Trace elements
concentrations, geographic variations and correlations

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Introduction

Knowledge of natural levels and variation in running water is generally low for most trace elements. In the monitoring programme for water chemistry in 20 Norwegian rivers (Fig. 1), trace element analysis has been included during the last years. Here we focus on variations between rivers and regions regarding concentrations of selected trace elements and their relation to other physical-chemical conditions

Materials and Methods

Trace element analysis of Fe, Ni, Cu, Zn, Sr, Cd, Ba, Pb, Th and U from 20 rivers has been conducted in the period 2001 - 2004, while Mn, Co, Rb, Y, Cs, La, Ce and Pr have been analysed since 2002. The number of analyses varies between 5 and 12 yearly; from 9 sites monthly samples has been taken. Trace elements have been analyzed using HR-ICP-MS. All samples are also analyzed for turbidity, colour, conductivity, pH, alkalinity, calcium, magnesium, sodium, potassium, sulphur, chlorine and silicon.

Figure 1 Rivers included in the Norwegian monitoring programme on water chemistry .

Results

- Concentrations of the trace elements in the studied rivers were generally low (Fig.2) and similar to levels found for Norwegian lakes. For Rb, Sr, Y, Cs, Ba, La, Ce, Pr, Th and U there exist little information on natural levels in Norwegian rivers.
- All trace elements showed statistically significant differences between regions (ANOVA $p<0.01$). The strongest regional variation was found for Ba, La, Ce (Fig. 3). However, the number of locations in each region is small (3-5 rivers).
- Most trace elements were positively correlated ($p<0.05$). Ba, however, correlated to only ten other metals; except for Sr and Rb all correlations were negative. The acidified rivers (locs 5, 6, 8) showed high similarity in the trace metal composition, indicated by the PCA plot (Fig. 4). These rivers showed highest similarity with non-acidified rivers with low ionic content. Rivers in northern Norway differed from the other rivers by high content of most metals.
- Rivers with high content of particles (turbidity) and organic matter (colour) showed highest concentrations of most trace elements. Fe, Ni, Cu, Rb, Sr, Ba and U all correlated positively to pH, calcium and alkalinity whereas Mn, Zn, Y, La, Ce, Pr and Pb correlated negatively to these parameters. Cd correlated negatively only to pH. Especially for Ce, Y and Pb high concentrations were measured in the most acidified rivers (locs 5, 6, 8) compared to other rivers, whereas particularly Sr showed low concentrations in the acidified rivers (Fig. 5).
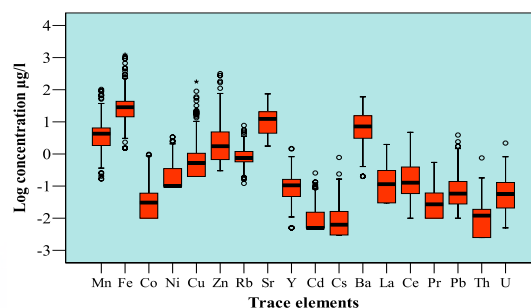
Figure 2. Box-and-whiskers plot showing log-transformed concentrations of all trace elements. Manganese (Mn), Iron (Fe), Cobalt (Co), Nickel (Ni), Cupper (Cu), Zinc (Zn), Rubidium (Rb), Strontium (Sr), Yttrium (Y), Cadmium (Cd), Barium (Ba), Lanthanum (La), Cerium (Ce), Praseodymium (Pr), Lead (Pb), Thorium (Th) and Uranium (U).

Figure 3. Box-and-whiskers plot showing log-transformed concentrations of Ba, La and Ce in five different regions of Norway.
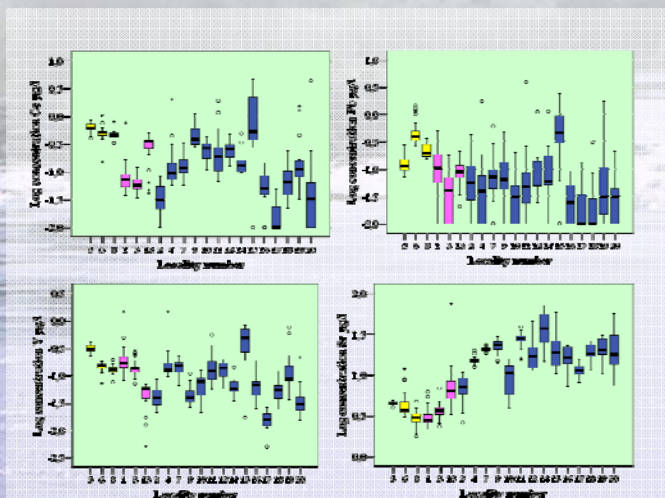

Figure 5. Box-and-whiskers plot showing log-transformed concentrations of Ce, Y, Pb and Sr in acidified rivers (yellow bars), non-acidified rivers with low ionic content (pink bars) and other rivers (blue bars).
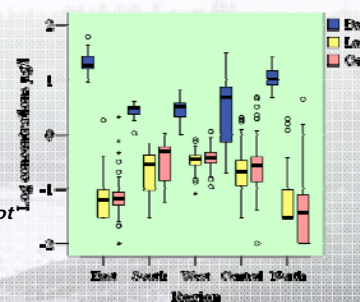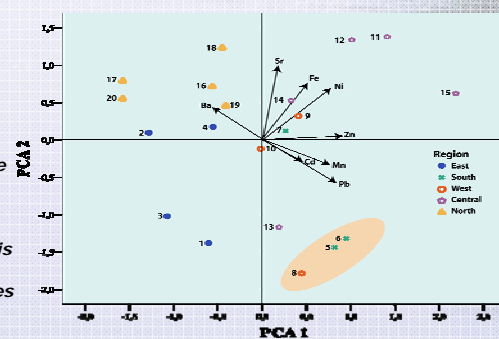

Figure 4. PCA biplot showing the site score and a selection of trace metals (arrows). The PCA analysis is based on log-transformed values of all elements (20).