Effekter av sjødeponier, erfaringer gjort i EWMA

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The brief history of EWMA

2009: Norwegian Government Initiative for boosting research in northern Norway

2009: EWMA awarded 5 year grant from the Research Council of Norway

2010-2014: EWMA I

2014: EWMA awarded an extra 3-year grant from the Research Council of Norway

2014-2017: EWMA II

EWMA I

- Establish cluster
- Bridging research institutions and industry
- Educational programme
- Research topics:
  - Effects of off-shore activities
  - Remediation technologies
  - Social impact

EWMA II

- Environmental effects
- Identifying actions
- Main focus on mineral extraction industry

Funding: The Research Council of Norway and ENI Norway A/S (70:30)

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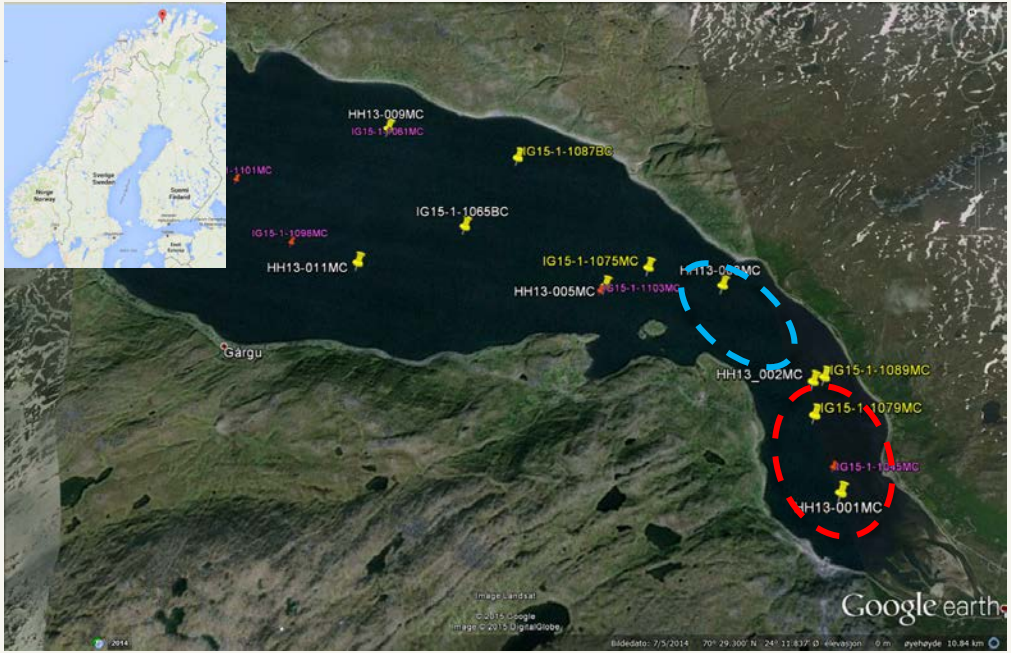
EWMA phase II joint case study: Effects of mine tailings in Repparfjorden



Repparfjoden, northern Norway

1972-1978: Disposal of approx. 1 million ton of Cu mine tailings

2018: Re-opening of the mine planned for 2019
Operating period ~30 years

Submarine disposal of mine tailings

Permit from the Norwegian Environment Agency
Submarine disposal of 1-2 million ton mine tailings per year

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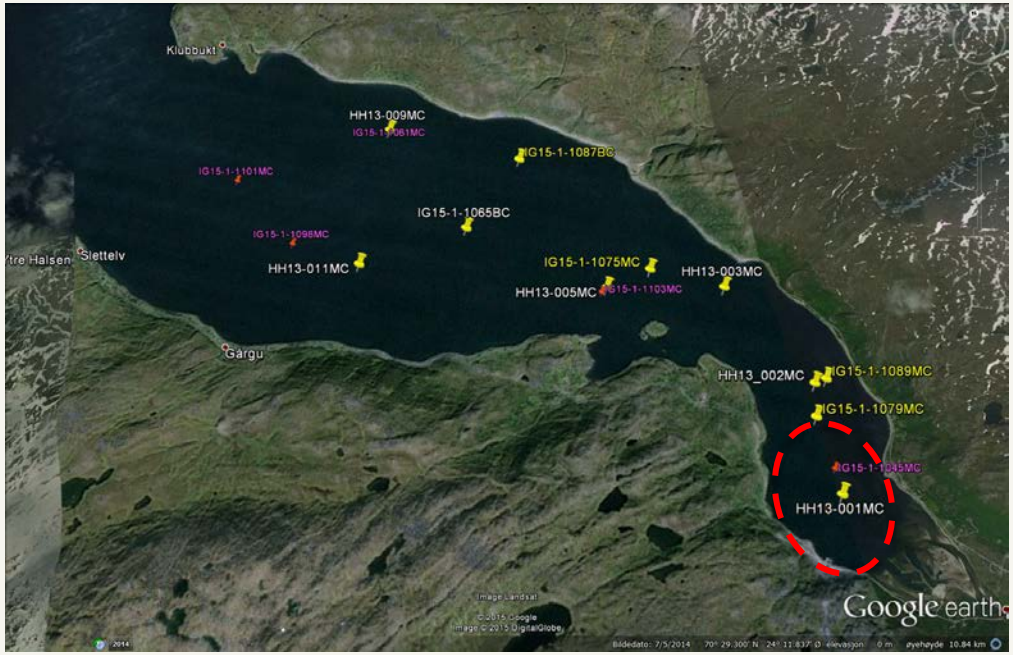
Environmental site investigations



Previous investigations

2008 – Environmental impact assessment

Surface samples – metal concentrations and benthic communities

Results – high copper concentrations in deposit area; no effect on benthic communities

New environmental investigations

More extensive – assess long term impacts and obtain baseline

15 cores covering the entire fjord

Analysis of metal concentrations and sediment properties

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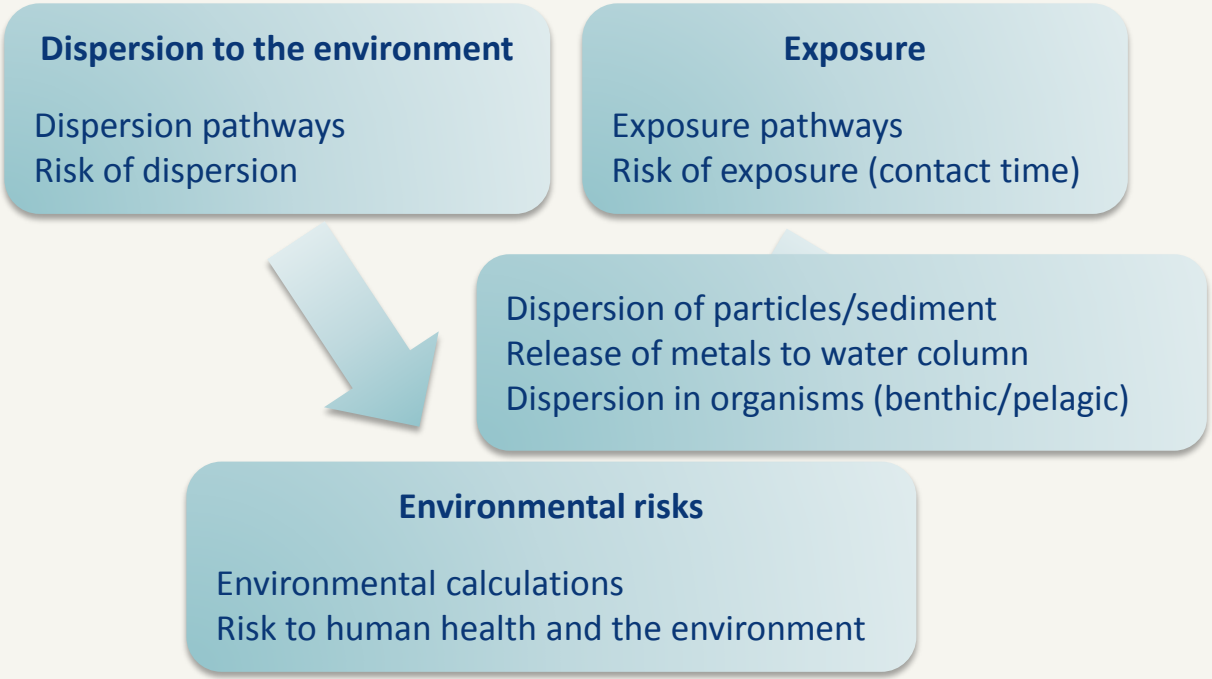
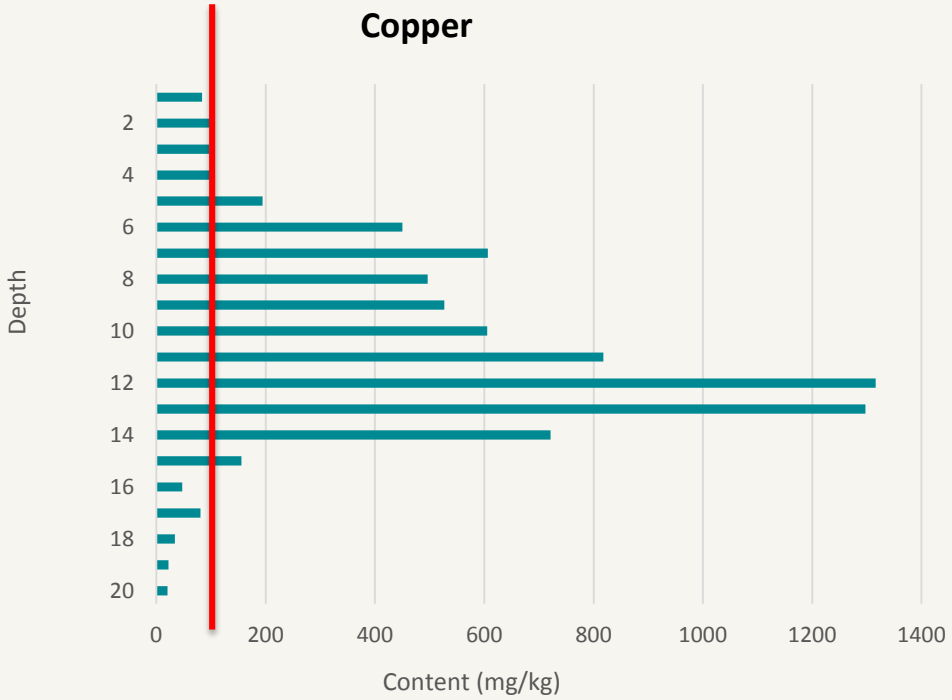
Assessing environmental impacts of the historical submarine mine tailings disposal

Environmental risk assessment



Sternal, B., Junttila, J.; Skirbekk, K.; Forwick, M.; Carroll, JL, Pedersen, K.B: *The impact of submarine copper mine tailing disposal from the 1970s on Repparfjorden, northern Norway* Marine Pollution Bulletin 2017

Copper concentrations of the submarine mine tailings disposal (core 1079)



Norwegian sediment quality criteria

Class 1: Background concentrations
Class 2: Effects range low
Class 3: Probable effect limit
Class 4: Potential toxic effect (long exposure)
Class 5: Potential toxic effect (short exposure)

mg/kg	Copper
Class 1	<20
Class 2	20-84
Class 3	84
Class 4	84-147
Class 5	>147

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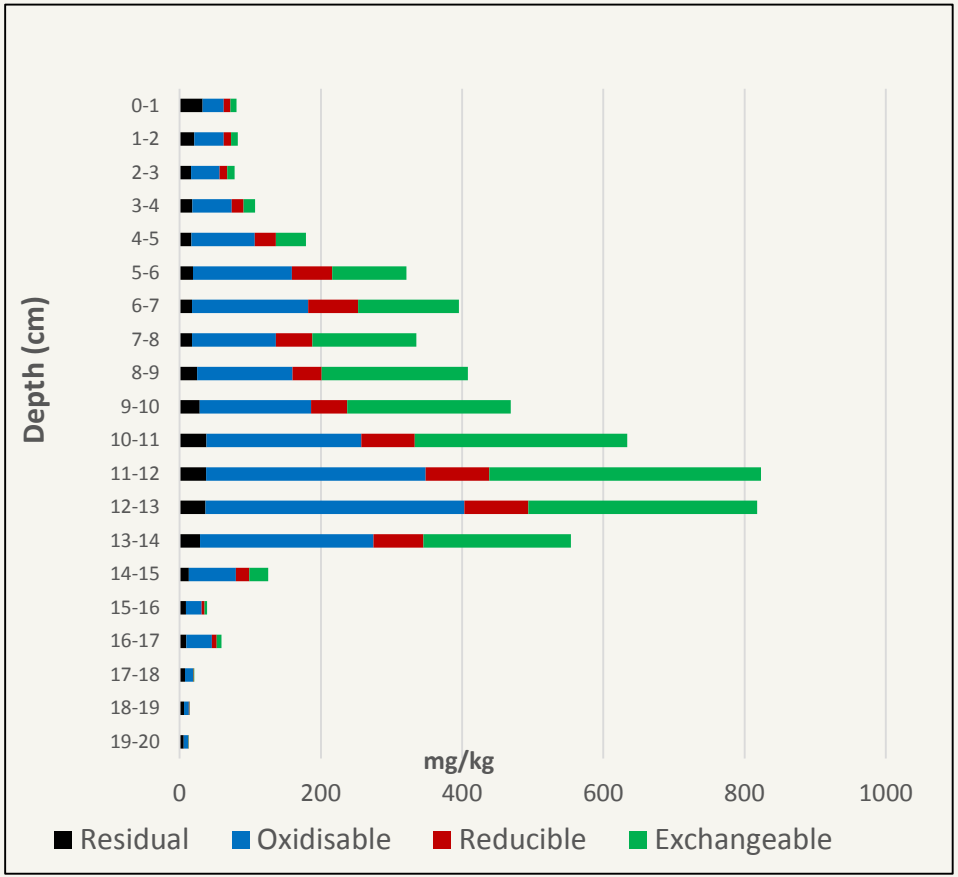

Availability of metals in the sediment

Exchangeable

Ion-exchange, acid-soluble

Reducible

Anoxic release, bound in Fe/Mn oxides

Oxidisable

Aerobic release, bound in organic matter

Residual

Strong acid release, bound in stable minerals

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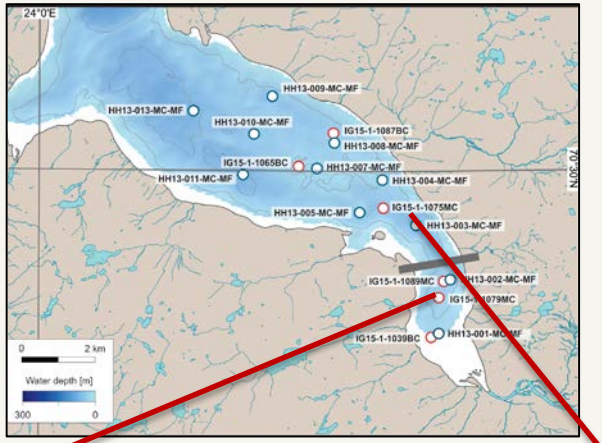
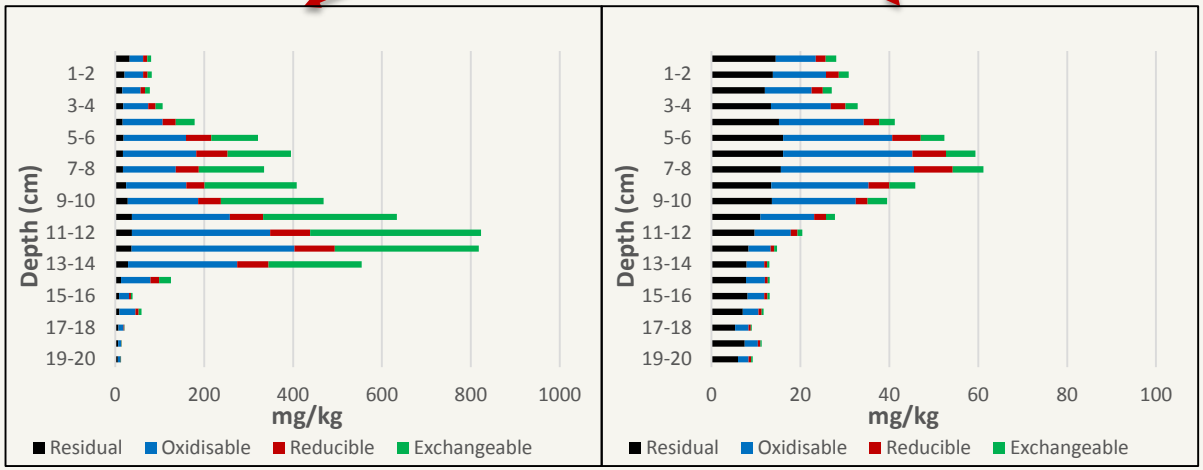
Dispersion of Cu from the submarine mine tailings disposal



Pedersen, K.B.; Jensen, P.; Sternal, B.; Ottosen, L.O.; Henning, M.V; Kudahl, M.M.; Junttila, J.; Skirbekk, K.; Frantzen, M.: *Long term dispersion and availability of metals from submarine mine tailings disposal in a fjord in Arctic Norway*. Environmental Science and Pollution Research 2017

- Elevated concentrations of Cu in the outer fjord
- Most of the excess Cu bound in organic matter
- Indication of historical dispersion
- Present day: no significant dispersion



Dispersion: 1-2km^2; 5-7 cm

2.5-10 ton Cu dispersed fra submarine tailings disposal to the middle part of the fjord

<5 % total amount Cu originally found in the tailings

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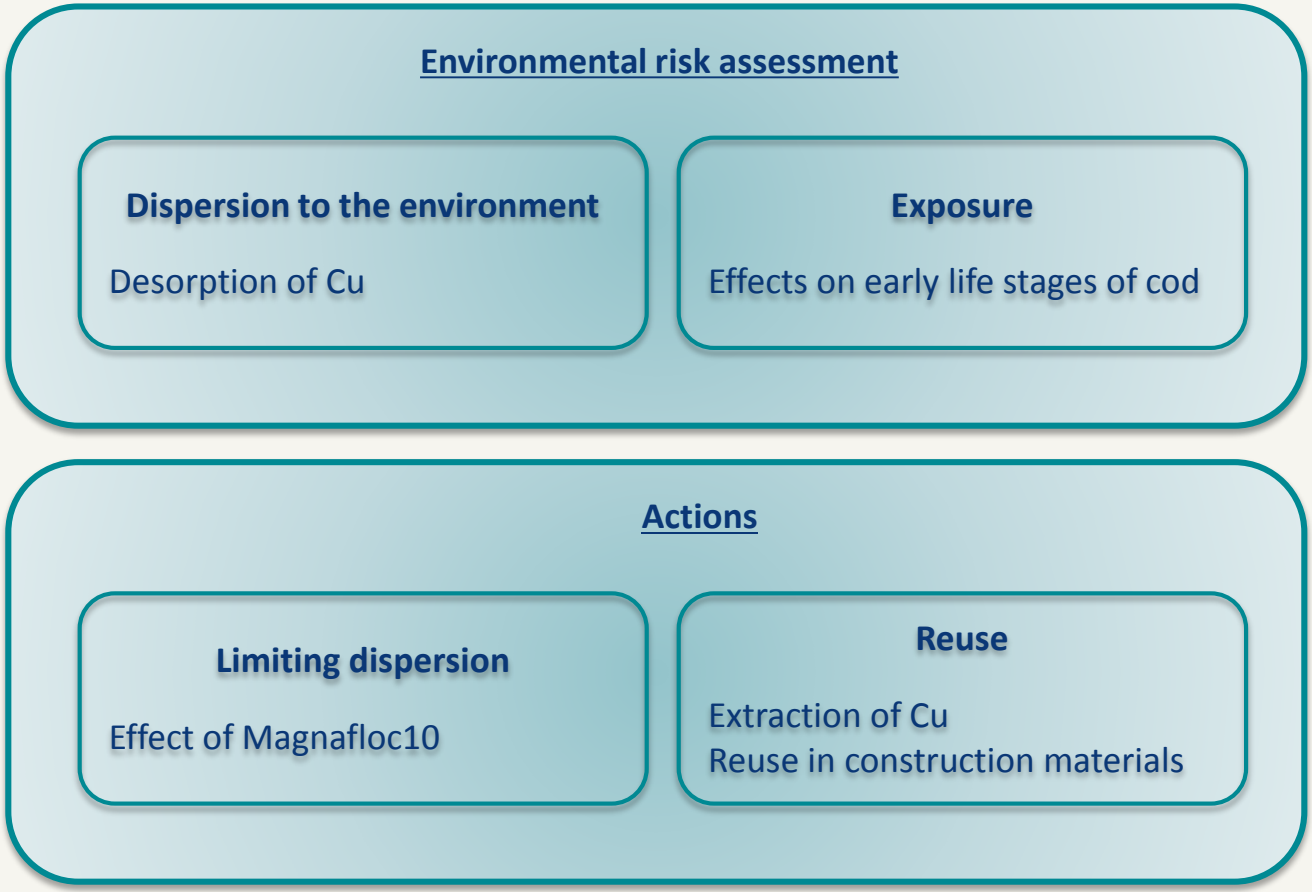
Environmental effects of future mine tailings disposal (2019)



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Mine tailings

- Rock from Nussir (90 %) and Ulveryggen (10 %) ores
- Processed (ground) by SGS Mineral Services, Canada
- Suspended into slurry

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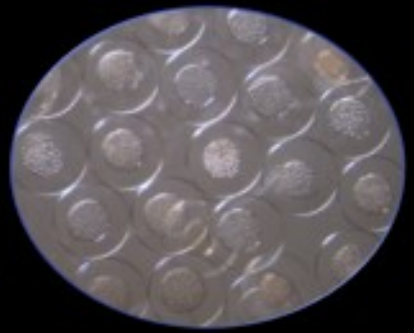
Clear as mud

Key objectives

- Expose newly fertilised Atlantic cod embryos and larvae
- Assess impacts of exposure on mortality, development…
- Investigate sublethal molecular effects
- Understand potential impacts submarine tailings disposal will have on cod spawning in the disposal area



Exposure to early life stages of cod

Lead: Helena C. Reinardy (UNIS)

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EXPERIMENTAL DESIGN

2016:

- 21 day exposure
- 2 hpf – 5 dph
- 12 incubators, 5000 embryos/incubator
- Control, low, mid, high
  (0 - 3.1 mg/L)

2017:

- 28 day exposure
- 1 dpf – 10 dph, including first feeding larvae
- 18 incubators, 5000 embryos/incubator
- Addition of floculant (Magnafloc)
- Control, low MT, high MT, high MT+MF, low MT+MF, MF control
  (0 - 10 mg/L)

Reinardy, H.C., Pedersen, K.B., Nahrgang, J., Frantzen, M..: *Effects of mine tailings exposure on early life stages of Atlantic cod*. ET&C, in review

Reinardy, H.C et al.: *Implications of mine tailings particles adhered to cod eggs and larvae*, in prep.

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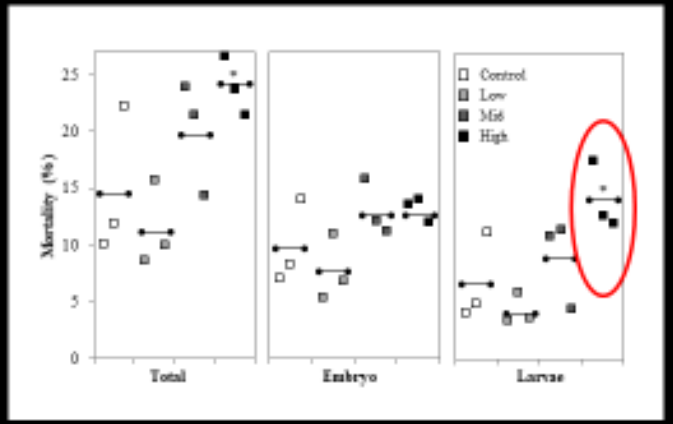
Mortality

2016

- Increased mortality after hatching

2017

- Increased larval mortality, higher overall mortality



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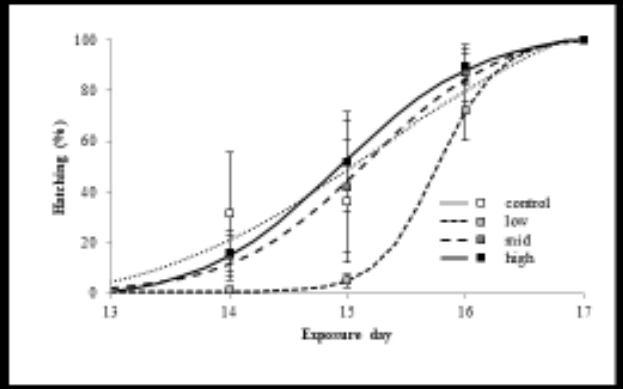
Hatching

2016/2017

- No treatment-related difference in timing of hatching

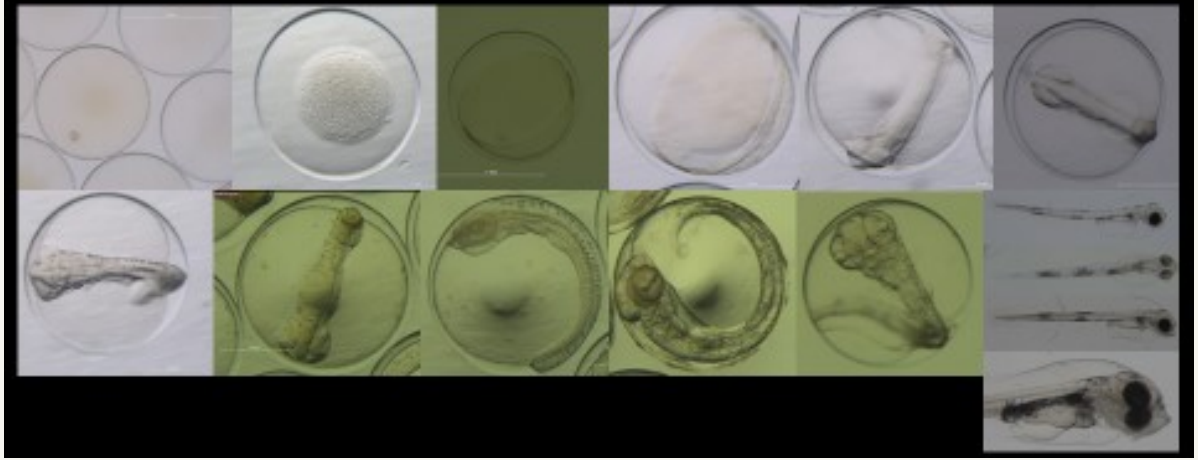


$$y = y_0 + \frac{a}{1+\left(\frac{x}{x_0}\right)^b}$$

Development

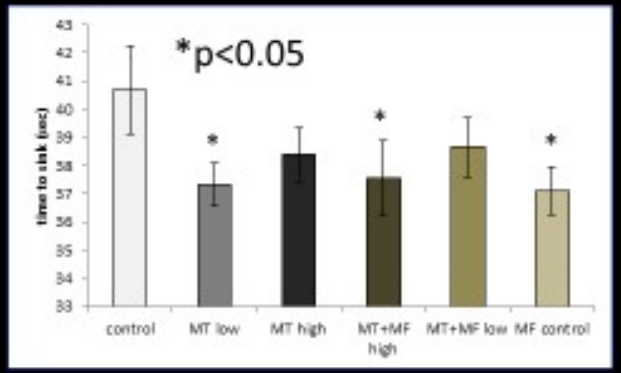
No changes in:

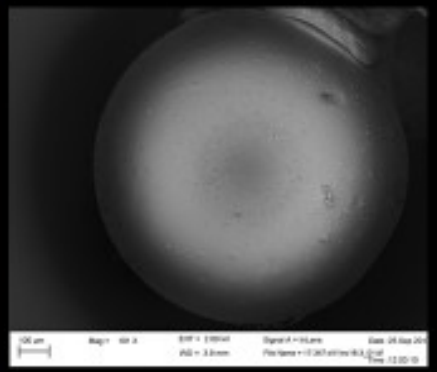
- abnormalities
- embryo and larval heart rates
- developmental morphometrics
- (length, yolk incorporation, head and eye dimensions)
- Larval swimming behaviour

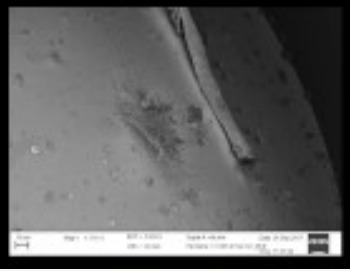


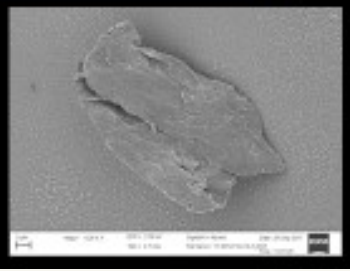
Buoyancy

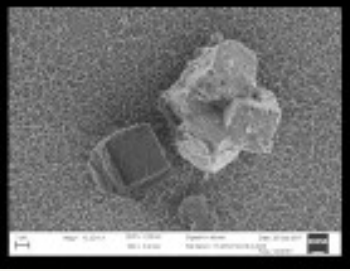
- Do particles on chorion surface affect bouyancy?



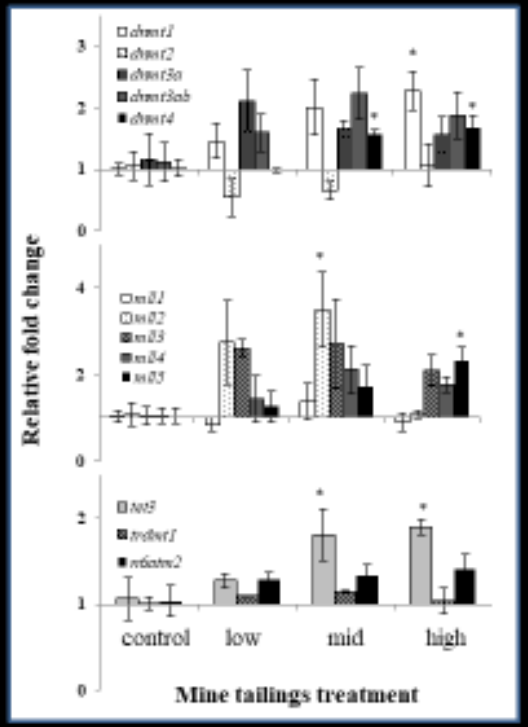








Gene expression: qRT-PCR



2016

- No changes in suite of stress and metal- related genes (*mt*, *hsp*, *cyp*, *p53*
- Changes in DNA and histone methylation gene expression patterns
- Methylation patterns are set during early development – implications on survival and reproduction?

*p<0.05

Risk of exposure (short term/long term)

Risk of exposure

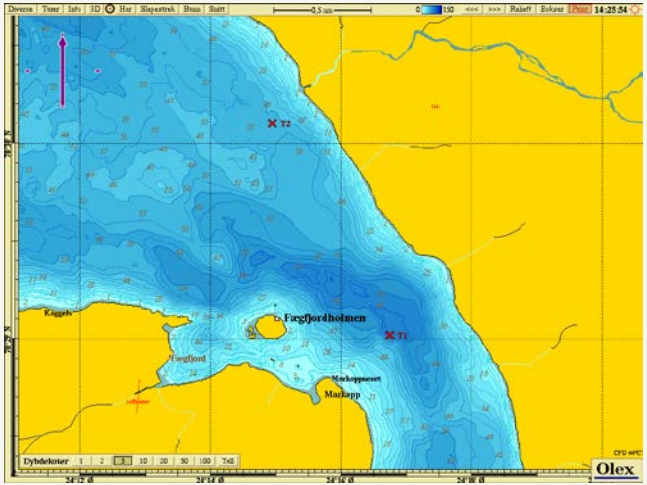
Dispersion of particles

Desorption of metals and process chemicals

Long-term dispsersion of particles

Investigations of currents in Repparfjorden 2016-2017

Current measurements 76-108 days; measurement frequency 10 minutes



Current measurements, results

At seabed, velocity: 4,6-6,4 cm/s

Upwhirling of sediments/particles requires >20 cm/s

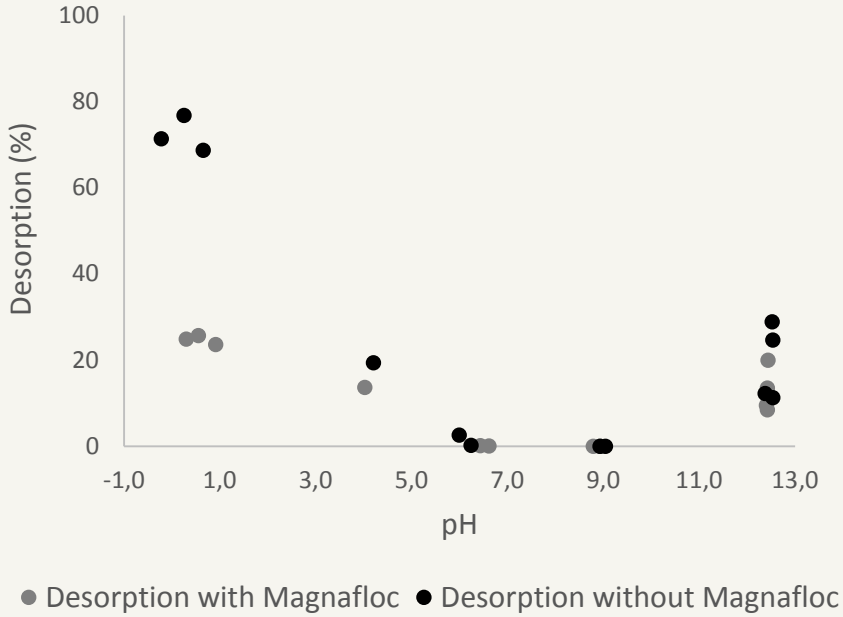
Previous studies showed occasional velocity >20 cm/s (rare occassions)

From the seabed to 30 m above seabed – limited/moderate transport of water out of Repparfjorden

30 m from the seabed and above – potential for transport of water out of Repparfjorden

Thomas Heggem, Øyvind Leikvin: *Strømmåling i Repparfjorden 2016-2017.*
Akvaplan-niva rapport 7592-01

Influence of Magnafloc10 on the desorption of Cu



Desorption experiments:

Mine tailings suspended in distilled water at different strengths of acid/base

Addition of Magnafloc10: 30µg/g mine tailings

Magnafloc10:

Flocculant planned to be added to mine tailings prior to discharge

Increases natural sedimentation by creating flocs

Pedersen, K.B.; Reinardy, H.C.; Jensen, P.E, Ottosen, L.O.; Junttila, J.; Frantzen, M. : *The influence of Magnafloc10 on the acidic, alkaline and electrodialytic desorption of metals from mine tailings*. Journal of Environmental Management 2018

Desorption of copper – influence of fjord chemistry and Magnafloc10

Variable	Range
pH	6-9
Salinity	0.5-40 ppt
Temperature	4-20 ^{o}C
Dissolved organic matter	0.5-20 mg/l
Air/nitrogen	Air or nitrogen
Stirring (upwhirling)	0-1000 rpm
Magnafloc10	0-60µg/g tailings

Desorption experiments

Objective: Evaluate the relative importance of the variables on the desorption of copper

Fractional factorial design – 2^{7-4}

8 + 3 experiments

Small scale experiments – 10 g mine tailings; 25 mL liquid; 21 days

Desorption and binding of copper in the mine tailings

Results: *0.01-0.2% copper desorbed during the experiments*

Equivalent to release of 100-2000 kg per 1,000,000 tons mine tailings

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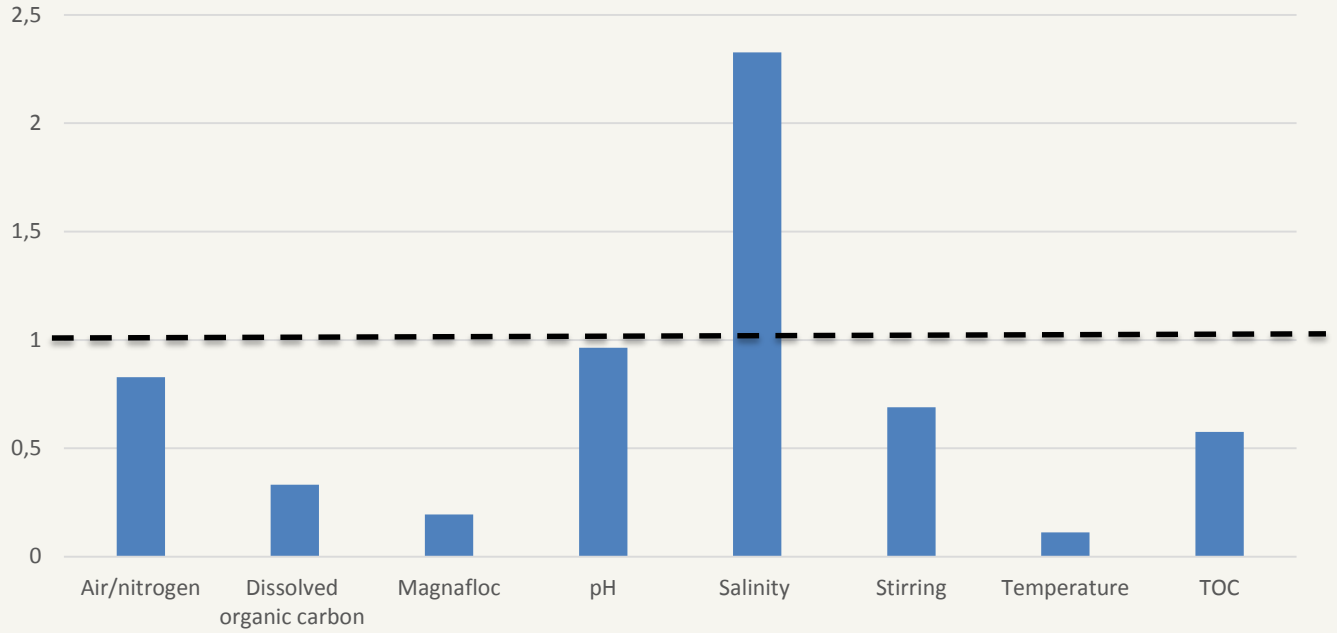
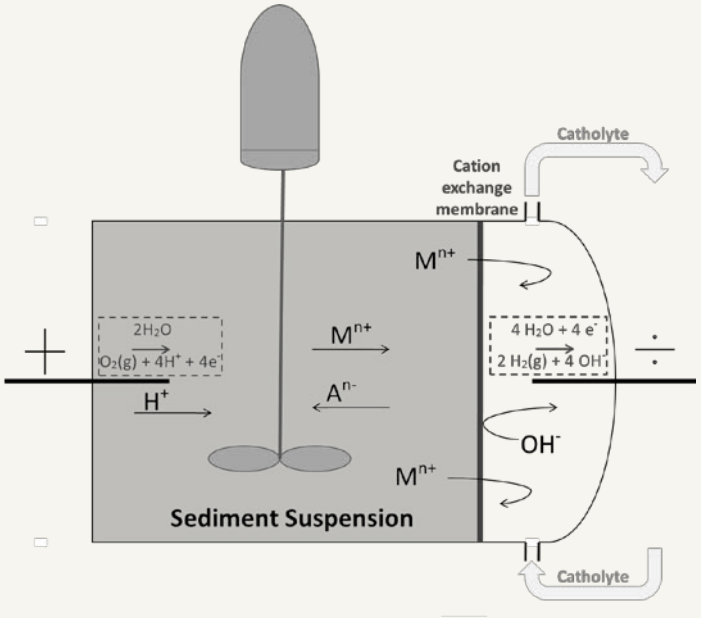
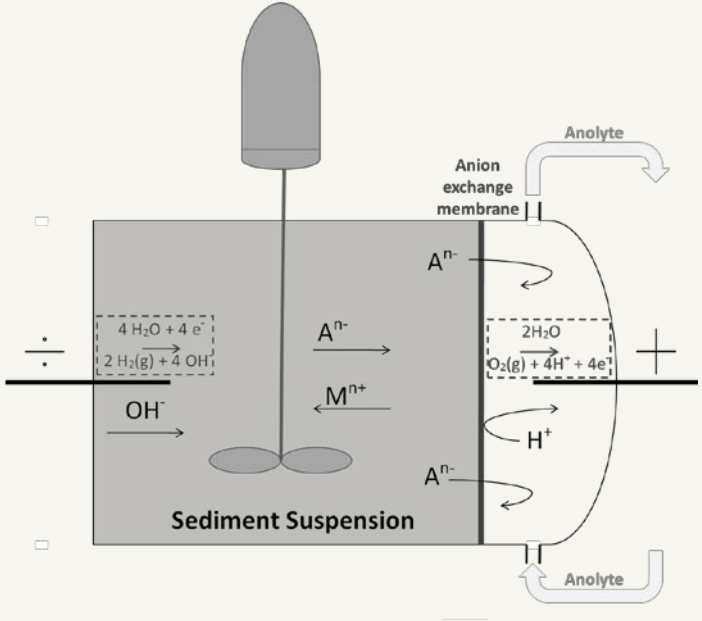
Relative influence of variables on the desorption and binding of copper in the mine tailings (PLS analysis – VIP plot)



Electrodialytic extraction of new mine tailings, 2-compartment cell





Pedersen, K.B.; Jensen, P.E, Ottosen, L.O.; Evenset, A.; Christensen, G.N.; Frantzen : *Metal speciation of historic and new copper mine tailings from Repparfjorden, Northern Norway, before and after acid, base and electrodialytic extraction.* Minerals Engineering 2017

Song, X.; Pettersen, J.; Pedersen, K.B.; Røberg, S.: *Comparative life cycle assessment of tailings management and energy scenarios for a copper ore mine: A case study in Northern Norway.* Journal of Cleaner Production 2017

Experimental variables:
Current: 50 mA
Time: 21-28 days
Acidic/alkaline set-up

Results
Removal of 76-86% Cu
Energy consumption: 17 kWh/g Cu
Alkaline – lower removal of other metals (<1%)

Bøkfjorden

Effects of mine tailings submarine disposal in Bøkfjorden
Anne Mette Tholstrup Simonsen made most of the chemical analysis as part of her master thesis (Copenhagen University)
Bøkfjorden – iron ore mine; low concentrations of priority metals and low mobility of iron
http://aktuelnaturvidenskab.dk/fileadmin/Aktuel_Naturvidenskab/nr-5/AN5-2017mineaffald.pdf


MINEAFFALD UNDER VAND

- den gode historie om miljøskånsom deponering

En ny undersøgelse viser, at mineaffald fra en jernmine deponeret i en norsk fjord ikke har medført en nævneværdig forurening, fordi tungmetallerne er bundet hårdt til jern i affaldet. Det er ny og vigtig viden i relation til fremtidig minedrift i for eksempel Grønland.

Foto: Kristine B. Pedersen.

Om forfatterne:

Anne Mette T. Simonsen er geograf fra Københavns Universitet. Artiklen udsprunger af AMTS' ...

Bo Elberling er professor i miljøbiologi og leder grundforskningscenteret Center for Permafrost (Cryosphere), Københavns Universitet. be@ign.ku.dk

Kristine B. Pedersen er forsker i metalforurening og rensning ved Alcoa ... Tomsk. kristine.pedersen@alcoa.com.ru

Lis Bach er artsbiolog, ekotoksikolog og seniorrådgiver ved Bioscience, Aarhus Universitet. lb@bios.au.dk

Vi tænker ikke over det til dagligt, men vores samfund er drevet og afhængig af råstoffer, som gemmer sig under jordens overflade. Råstofferne er nødvendige for de kyllepenicler, vi omgiver os med. Men mellem 20 og 90 % af den malm, der udvindes fra miner, ender som affald, og mineselskaberne er udfordret med at håndtere affaldet på en ansvarlig måde, uden at omkostningerne gør minedriften urentabel. Der er en reel bekymring for de konsekvenser, mineaffaldet kan have på naturen på grund af affaldets forhøjede metalindhold. Der findes mange eksempler på betydelige negative effekter, når miljøet bliver udsat for høje metalniveauer. Et af de mest berygtede eksempler på utilsigtet forurening fra mineafald findes ved Den Sorte Engel ved Maarmorilik i det nordvestlige Grønland. Mere end 30 år efter minen blev indstillet, kan man stadig spore rester fra deponeringen af de 8-9 millioner tons bly- og zink-affald, som både blev placeret over og under vand.

Præmissen for at deponere mineaffald under vand er forventningen om, at der ikke forekommer omfattende spredning eller miljøeffekter ved deponering. Mineselskabernes planer og forudsigelser for affaldshåndteringen skal godkendes af myndighederne, inden mineralkoncessionen kan startes sin operation. Alligevel kan det hænde, at uforudsete naturlige processer kan have en uheldig indvirkning på mineaffaldet.

Nye resultater har vist, at marin deponering af mineaffald ikke altid har konsekvenser for miljøet. Resultaterne blev opnået af et hold forskere, som i efteråret 2016

34 AKTUEL NATURVIDENSKAB | NR.5 | 2017

Anne Mette T. Simonsen & Kristine B. Pedersen & Lis Bach & Beata Sternal & Juho Junttila & Bo Elberling: *Applying Chemometrics to Determine Dispersion of Mine Tailing-Affected Sediments from Submarine Tailing Disposal in Bøkfjorden, Northern Norway.* Water, air, soil pollution 2018

Anne Mette T. Simonsen & Kristine B. Pedersen & Pernille E. Jensen & Lis Bach & Bo Elberling: *Toxicity of heavy metals from Submarine Tailings Disposal: The relationship between metal fractionation and metal uptake by study organism.* In prep.

THANK YOU!

EWMA Environmental Waste Management

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eni norge

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