Project information

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Repparfjord, mine tailings, subsea deposit, benthos, chemistry
Project title
Fate and Impact of MIne Tailings on marine Arctic ecosystems – FIMITA
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2016
Project leader
Anita Evenset
Geographical localization of the research project in decimal degrees (max 5 per project, ex. 70,662°N and 23,707°E)
70,417°N 24,550°E
Participants

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Flagship
MIKON
Funding Source

MIKON

Summary of Results

Fieldwork in the marine environment was carried out in 2015, and analyses of samples have been prioritized in 2016. In addition, laboratory experiments have been carried out in 2015 and 2016, as well as fieldwork in WP 4. Brief summaries of main results so far are given below.

WP 1: The plan for the fieldwork in 2015 was to collected sediment cores at various distances from the deposit (core to fringe) and in the area outside the old deposit in Repparfjord. Prior to sediment sampling, bathymetry and backscatter data was obtained by Seisma, NGU's research vessel. These data provided a picture that delineates the successive filling on the seafloor along the western side of the southern inlet of Repparfjorden and it shows how the outlet point has been moved towards north-east. Therefore, the deposit seems to lie in a series of cone-like shapes. Analytical results from cores taken around the deposit, by NGU and UiT, suggest that

some sliding of the deposit material has taken place from the cones onto nearby lower levels.

NGU collected samples of surface sediments (0-20 cm depth) in several locations. In addition, NGU sampled sediments and pore water from a 61 cm core taken by UiT. "Background" samples were obtained of floodplain sediments in the Repparfjordelva. The results of chemical analyses show that mine tailings are, in relation to the natural materials lying under and on top, clearly enriched with the elements Au, Ba, Bi, Cr, Cu, Hf, Ni, Re and Zr. On the other hand, the tailings are depleted of the elements: Be, Cd, Cs, In, Li, Nb, P, Pb, Rb, S, Sc, V and Zn (Figure 1). The concentrations of uranium and thorium in the old deposit, as well as in pore water within the deposited material and in the naturally occurring sediments are low.

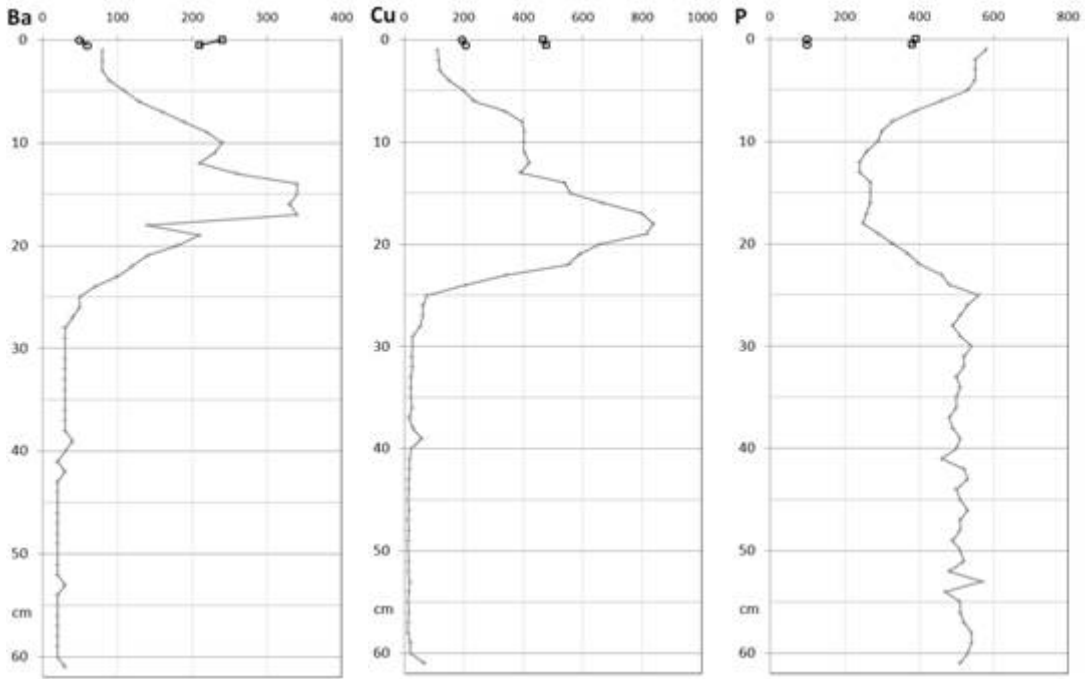

Figure 1: Examples of elements within the longer core, which defines the chemical signature. The tailings material is present in a horizon at 5-25 cm depth. The markers at the top of the diagram show the analytical results for the fresh tailings from Ulveryggen (circles) and Nussir (squares). All samples are extracted by Aqua Regia.

The comparison between sediment and pore water does not paint a clear picture or show any consistent patterns as the sediment samples do, but Pb, Fe, Cr and Cd, and Cu, Mg to some degree, seem to be the elements with a certain correlation between

the pore water and sediments.

In addition to the samples collected in the field, fresh tailings were produced within the project. Fresh tailings have been analyzed for metals. The mine tailings deposited in the 1970's, which originate from the Ulveryggen deposit, differ considerably in concentration for many chemical elements when comparing to the fresh tailings produced in 2015.

A new study was added to the project after the fieldwork in 2015.The focus of this part was to evaluate deposited mine tailings from Repparfjorden as well as the newly processed mine tailings, in terms of metal availability, potential mobilisation of metals with changes in pH, and the possibility of extracting more Cu from the new tailings. Acid and base extraction experiments provided desorption curves of mine tailing suspensions as a function of pH (0.5-12.7), and showed that Cu was more easily desorbed in the historic mine tailings (Figure 2). Substantial desorption (>40%) for both historic and new mine tailings occurred at pH values below 3 and above 12. These results combined with metal speciation, showing that the binding of Cu in the sediment changes around pH values 3 and 10, indicate potential for extraction of more Cu from the new mine tailings. Electrodialysis, based on applying an electric field of low intensity to extract metals from polluted soils/sediments, was designed for acidic and alkaline extraction, and in both cases more Cu was extracted than in the pure acid/base extractions, while maintaining low mobilisation of other metals. Electrodialysis can hence be designed to target extraction of Cu while limiting the mobilisation of other metals (Pedersen *et al.* in press).

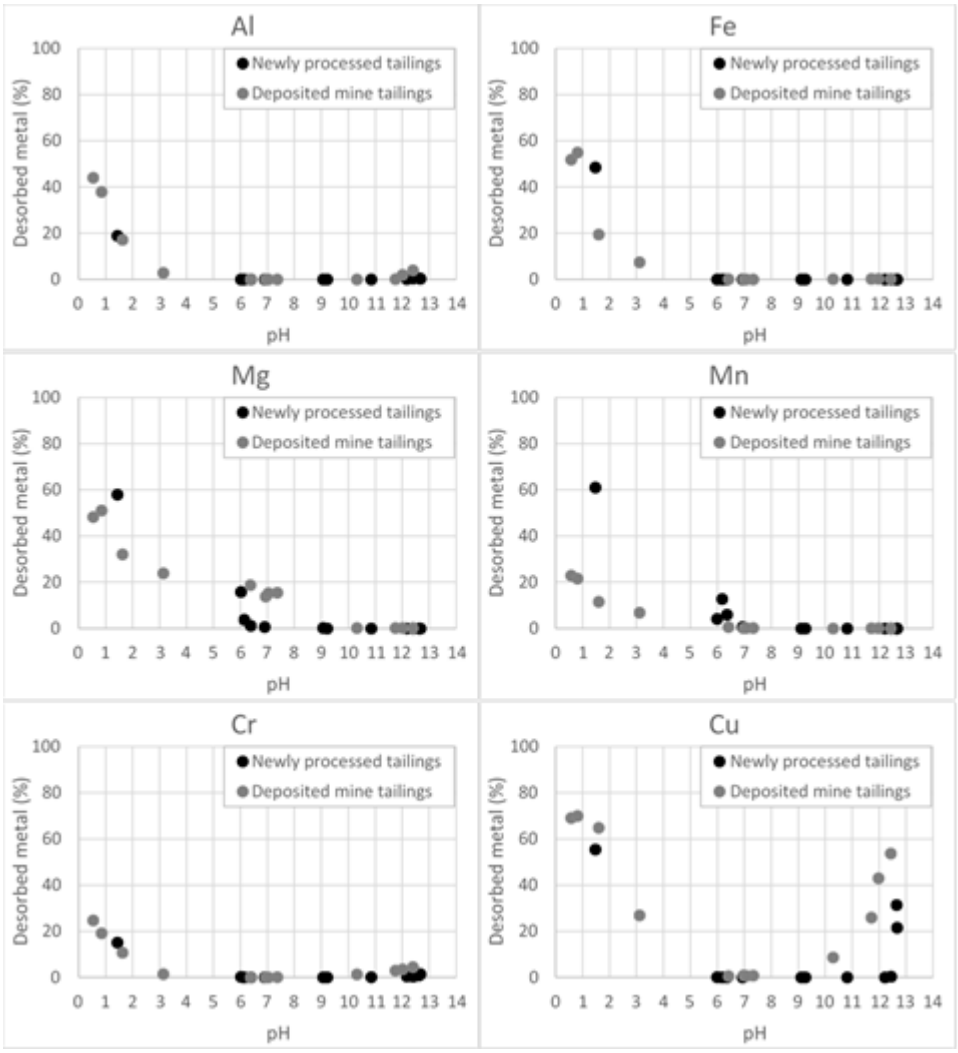

Figure 2: Desorption of metals (%) from fresh tailings and aged mine tailings as function of pH (from Pedersen et al. in press).

<u>WP 2:</u> The benthic community was sampled as planned at various distances from the old deposit, and in a reference area in June 2015. These samples have been sorted and all faunal taxa identified to species level. The results are currently being analysed together with data on sediment composition (from WP 1). An in situ recolonization experiment was performed in Repparfjord in the period June 2015 – September 2016. Experimental bottom frames were filled with manipulated sediments and placed on the seafloor in early June 2015. Three different treatments (varying thickness of tailings) were used, plus one control group. The frames were retrieved in September 2016 November (Figure 3). All macrofauna from the boxes retained on a 1 mm sieve are currently being sorted and identified to species level, and biomass measurements conducted. Sub-samples from the boxes will be analysed for metals and radionuclides, and foraminifera analyses will be conducted through the EWMA-project.

Figure 3. Boxes that had been placed on the seafloor in Repparfjorden from June 2015 – September 2016. Left: Control (no tailings). Right: 14.5 mm tailings.

WP 3: In 2015-2016 a laboratory experiment, where *Acesta excavata, Primnoa reseadeformis* and *Geodia atlantica* were exposed to suspended solids and different temperatures, was carried out. The study showed that exposure to sediment does not affect the oxygen consumption and metabolism in *A. excavata*. However, elevated levels of NH_3 during incubations and a reduced conditions index indicates that the bivalves uses stored energy to maintain metabolism during times of sediment exposure. This is probably not sustainable in the long run (laboratory study was limited to 40 days). It is therefore possible that long-term effects on populations of this species may occur in areas with continuous discharge of particulate material (Scanes *et al*. in prep.). *P. reseadeformis* and *G. atlantica*, which also were exposed in the same experiment, reacted a little differently, but data interpretation is still in progress for these species.

WP 4: In 2015 the debates on mining in Kvalsund and Kirkenes were mapped using literature study of media, reports and government documents. The main statements in the two cases were identified as a basis for Q-studies. Q-methodology is a method used to identify the different opinions, or perceptions, on a topic in a population of stakeholders. The first step is to map the debate on a topic, in this case the mining operations in Finnmark. The core elements in the debate are identified and short statements representing the debate are selected for the Q-sort. These statements are called "Q-statements". The Q-statements are presented to stakeholders who have to sort the statements (do a Q-sort) according to how much they emphasise that statements and if they agree or disagree. The Q-sorts of the different stakeholders are analysed to identify the main perceptions and agreements/disagreements between the different perceptions on the topic studied. Fieldwork was conducted in Kirkenes, where 13 local informed stakeholders sorted the 43 Q statements identified for the Sydvaranger mining operations. The stakeholders also commented on the statements. This gave the basis for both a Q-analysis and qualitative data that can inform the results. In 2016 the Q-sort for Kvalsund and the proposed mining activity by Nussir ASA was designed, and field work was conducted in Kvalsund and Hammerfest, where 12 stakeholders were interviewed using Q-sort. Qualitative data supplemented the Q-sorts. In 2017 final stakeholder interviews, to cover in particular Sami stakeholders that were identified through the interviews in 2016, will be conducted. Results from all field activities will be compiled and analysed, and presented in a paper where the Nussir and Sydvaranger cases are compared.

References:

Pedersen, K.B., Jensen, P.E., Ottosen, L.M., Evenset, A., Christensen, G.N., Frantzen, M., in press. Metal speciation of historic and new copper mine tailings from Repparfjorden, Northern Norway, before and after acid, base and electrodialytic extraction. Miner. Eng.

Scanes, E. et al. in prep. Chronic sediment exposure and acute temperature elevation cause physiological stress on the deep living bivalve *Acesta excavata*.

Master and PhD-students involved in the project

Two batchelor students have been involved:

Manja Marie Kudahl and Mie Vesterskov Henning from Denmark Technical University. Title batchelorproject: 'Miljøundersøgelse af Cu minetailings fra Repparfjorden'.

For the Management

FIMITA is producing new knowledge about effects of subsea mine tailing deposition on marine habitats and their ecosystems. As such sub-sea tailing deposits are present already in Northern-Norway and new ones are planned, knowledge about environmental impacts of mine tailings is highly demanded by environmental managers, NGOs and the public. It is also important for environmental managers to know how ecosystem services and local communities are affected by mining activities, and this will also be investigated in FIMITA.

Some important preliminary results:

- Chemical analyses of old mine tailings show that tailings are, in relation to the natural materials lying under and on top, clearly enriched with the elements Au, Ba, Bi, Cr, Cu, Hf, Ni, Re and Zr. On the other hand, the tailings are depleted of the elements: Be, Cd, Cs, In, Li, Nb, P, Pb, Rb, S, Sc, V and Zn.
- Binding of Cu in the sediment changes around pH values 3 and 10, and this indicate potential for extraction of more Cu from the new mine tailings. Electrodialysis, based on applying an electric field of low intensity to extract metals from sediments, was designed for acidic and alkaline extraction, and in both cases more Cu was extracted than in the pure acid/base extractions, while maintaining low mobilisation of other metals. Electrodialysis can hence be designed to target extraction of Cu while limiting the mobilisation of other metals.
- Laboratory studies where *Acesta excavata* was exposed to suspended sediment showed oxygen consumption and metabolism was unaffected. However, elevated levels of NH_3 during incubations and a reduced conditions index indicates that the bivalves uses stored energy to maintain metabolism during times of sediment exposure. This is probably not sustainable in the long run (laboratory study was limited to 40 days). It is therefore possible that long-term effects on populations of this species may occur in areas with continuous discharge of particulate material.

Published Results/Planned Publications

Pedersen, K.B., Jensen, P.E., Ottosen, L.M., Evenset, A., Christensen, G.N., Frantzen, M., in press. Metal speciation of historic and new copper mine tailings from Repparfjorden, Northern Norway, before and after acid, base and electrodialytic extraction. Miner. Eng.

Several publications are planned. Working titles are given below:

Scanes, E. et al. in prep. Chronic sediment exposure and acute temperature elevation cause physiological stress

on the deep living bivalve *Acesta excavata*.

Trannum et al. Recolonisation of benthic communities at a sub-sea tailing deposit; a case study from Repparfjorden, Norway.

Andersson et al. Metal speciation and mobilization from a sub-sea tailing deposit.

Scanes et al. Cellular stress responses in hard-bottom communities exposed to mine-tailings.

Falk-Andersson et al. Local populations assessment of impacts of sub-sea tailing deposition on ecosystem services – the Nussir and Sydvaranger cases.

Communicated Results

The project has been presented at a French - Norwegian seminar at the Fram Centre in October 2016. It has been presented to Troms Fylkeskommune in November 2016, as well as at 3 conferences:

Pedersen. Environmental Waste Management - Mine tailings in Repparfjorden – Availability of Metals. Arctic Froniters 2016 - Side events Forskningsløft i nord.

Pedersen. Submarine mine tailings disposal in Repparfjorden, northern Norway – long-term dispersion and availability of Cu. ARTEK event 2016 (Sisimiut, Grønland).

Pedersen. Metal speciation of historic and new copper mine tailings from

Repparfjorden, Northern Norway, before and after acid, base and electrodialytic extraction. Sustainable Minerals '16 (Falmouth, England).

Interdisciplinary Cooperation

FIMITA is a truly multidisciplinary project. The research team has expertise within sediment geology, geochemistry, ecology, ecotoxicology, economics and planning studies. During the last year of the project data integration between the different science disciplines will be very important.

Budget in accordance to results

The Fram Centre funding is essential for this project. The subject has not been covered by NFR programs (NOT BEFORE 2017), and therefore other funding is difficult to obtain.

No other funding provided.

Could results from the project be subject for any commercial utilization

No

If Yes

No