Metal fluxes from a sea deposit site for mine tailings

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Norwegian Institute for Water Research (NIVA)

NRC Project ES532333

New knowledge on submarine tailings disposal (NYKOS)

WP 4: Effects of mine tailings and associated chemicals on marine, benthic ecosystems

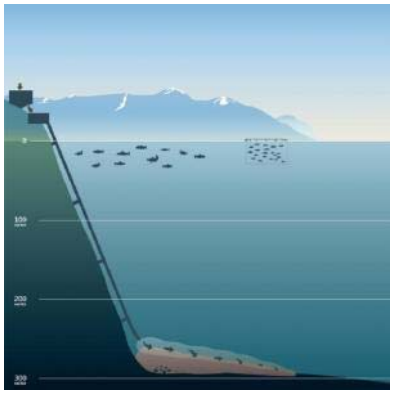
Funded

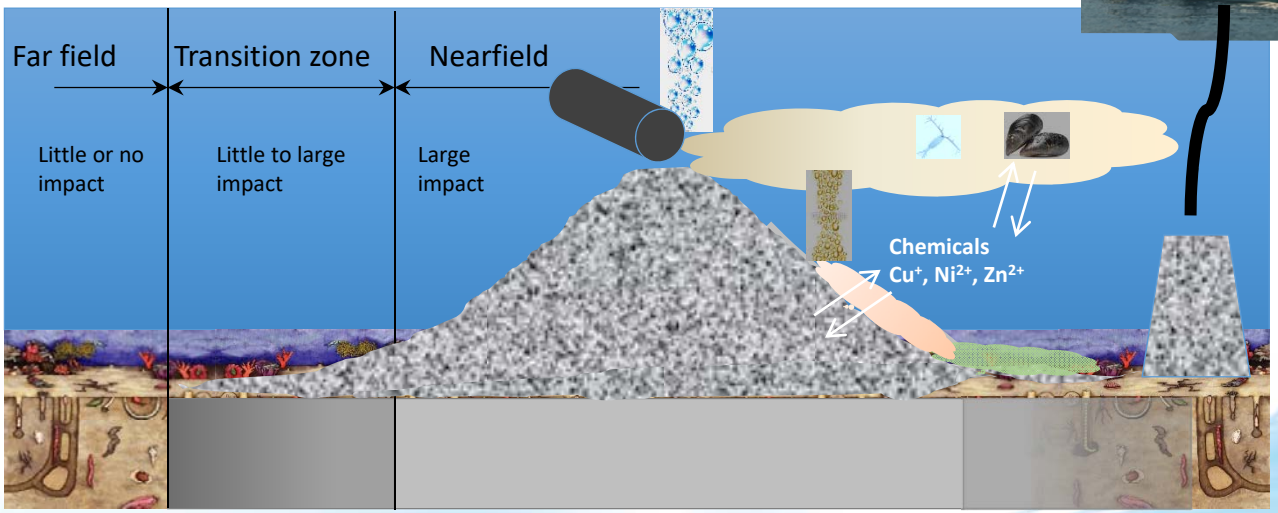
80 % by the Norwegian Research Council.

20% from industry partners

Titania As, Rana Gruber As, Omya Hustadmarmor As, Sibelco Nordic As, Sydvaranger Gruve As, Nordic Mining Asa, Nussir Asa

Subsea deposition challenges



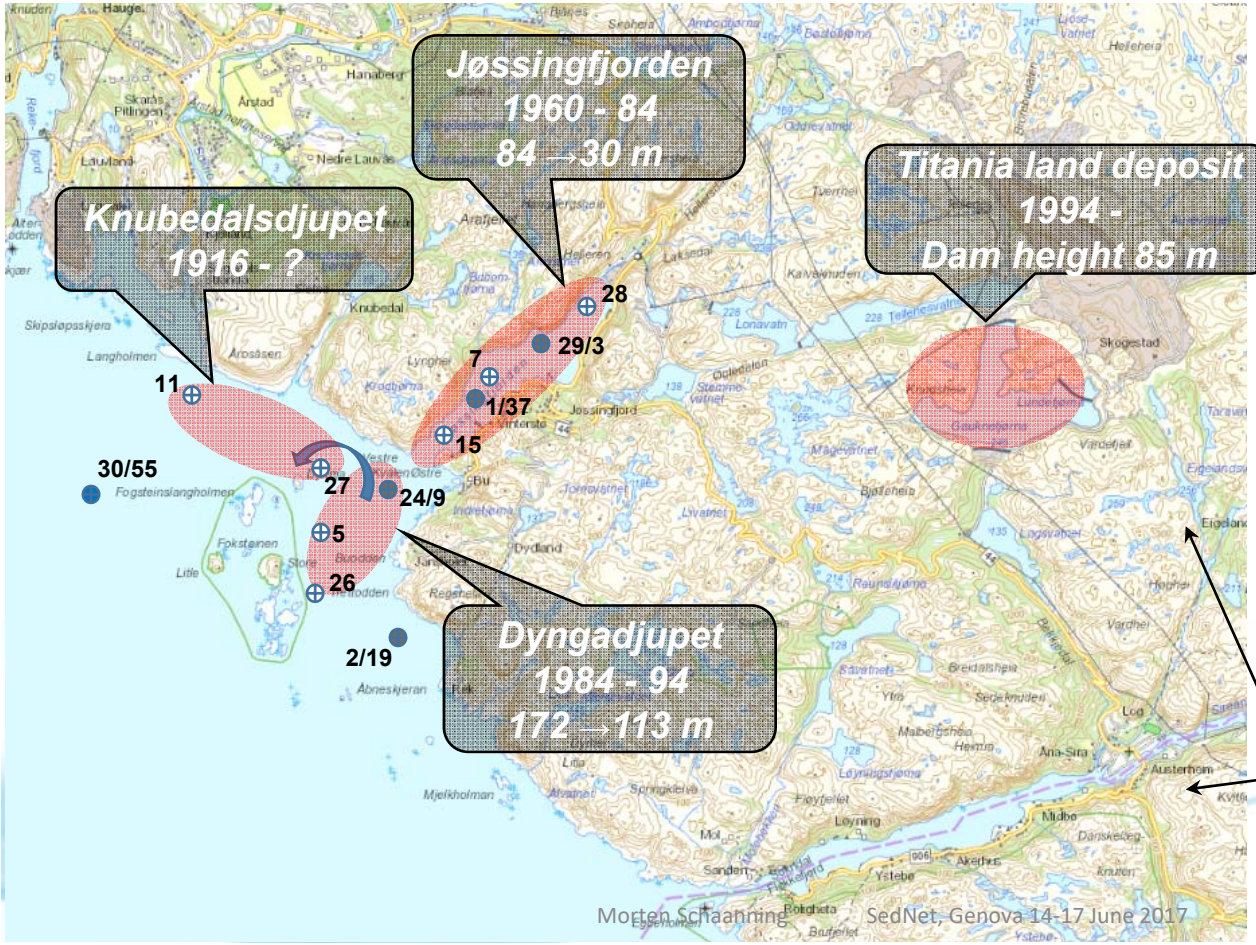


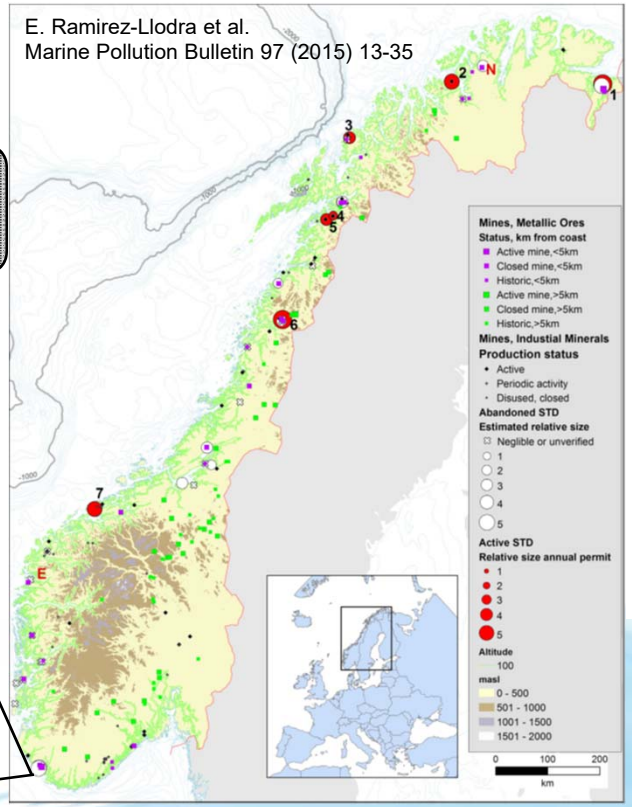
Titania AS
7% of world production of ilmenite

- Exploiting the Tellenes ore in South Norway
- ~ 30-40% ilmenite $FeTiO_3$
- ~18% titanoxide TiO_2
- pigment for paint, cosmetics, food design and more
- <2% sulfide minerals

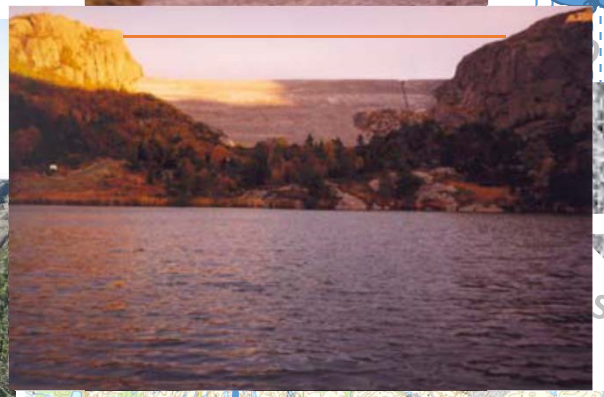
	Tailings ($\mu g\ g^{-1}$)	Discharge water ($\mu g\ L^{-1}$)
Cobolt	-	83
Cadmium	<0.05	-
Lead	<0.20	-
Copper	140	8
Chromium	49	<8
Nickel	270	1 370
Zinc	15	84
Mercury	0.013	-

Location


Jøssingfjorden
1960 - 84
84 → 30 m
Knubedalsdjupet
1916 - ?
Titania land deposit
1994 -
Dam height 85 m
Dyngadjupet
1984 - 94
172 → 113 m
28
29/3
7
1/37
15
11
30/55
27
24/9
5
26
2/19

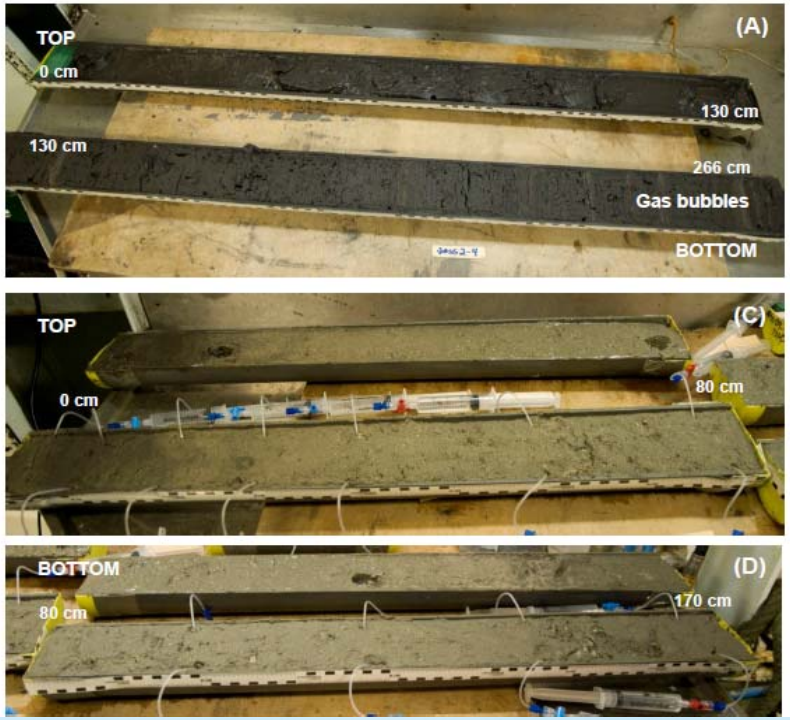

E. Ramirez-Llodra et al.
Marine Pollution Bulletin 97 (2015) 13-35
Mines, Metallic Ores
Status, km from coast
Active mine,<5km
Closed mine,<5km
Historic,<5km
Active mine,>5km
Closed mine,>5km
Historic,>5km
Mines, Industial Minerals
Production status
Active
Periodic activity
Disused, closed
Abandoned STD
Estimated relative size
Negligible or unverified
1
2
3
4
5
Active STD
Relative size annual permit
1
2
3
4
5
Altitude
100
masl
0 - 500
501 - 1000
1001 - 1500
1501 - 2000
0
100
200
km

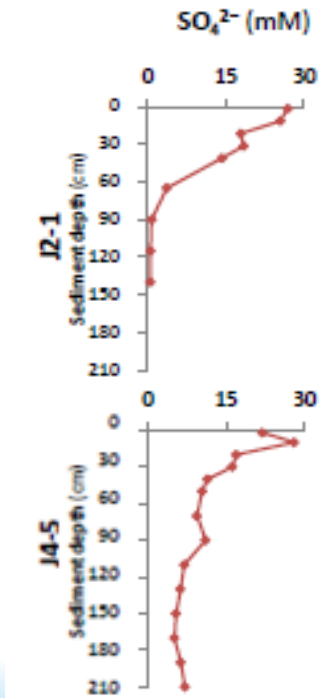
Titania land deposit



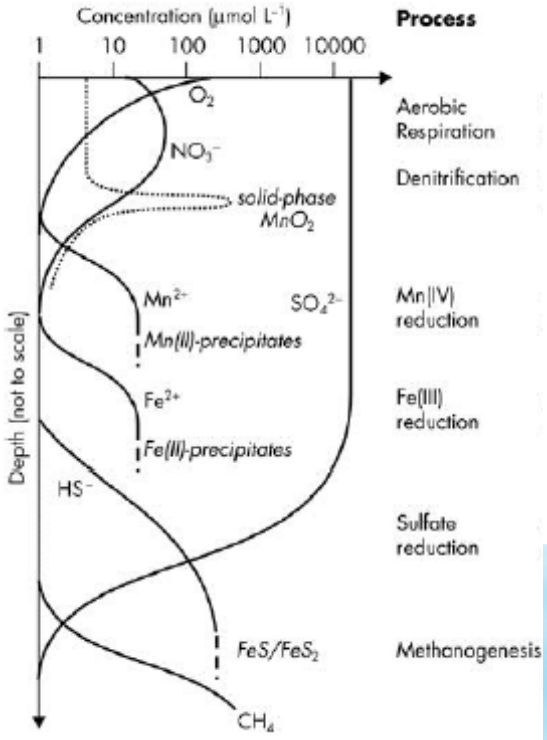
Titania sea deposit

From Gravdahl, 2013. Stability of heavy metals in submarine mine tailings. MSc thesis, UiB.



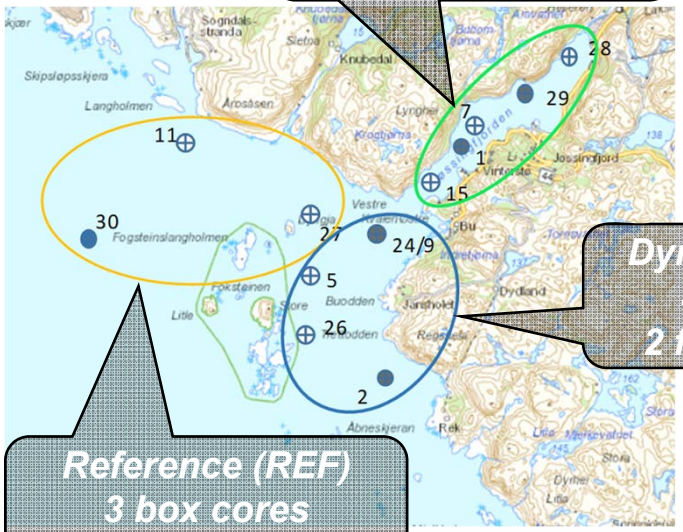


Model after Konhauser, 2007:



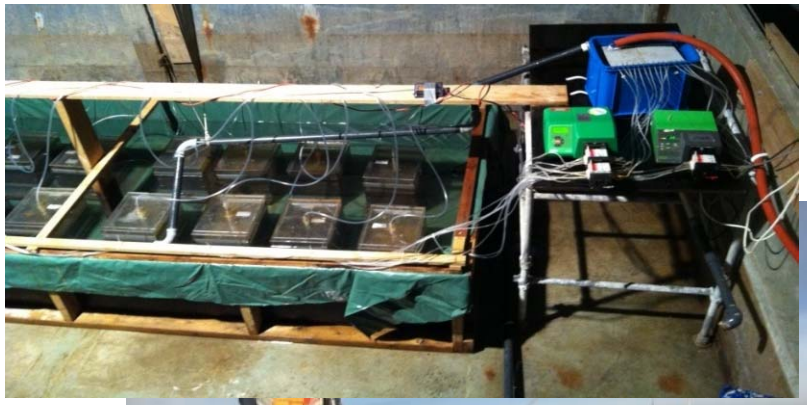
Sampling and set-up

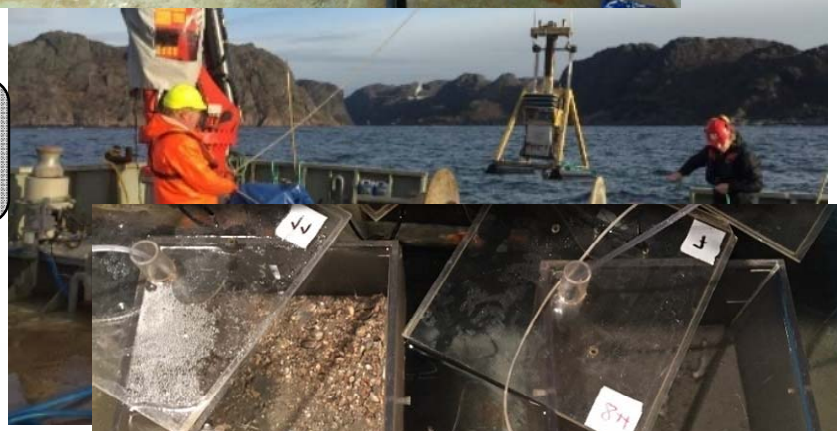
Jøssingfjorden (JF)
5 box cores
2 fauna stations



Reference (REF)
3 box cores
1 fauna stations

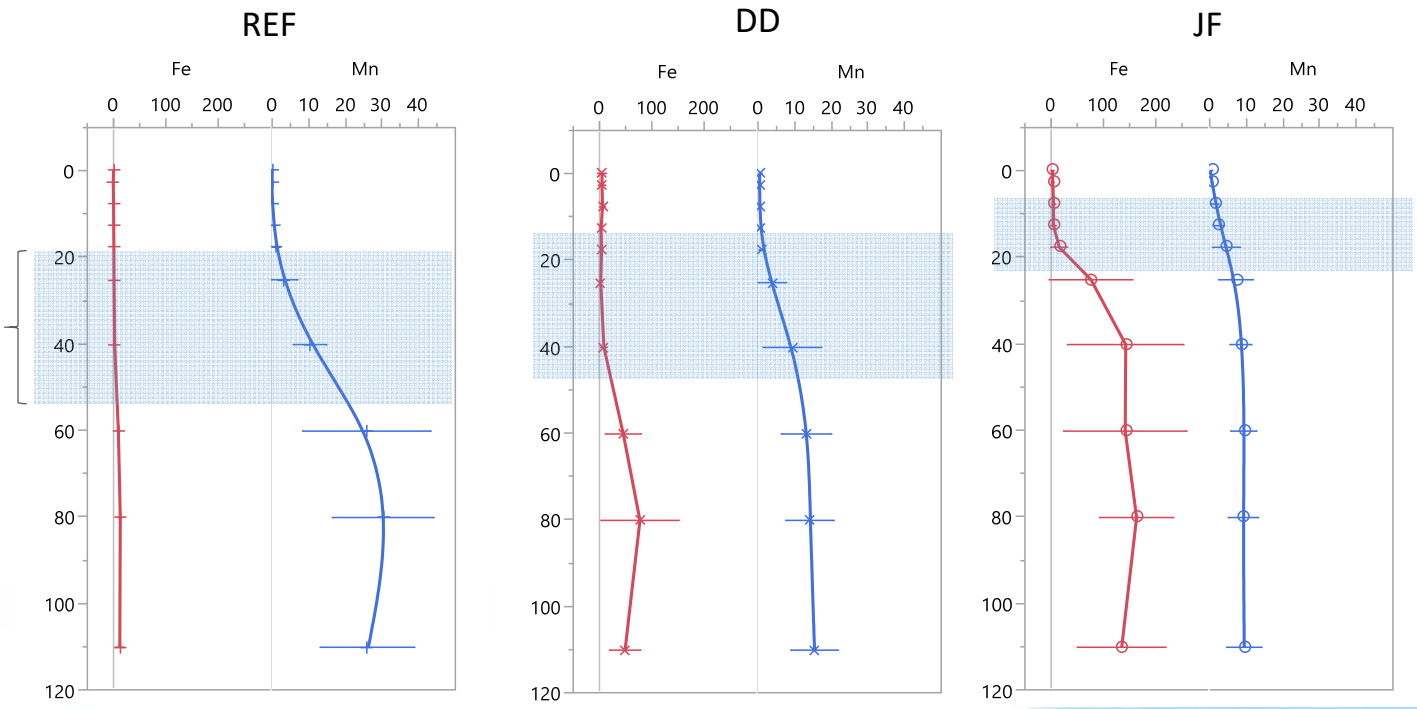
Dyngadjupet (DD)
4 box cores
2 fauna stations





DGT-probes; Fe & Mn

Fe&Mn redox transition zone

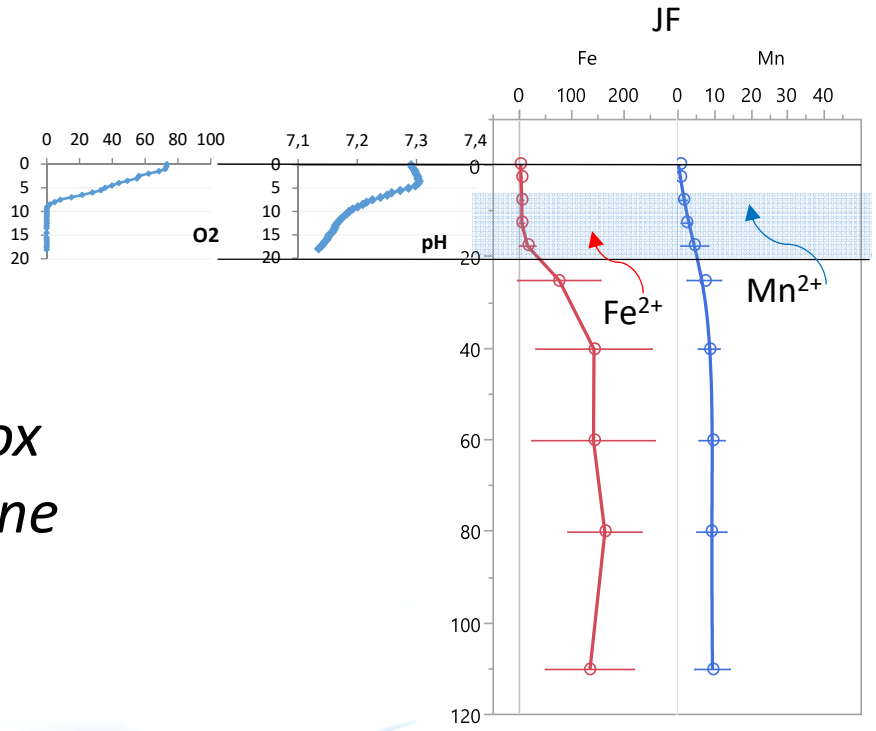


C*10 = ng cm^{-2}

Oxidation, precipitation and acidification

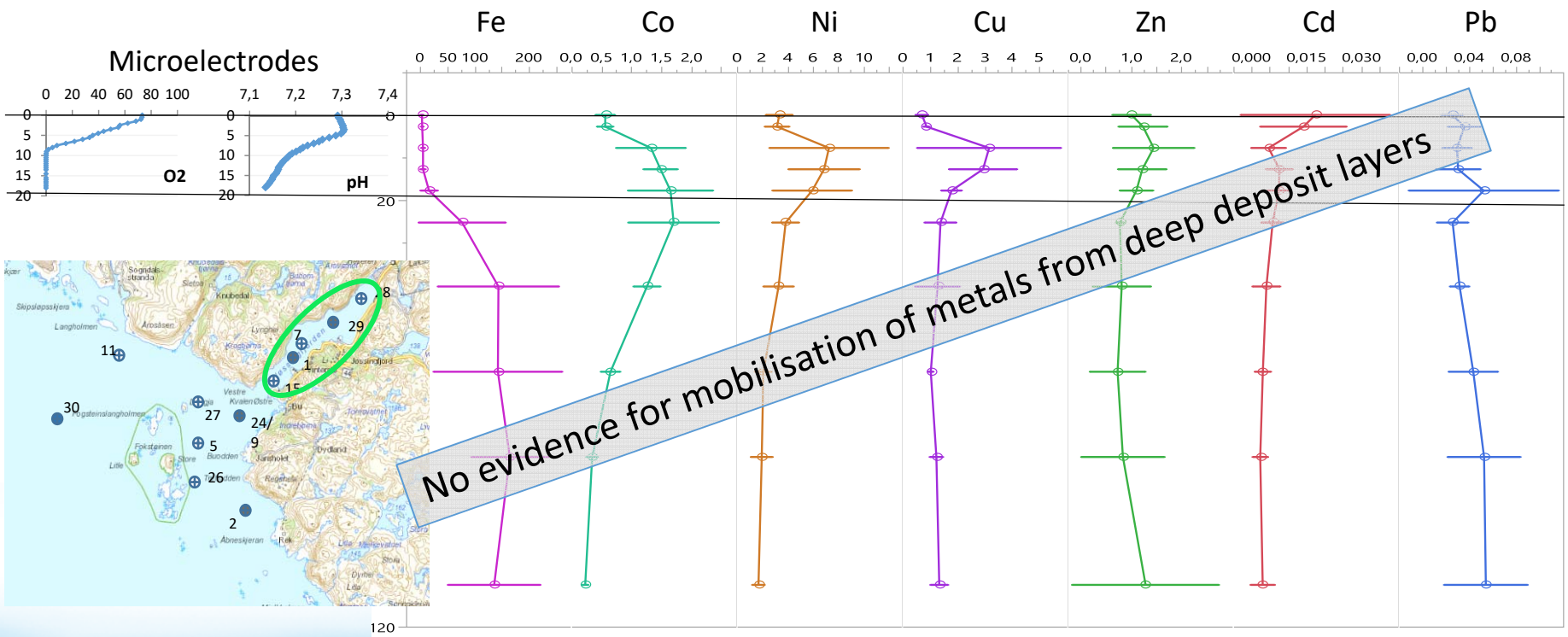
$Mn^{2+} + 1/2O_2 + H_2O = MnO_2 + 2H^+$

$Fe^{2+} + 1/4O_2 + 5/2H_2O = Fe(OH)_3 + 2H^+$



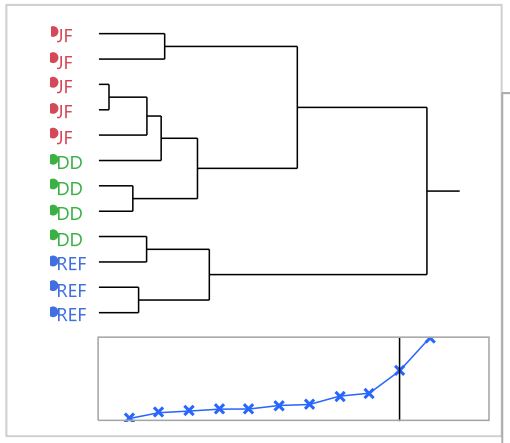
Fe&Mn redox transition zone

DGT-probes; Metals in Jøssingfjorden deposit

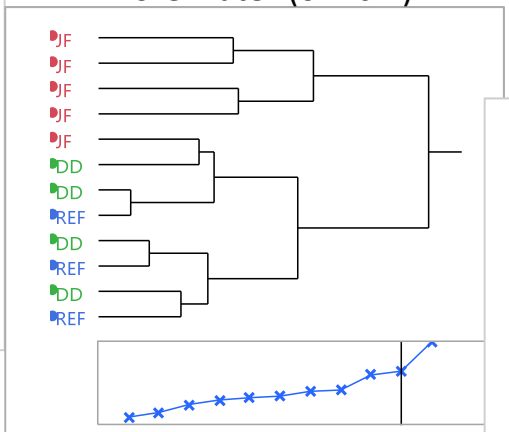


Cluster analyses of Ni, Cu, Co, Zn and Cd in various matrixes

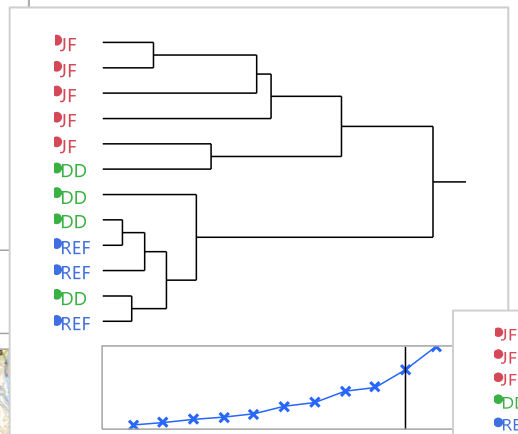
Sediment (0-1 cm)



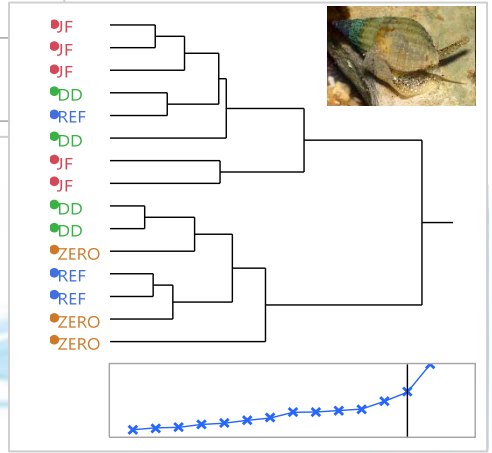
Pore water (0-1 cm)

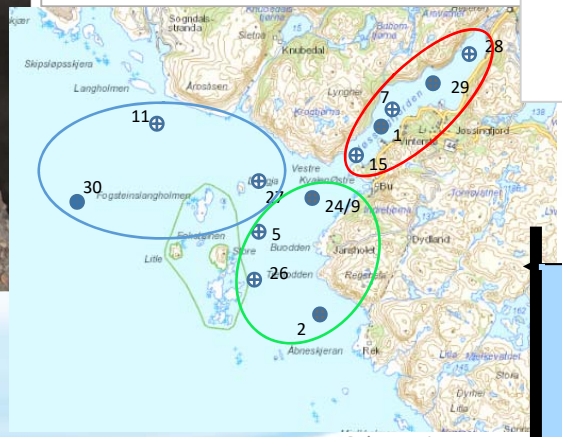


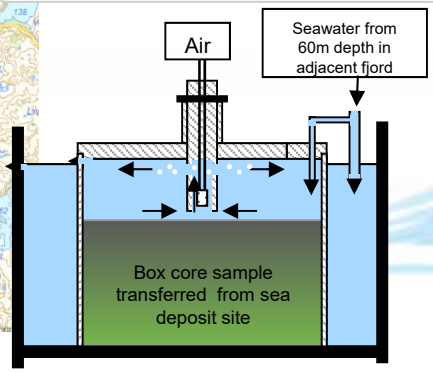
Flux from sediment to water



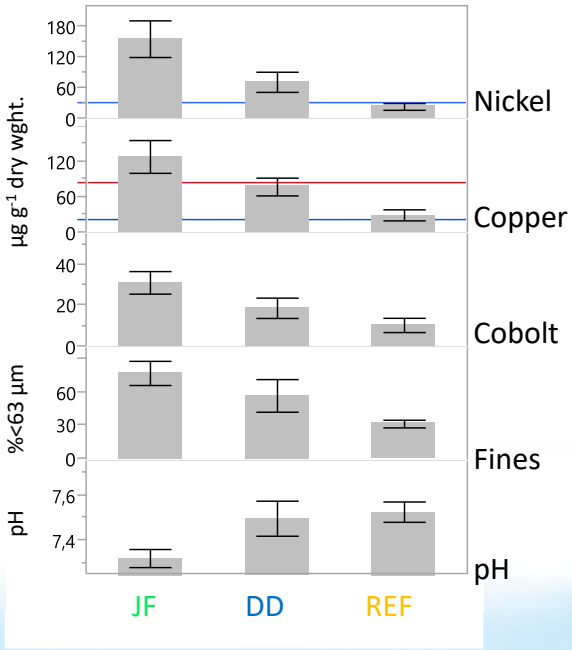
Snails (*Hinia reticulatae*)

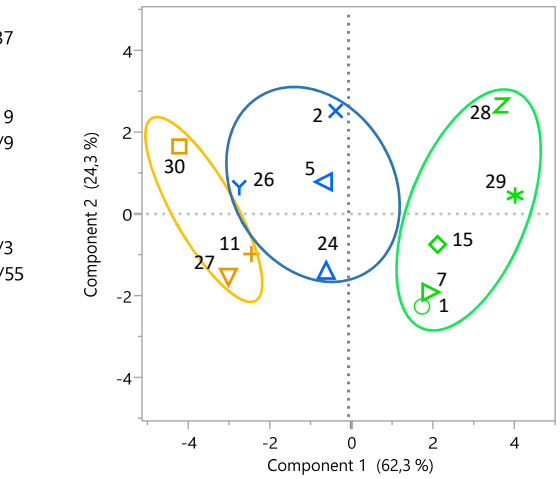


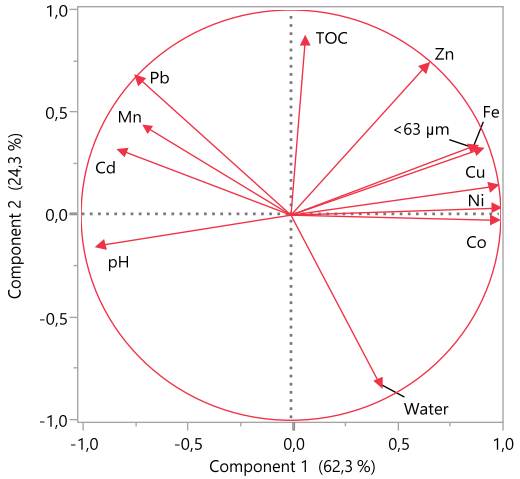


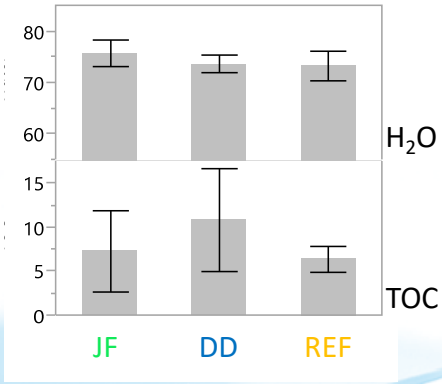


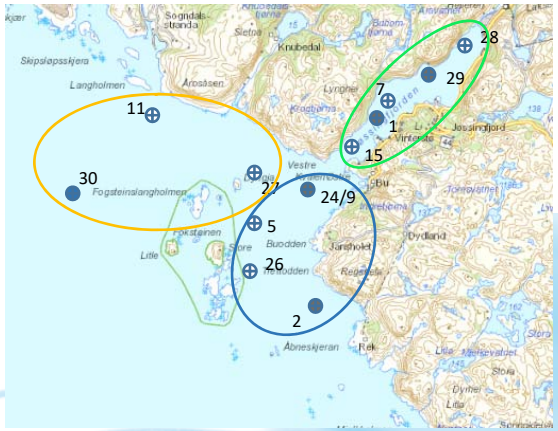
Surface sediment (0-1 cm)



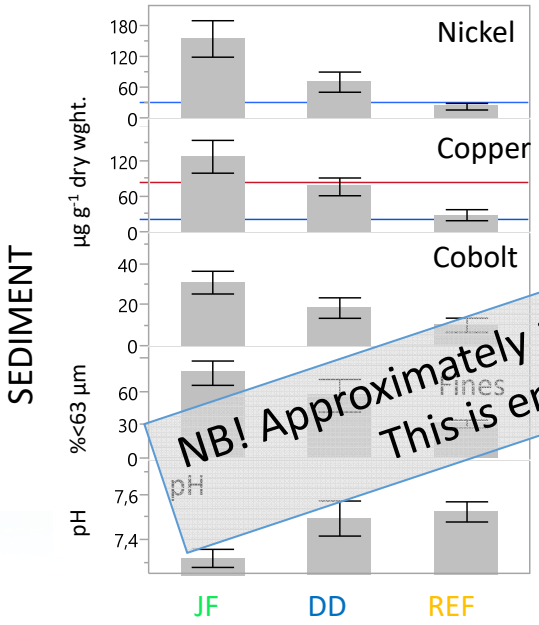


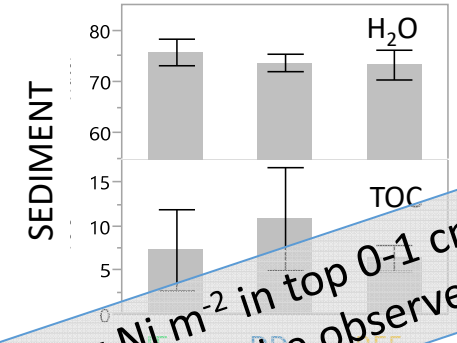


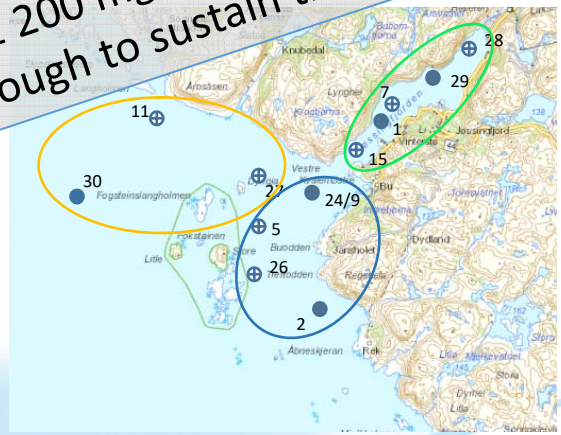


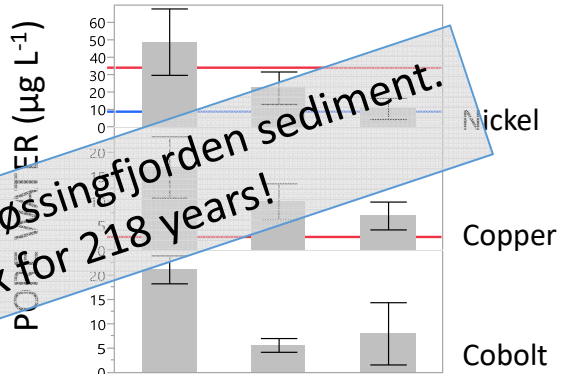


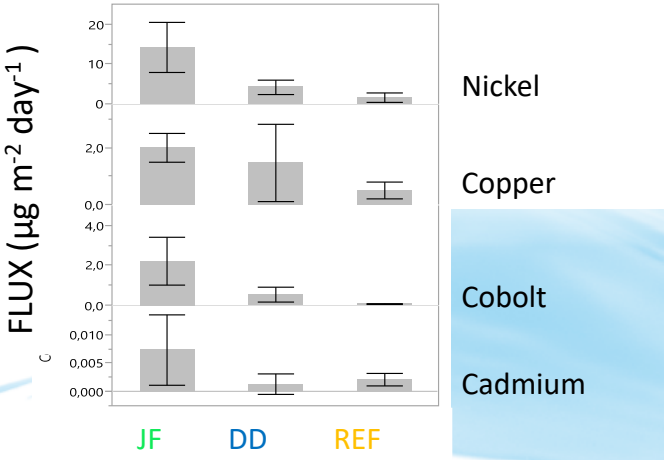
Sediment, pore water and fluxes to overlying water











NB! Approximately 1 200 mg Ni m^{-2} in top 0-1 cm of Jøssingfjorden sediment.
This is enough to sustain the observed flux for 218 years!

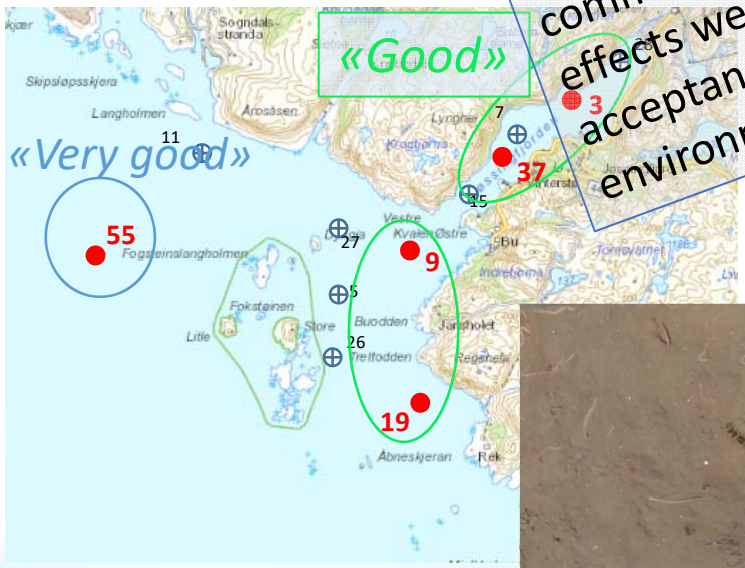
Summary of EQS exceeded

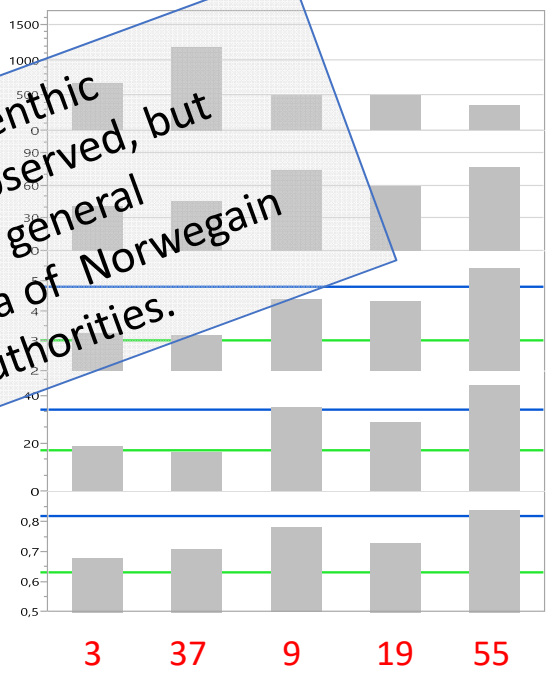
		Copper	Nickel
JF deposit	Sediment	Acute	Chronic
JF deposit	Pore water vs EQS for Coastal water	Acute	Acute
DD deposit	Sediment	Chronic	Chronic
DD deposit	Pore water vs EQS for Coastal water	Acute	Chronic
REF	Sediment	Chronic	No
REF	Pore water vs EQS for Coastal water	Acute	Chronic

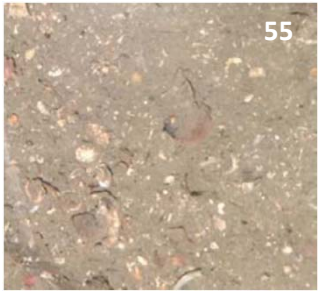
High risk of effects on organisms living in deposit sediments!

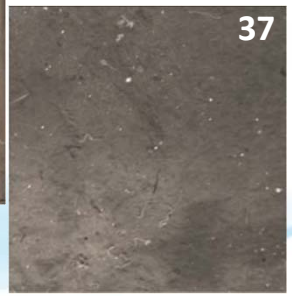
Benthic fauna (>1mm)

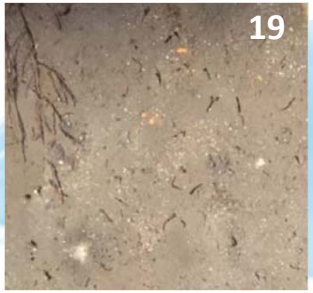
Reduced quality of benthic communities was observed, but effects were within general acceptance criteria of Norwegain environmental authorities.



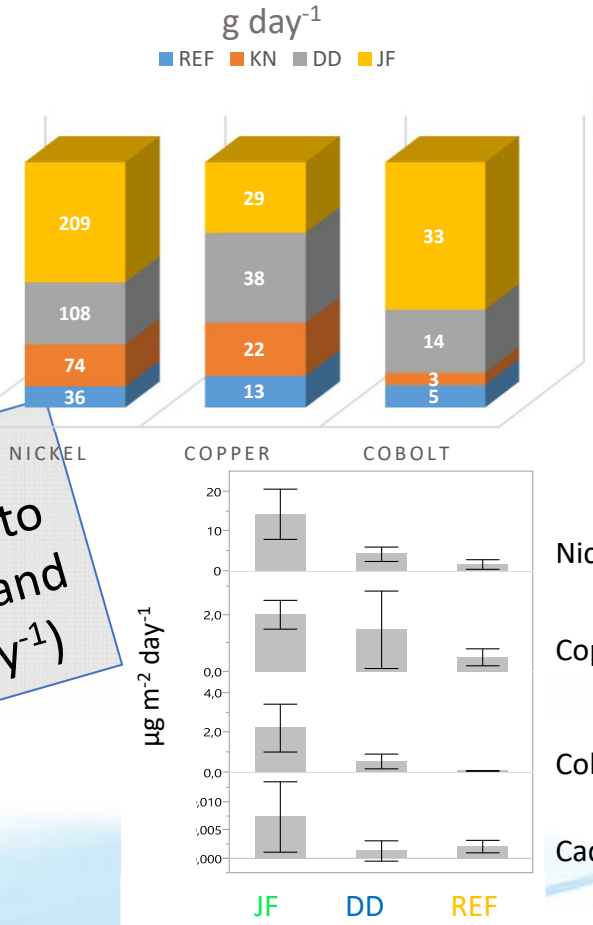


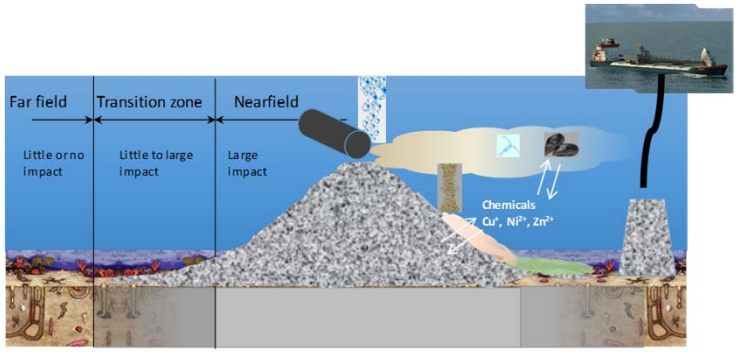




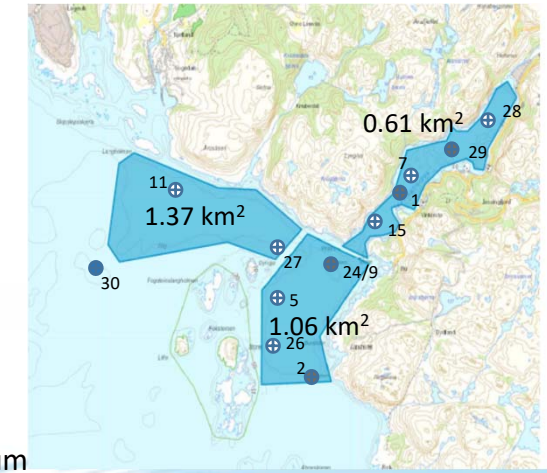


Fluxes from sediment to water





Flux of nickel from sea deposits corresponded to 5.2% of leakage from land deposit (7 500 g Ni day^{-1})



Nickel

Copper

Cobolt

Cadmium

Conclusions

- EQS for Ni and Cu were exceeded in sediments in all deposit sites for mine tailings (i.e. Jøssingfjorden, Dyngadjupet and Knubedalsdjupet)
- Quality criteria for benthic communities were reduced compared with reference station, but within acceptance criteria of Norwegian legislation
- Leakage of nickel from all deposit areas was ~5% of leakage from land deposit
- No evidence for upwards diffusion of metals from deep deposit layers (DGT probes)

  =>Leakage of metals to the overlying seawater is proportional to area rather than volume of deposit
- Concentration of metals in surface sediments was enough to sustain observed fluxes for ~200 years

  => natural sedimentation will slowly reduce leakage after deposition is ended

Recommendations

- If leakage of metals is proportional to deposit area rather than volume,

  =>sea deposit should be confined within clear boundaries by natural bathymetry (semienclosed basins) or subsea dam constructions

- If concentration of metals in surface sediments are enough to sustain observed fluxes for ~200 years

  => enhancement of natural recovery by postdeposition capping may be a good option

That's all,

thank you for your attention!