Dispersion and Transfer of NOR & Metals due to Construction in U-bearing Minerals
Case: Road- and Tunnel-construction

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Why Road- and Tunnel Construction?

• Black shale minerals - ALUM SHALE
  – Sedimentary minerals that might produce sulfuric acid
  – Contains a lot of radionuclides, metals, etc.
  – Exceeding easily the limit of 1 Bq/g for U

• Lots of Alum Shale in Norway and the rest of Scandinavia

• With the new Norwegian pollution act and BSS, building roads and tunnels is no longer straight forward
  – Produce large amount of radioactive waste
  – Contaminate the surrounding environment by leachate to aquatic environment
Effects and environmental risks associated with interventions in areas of alum shale minerals.

Main objective:

- Consider the mobility, uptake and effects of radionuclides and metals from alum shale, in order to say something about the environmental impacts and risks associated with road and tunnel construction and dumping of tunnel waste.

  - Impact from construction work?

Site: The construction of new road and tunnel at Rv4 at Gran, Hadeland, Norway
Alum shale (oil shale) from the new tunnel – deposit into bog, re-use of the masses under the new road
Risk and impact from NORM – Lessons learned/confirmed

What have this case-study confirmed:
• There is also a need to look into other stressors alongside NORM that could add to the risk and impact.
• Not only measurements of total concentrations – this can overestimate the environmental risk assessments
• Important need of other water quality parameters (pH, Eh, Ca content etc.) to explain results.

Multiple stressors such as organics and metals can simultaneously affect the same sensitive biological endpoints as radionuclides, resulting in additive, synergetic or antagonistic effects.
What did we do in the project?

• Source characterisation - fieldworks
  – Samples: water (total and fractionation), soil, sediments, plants, fish organs, benthic organisms
  – Before construction work, during construction work - spring and autumn
  – Identifying heterogenities in minerals, soils and sediments
• Laboratory experiments
  – Leaching experiments and sequential extractions
  – Uptake and effect studies
• Radionuclides (U, Th, Po-210) and metals (Cd, Al, Cu, As, etc.)
• Risk and impact assessment…
Concentrations in water

WHO: drinking water limit 30 ug/L

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<th></th>
<th>Al</th>
<th>Ca</th>
<th>V</th>
<th>Mn</th>
<th>Fe</th>
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<td>13 ± 4</td>
<td>0.35 ± 0.1</td>
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<td>0.29 ± 0.02</td>
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<td>&lt;0.016</td>
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Fish *Salomo trutta* – field studies

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<tbody>
<tr>
<td>Po-210 in bone (Bq/kg)</td>
<td>3.29</td>
<td>2.04</td>
<td>0.56</td>
<td>0.69</td>
<td>0.80</td>
<td>1.11</td>
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<td>703</td>
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<td>386</td>
<td>175</td>
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</table>

- Clearly uptake, but low concentrations of U and other metals (much Mo and Cd)
- Could be small increase in uptake due to construction work
- Low levels of Po-210 in bones but relatively high Cf (as seen elsewhere in Scandinavia)
- No effects observed!
Uranium on fish gills

\[ \gamma(\text{K34 AS}) = 0.0462 \ln(x) + 0.1047 \]
\[ R^2 = 0.68228 \]

\[ \gamma(\text{Rv.4 AS}) = 0.0271 \ln(x) + 0.0319 \]
\[ R^2 = 0.75702 \]
Benthic community – ASPT index score
Risk assessment

• ERICA tool
  – Modelling of radiological dose to biota
• EQS – environmental quality standards
  – Possible effects from toxic metals
• Cumulative risk estimation
  – Modelling of chemical toxicity on biota

• Used actual data from the fieldwork in 2015
Risk assessment of field data – ERICA

- Measured activity of $^{238}\text{U}$, $^{232}\text{Th}$ and $^{210}\text{Po}$ in water, sediments and organisms was used to estimate the effect (screening value 10 µGy/h).
- ERICA assessment tool provides an estimate of the expected dose rate and an estimate of conservative dose rate for selected organisms.

![Graph showing dose rate for different organisms](http://www.erica-tool.com/)

http://www.erica-tool.com/
Cummulative risk estimation of U and metals

- Model to identify the organisms at risk (chemical toxicity)

- Predicted risk:
  Algea > Bentic > Fish

- Elements giving possible risk of toxicity:
  - U – 90% for algea
  - Ni – 46% for bentic
  - Al – 95% for fish

Total risk:
> 1 predicting risk
> 10 predicting high risk
Conclusions

• There is an effect on the benthic community in the area – significantly affected by the construction work.
• No effects seen on fish in the field.
• Both in the field and in the fish experiments, clear uptake of U and other elements was shown for gills, kidney and liver. Po-210 was found in bones.
• High pH and high Ca levels are protective of aquatic organisms such as fish, therefore, despite the fact that radionuclide and metal deposition was detected in fish organs, any significant negative effects on the fish was not found.

• Lower pH and lower Ca content gives much higher uptake of U – and increase probability of effects on fish and other aquatic organism.
Conclusion cont.

• Measurements of total concentration would not have given the mobile and possible bioavailable fraction
  – Showing high possibility of biological uptake of U and some other metals, but NOT all metals.
• Possible risk from Alum Shale to environment is not from NORM alone
  – Predicted risk also includes other metals leached from Alum Shale – there is a multiple stressor scenario
• In this area, the quality of the waters – high pH and Ca content – prevented the effects that can be seen other places.
  – Especially pH is important when it comes to uptake of U in fish
Thank you!

• Funding: the Nordic Road Water Project (NORWAT)

• Hedda Vikan, Sondre Meland, Halldis Fjermestad, Malin Torp, Turid Hertel-Aas, Per Hagelia at Norwegian Road Construction Authority

• Frøydis Meen Wærsted, Hans-Christian Teien, Lene Sørlie Heier, Marit Nandrup Pettersen, Lene Valle at Center for Environmental Radioactivity (CERAD), Norwegian University of Life Science (NMBU),

• Knut Erik Tollefsen, Øyvind Aaberg Garmo, Tore Høgåsen, Maria Hultman, Tânia Gomes og Ailbhe Macken at The Norwegian Institute for Water Research (NIVA)

• 7 MSc students