Rural emission to Kaldvellfjorden in Norway and characterization of cumulative risk of metals

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Background

Kaldvellfjorden is located in the Lillesand area situated near the border of the Skagerrak Rift south in Norway and the fjord are impacted by acid rock drainage (ARD) due to construction work in the nearby sulfide-bearing bedrocks. Exposure of rock surfaces to air and precipitation have occurred over a long time, however the oxidation of the rock increased especially after the E18 road construction during 2006 and 2008, when also three large landfills of waste rock material were constructed. Especially landfill close to Kaldvellfjorden has contributed to high ARD (Hindar and Nordstrom, 2015) and one treatment plant has been constructed to reduce the metal concentration in the ARD.

Analyses of water samples demonstrate still high concentration of trace elements in downstream tributaries, before dilution in the coastal water (Teien et al., 2017). The concentration of trace elements in the coastal water show following order of exposure Al> Cu> Zn> Fe> Mn> Cd> Ni> Co>Pb (Fig. 1) in addition to increased concentration of several rear earth elements such as Ce, La, Nd and Ge.

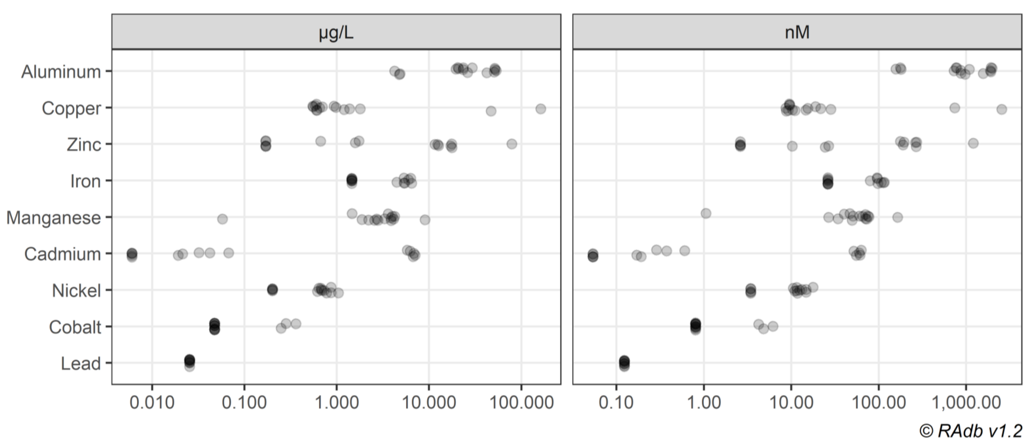

Figure 1. Concentration range of trace metals from the surface water (1-3 m depth) in Kaldvellfjord during date of sampling in 2015 and 2016. Black to gray indicate gradient of several to few datapoint.

Approach

The exposure data from Kaldvellfjorden was subjected to a component-based Cumulative Risk Assessment (CRA) using the NIVA Risk Assessment database (NIVA RAdb) to predict site-specific impacts, identify species groups (taxa) of highest risk and identify the main contributing stressors (risk drivers).

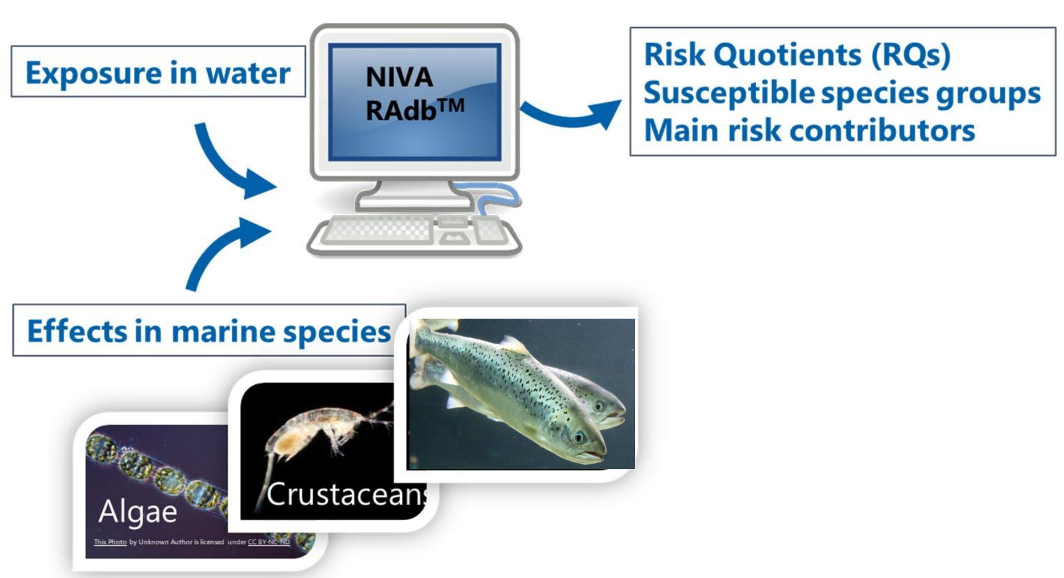

Figure 1. Component-based cumulative risk assessment (CRA) analysis

References

Hindar, A., Nordstrom, D. K. 2015. Applied Geochemistry, vol 62, pp 150-163

Teien, H.-C., Pettersen, M.N., Kassaye, Y.A., Hindar, A., Lind, O.C. & Håvardstun, J. 2017. - MINA report 47. 61 pp. ISSN: 2535-2806

Results

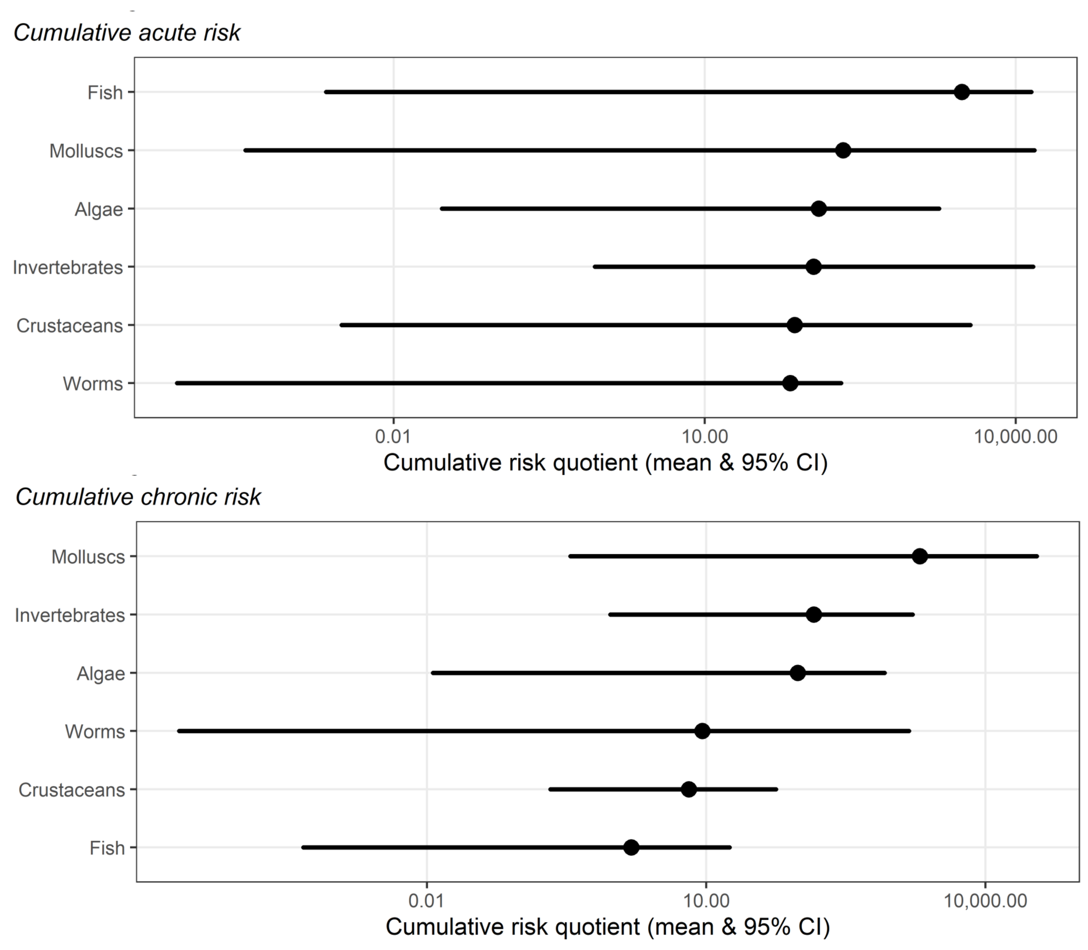

Figure 2. Prediction of cumulative acute and chronic risk (cumulative risk quotient, mortality) to different marine species groups in Kaldvellfjord. The data display the variance (Circle: time-weighted average, line: 5 to 95 percentile range).

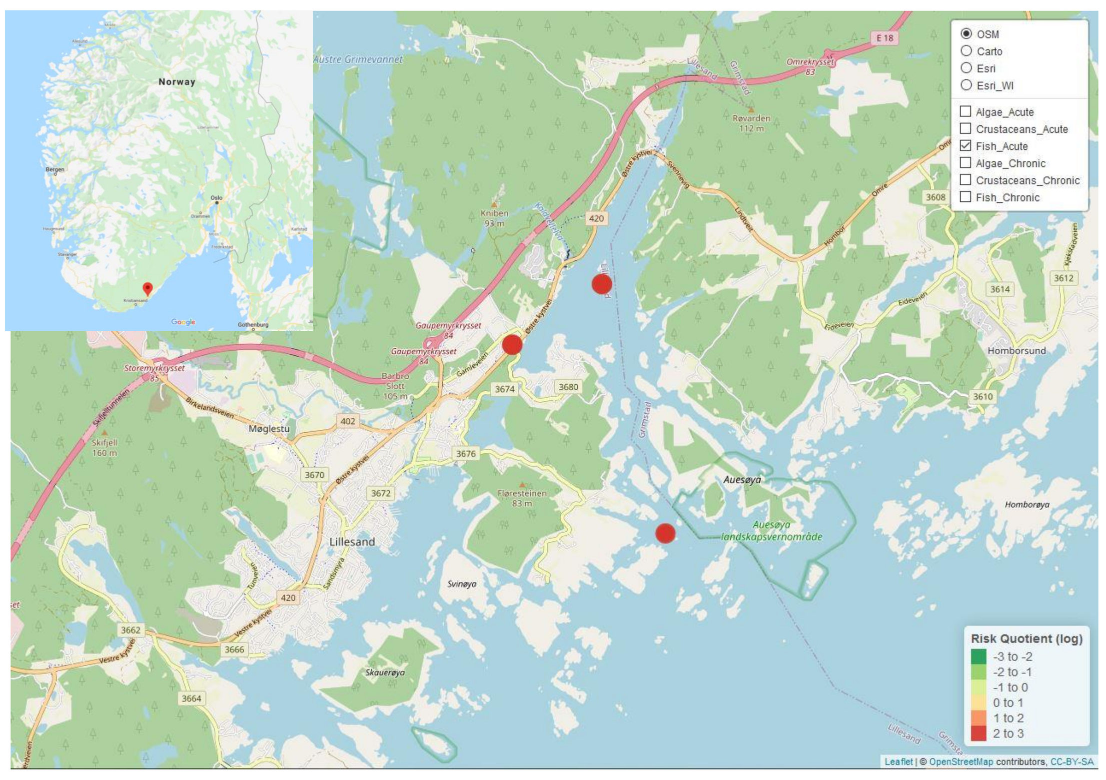

Figure 3. Kaldvellfjord in Norway and cumulative acute risk quotient (CRQ) for fish (mortality) at three different location October 2016.

- The resulting CRA demonstrated that several taxa were at risk (risk quotients > 1), and that the risk profile was clearly depending on the metal composition (Fig. 2).
- Calculation of cumulative acute risk quotient (CRQ) in Kaldvellfjord indicate that fish had the highest risk (i.e. risk quotient) for acute effects (mortality) (Fig. 2)
- For fish the acute cumulative risk was estimated to be high in surface water at various locations in the fjord (Fig.3), potentially due to large contribution of freshwater in the upper 2 m of the surface water.
- For fish several elements were estimated to contribute significantly to the acute risk and in the following order Fe>Zn>Cu > Cd. (Fig. 5)
- Analyses of gills of caged Atlantic Salmon smolt exposed to the fjordwater showed significant accumulation of several of the elements identified to cause risk (Fig. 4), albeit limit transfer to other organs such as liver indicated that gills may be the main target organ for these complex mixtures.
- Although the risk contribution of several elements was identified, the contribution from other elements was not identified due to lack of information about toxicity in the marine environment. This highlight the need of more knowledge on toxicity of especially Al and rear earth elements that was identified to be significant in the fjord water.

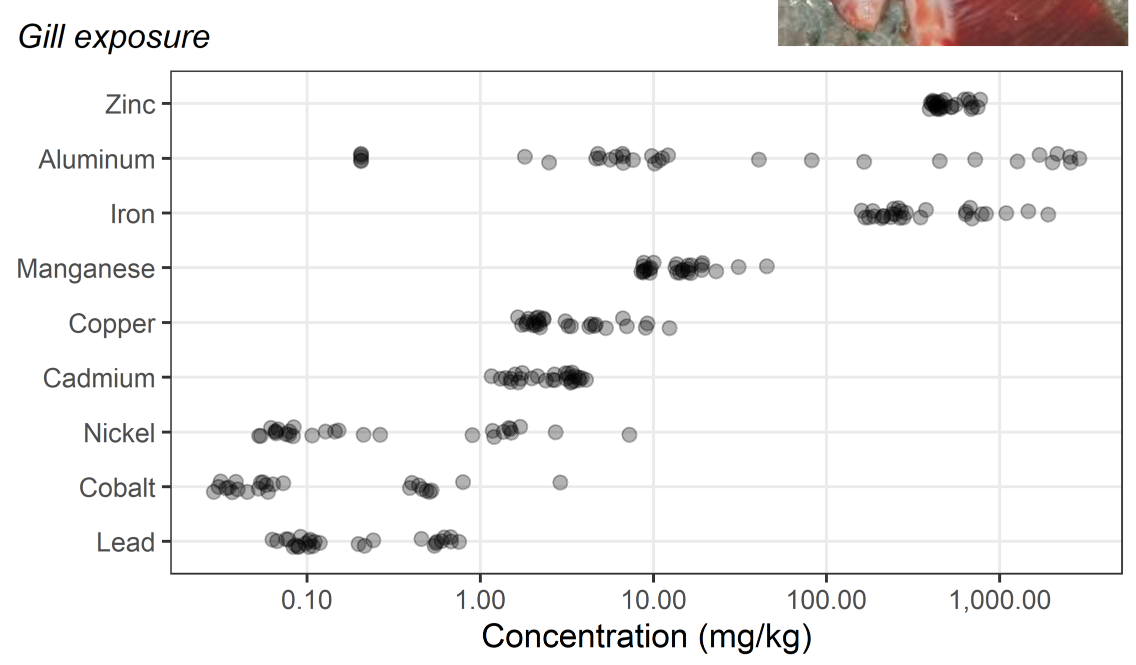

Figure 4. Gill of Atlantic salmon smolt (Salmo salar L.) and concentration range of trace metals in gills of fish exposed to the fjordwater (1-3 m depth) for 7-21 days. Black to gray indicate gradient of several to few datapoint.

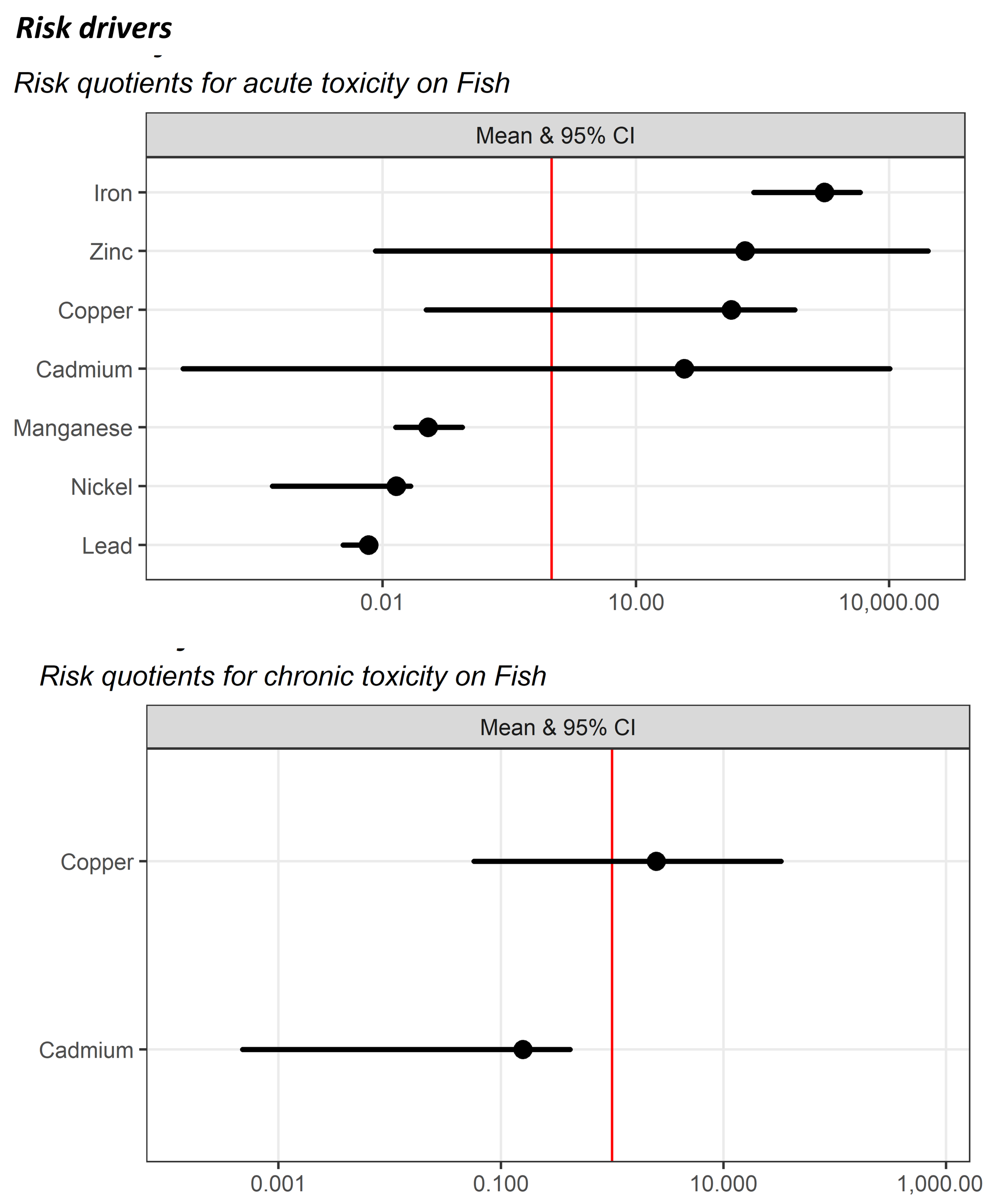

Figure 5. Risk Drivers for acute and chronic toxicity (mortality) on fish in Kaldvellfjord. Red line indicate risk quotient of 1.

Conclusion

The observed data suggest that several of the trace metals contribute to risk to several species groups (taxa) in Kaldvellfjord. Furthermore, combination of computational and experimental efforts presented herein may provide complementary information to impact assessments of complex exposure scenarios.

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