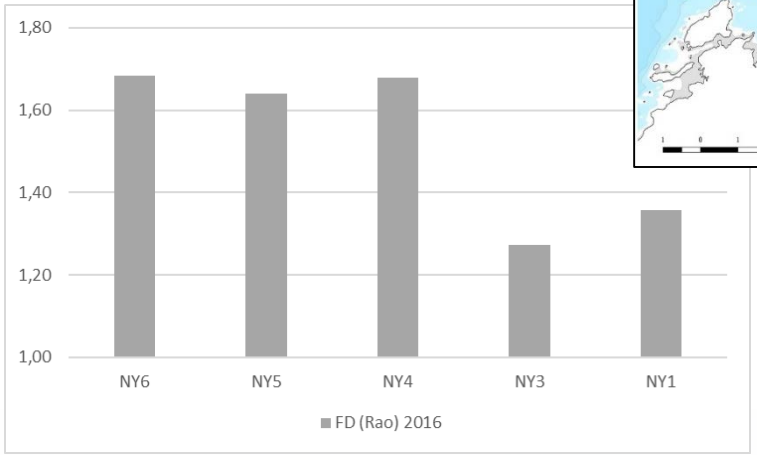
Tailings gradient

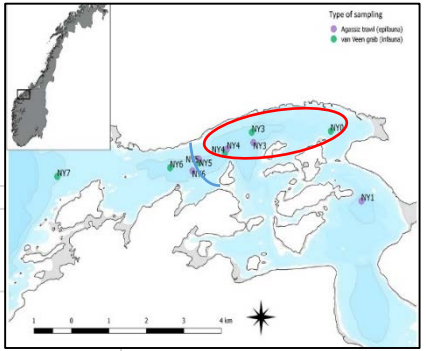
Functional diversity

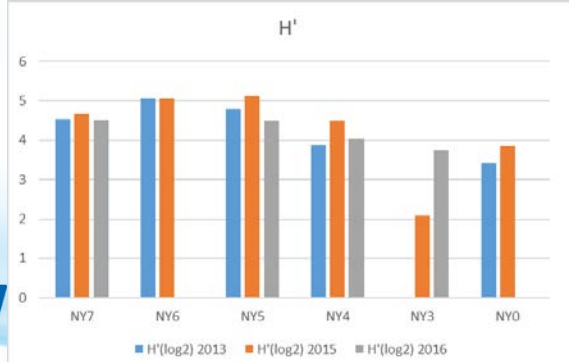
Infauna



Epifauna



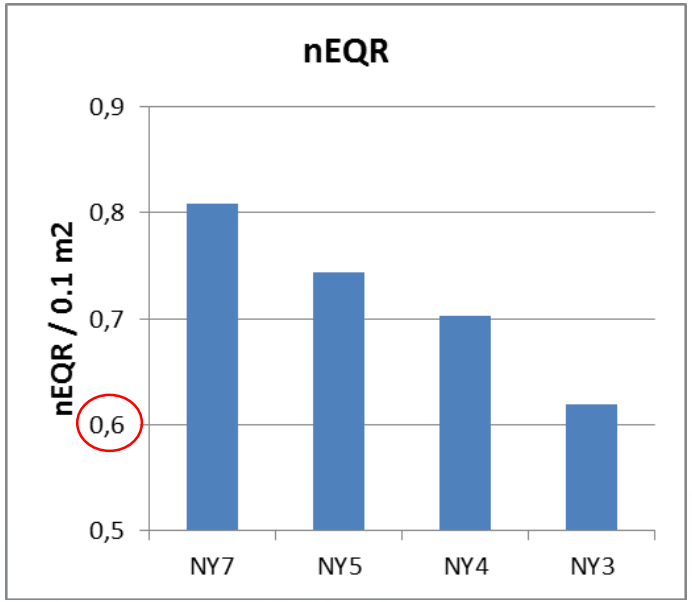


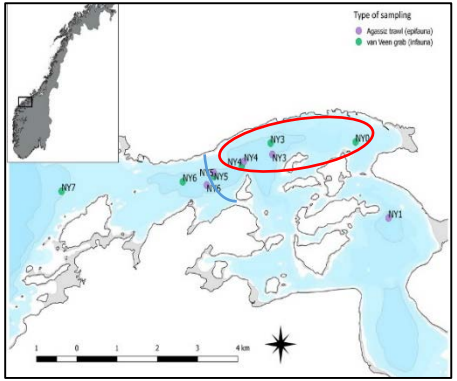


Improved status due to replacement of chemical from Lilaflot to FLOT2015?

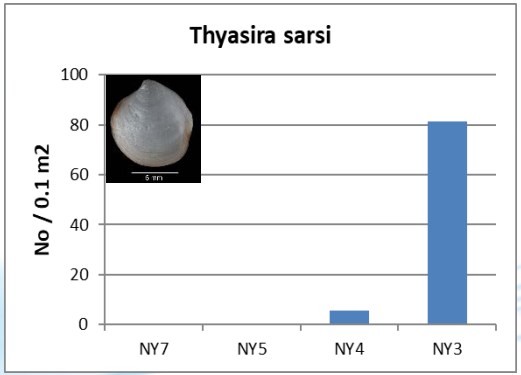
Ecological classification

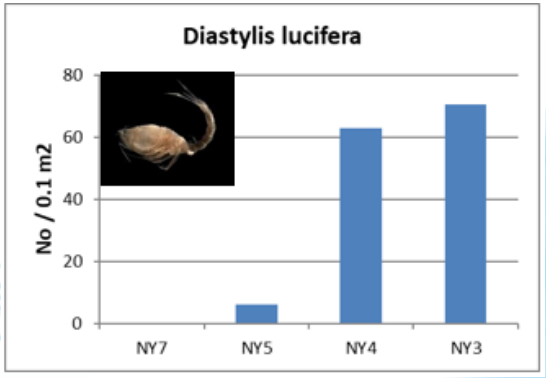
Infauna 2016





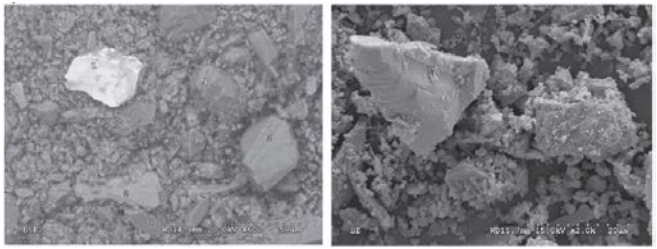
All stations obtained at least «good» condition (> class II) !





IMPACT MECHANISMS

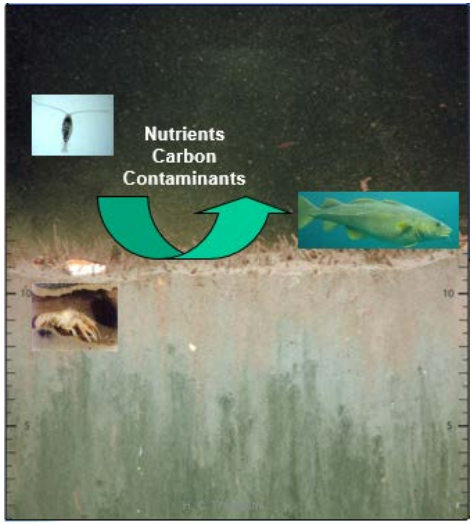
- Hypersedimentation
- Particle properties (freshly grinded, fine-grained, homogenous)
- Reduced oxygen penetration (fatty acids)
- Toxicity
  - (Metals from the ore)
  - Process chemicals; flotation chemicals (and flocculation chemicals)



In combination?

Research highlights: benthos

- Epifauna responded stronger than infauna
- Traits-analysis points out which ecological functions are most sensitive to the mine tailings
- Functional diversity a novel tool to quantify the functional responses of a disturbance
- Impact mechanisms complex



- Include epifauna in benthic monitoring? A monitoring including the most vulnerable ecosystem compartment would also be according to precautionary principle

FURTHER READING

Science of the Total Environment 630 (2018) 189–202

Contents lists available at ScienceDirect

Science of the Total Environment

journal homepage: www.elsevier.com/locate/scitotenv

Effects of submarine mine tailings on macrobenthic community structure and ecosystem processes

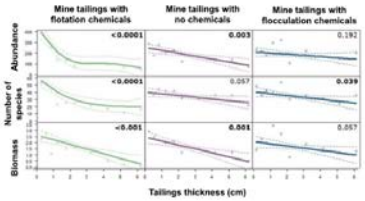
Hilde C. Trannum *, Hege Gundersen, Carlos Escudero-Oñate, Joachim T. Johansen, Morten T. Schaanning

Norwegian Institute for Water Research, Gaustadalléen 21, NO-0349 Oslo, Norway

HIGHLIGHTS

- Dose and response of 3 types of mine tailings studied in a soft-bottom mesocosm
- Apparent effect threshold at 2 cm layer thickness
- All tailings affected the fauna through more factors than hypersedimentation.
- Most severe effects of fine grained $CaCO_3$ with remnants of flotation chemicals.
- Indications were found on *in situ* biodegradation of flotation chemicals.

GRAPHICAL ABSTRACT



Marine Pollution Bulletin 97 (2015) 13–35

Contents lists available at ScienceDirect

Marine Pollution Bulletin

journal homepage: www.elsevier.com/locate/marpolbul

Review

Submarine and deep-sea mine tailing placements: A review of current practices, environmental issues, natural analogs and knowledge gaps in Norway and internationally

Eva Ramirez-Llodra [a,*], Hilde C. Trannum [a], Anita Evenset [b], Lisa A. Levin [c], Malin Andersson [d], Tor Erik Finne [d], Ana Hilario [e], Belinda Flem [d], Guttorm Christensen [b], Morten Schaanning [a], Ann Vanreusel [f]

[a] Norwegian Institute for Water Research, NIVA, Gaustadalléen 21, 0349 Oslo, Norway
[b] Akvaplan-niva, Fram Centre, High North Research Centre for Climate and the Environment, Tromsø, Norway
[c] Center for Marine Biodiversity and Conservation and Integrative Oceanography Division, Scripps Institution of Oceanography, UC San Diego, La Jolla, CA 92093-0218, USA
[d] Geological Survey of Norway, Postboks 6315 Sluppen, 7491 Trondheim, Norway
[e] Departamento de Biologia & CESAM, Universidade de Aveiro, Portugal
[f] Marine Biology Research Group, Ghent University, Krijgslaan 281, B-9000 Gent, Belgium

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ABSTRACT

The mining sector is growing in parallel with societal demands for minerals. One of the most important environmental issues and economic burdens of industrial mining on land is the safe storage of the vast amounts of waste produced. Traditionally, tailings have been stored in land dams, but the lack of land availability, potential risk of dam failure and topography in coastal areas in certain countries results in increasing disposal of tailings into marine systems. This review describes the different submarine tailing disposal methods used in the world in general and in Norway in particular, their impact on the environment (e.g. hyper-sedimentation, toxicity, processes related to changes in grain shape and size, turbidity), current legislation and need for future research. Understanding these impacts on the habitat and biota is essential to assess potential ecosystem changes and to develop best available techniques and robust management plans.

Questions ?

NYKOS

NIVA

DNV·GL

Thank you !