SPATIAL DISTRIBUTION OF DISSOLVED CONSTITUENTS IN ICELANDIR RIVER WATERS

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The objective of this study was to map the spatial distribution of dissolved constituents and the alkalinity of Icelandic river waters using GIS methods, in order to study and interpret the connection between river chemistry, bedrock, hydrology, vegetation and aquatic ecology.

The results of this study can be used for example to: 1) predict river water response to acidification and the spatial variation of the response and 2) predict the rate that determines macronutrient quantities for primary production within the rivers and how this varies spatially.

Spatial distribution of constituents has been modeled before (Arnason, 1976; Sigurdsson, 1993; Kardjilov et al., 2006) but GIS methods have not been used to map the distribution of dissolved constituents in Icelandic rivers until now and therefore this emphasis was the main scientific objective of this study.

By applying the methods of the spatial analysis in GIS, a clearer view of the distribution of dissolved constituents and alkalinity for the whole country can be achieved and the changes in the concentration of dissolved elements and alkalinity can be studied further with respect to, bedrock age, hydrological classification, soil and vegetative cover.

For this purpose five parameters were selected and are listed below:

1. Alkalinity – indicates how the river waters will respond to external acidification. The higher the alkalinity, the more acidification the water can sustain without great pH changes.
2. Silica (SiO_2) – is the most abundant element in the basalt bedrock but with low concentrations in the oceans and is a good criterion for weathering. It is also a very important nutrient for aquatic life and primary production
3. Molybdenum (Mo) – an important element of nitrogen-fixing enzymes, called nitrogenases. It is suggested that it may govern the N fixation in the terrestrial environment.

4. Fluorine (F) – is not consumed by a secondary mineral and is therefore an indicator of how much rock-weathering a unit mass of water has caused. Its presence also indicates some geothermal activity.
5. DIN/DIP mol ratio[1] – nitrate and phosphorous are very important nutrients for life in rivers, lakes and soil. These nutrients were chosen since their availability could limit primary production in rivers and lakes when the DIN/DIP mol ratio is > 16 it is likely that DIP is the limiting factor and vice versa when the mol ratio is <16.

MATERIAL AND METHODS

The concentration of each dissolved constituent was mapped in GIS by applying GIS techniques.

In 2006 the Hydrological Service of the National Energy Authority (Halldorsdottir er al., 2006). divided river catchments into several sub-basins where the sub-basins were classified into a category, representing the hydrological condition of the region. The concentration of each chemical constituent was applied to the hydrological classification in order to connect the river chemistry to the hydrological classification to get a better view of the conjunction between precipitation, hydrology and river chemistry.

The databases used in this study are of various size and are described as follows:

1. 30 rivers were sampled and samples were collected up to 10 – 12 times each year and up to 50 parameters were analyzed and pH and temperature and electrical conductivity were measured. These databases therefore give the best information on variation in both discharge and the concentration of dissolved constituents (Armannsson et al., 1973; Rist, 1974; Rist, 1986; Gislason et al., 2004; Gislason et al., 2003 and 2006; Gislason et al., 2006; Kristmannsdottir et al., 2006).
2. 47 rivers were sampled and only one sample was collected in each river. 31 parameters were analyzed along with measurements of discharge, pH/T, temperature and electrical conductivity (Adalsteinsson and Gislason, 1998; Louvat et al., 2007).

All the samples were collected close to the hydrometric stations run by the Hydrological Service. Discharge, water and air temperature were measured at the time of sampling.

The discharge and concentration of dissolved elements in direct run-off rivers and glacial rivers varies considerably over the year. The discharge and concentration were fitted by a second order power function and a regression coefficient that describe the relationship between discharge and concentration

[1] DIN/DIP mol ratio: the ratio of Dissolved Inorganic Nitrate and Dissolved Inorganic Phosophorous.

mathematically, a relationship called rating curve (Gislason et al., 2006). Rating curves were calculated for each constituent in each river in this study. Thus the variability in discharge and concentration between seasons does not have to be accounted for. The long-term average concentration values are then imported in ArcGIS and mapped.

Various agents own the data and they were used by their permission. The data were imported in a relational chemical database where both the owners and the users of the data can watch and alter the data.

The attributes of the spatial distribution were added to the hydrological classification using Zonal analysis method in GIS, where the values of each dissolved constituent in the spatial distribution are assigned to the hydrological classification and mean and standard deviation are calculated (Oskarsdottir, 2007; Oskarsdottir et al., 2008).

RESULTS

The main results of the spatial distribution are that alkalinity, SiO_2 and F concentrations are highest in catchments draining the youngest rocks and are located within the volcanic rift zone (Fig. 1). In contrast SiO_2 concentration was lower in catchments draining lakes due to primary production of diatoms in the lakes. All three constituents had low concentration in catchments draining older Tertiary rocks despite some catchments that drain wetlands or are influenced by geothermal activity outside the volcanic rift zone. As for the three constituents, Mo concentrations were highest within the volcanic rift zone and especially in catchments draining rhyolitic terrain and central volcanoes. In contrast the lowest concentrations are in catchments draining older Tertiary rocks outside the volcanic rift zone. Mo is thought to play a role in N fixation and that it may govern the primary production in Icelandic lakes where primary production is limited by the amount of fixed nitrogen (NO_3^-, NO_2^-, NH_4^+) (Oskarsdottir, 2007; Oskarsdottir et al., 2008).

In terms of DIN/DIP mol ratio the highest concentrations were within catchments that drain rocks older than 2 My (Tertiary and older). It was higher than 16 in rivers draining old rocks, but lowest in rivers within the volcanic rift zone (Fig. 2). Thus primary production in the rivers is limited by fixed dissolved nitrogen within the rift zone but dissolved phosphorous in the old Tertiary catchments. Nitrogen fixation within the rift zone can be enhanced by high molybdenum concentration in the vicinity of volcanoes.

A study of the hydrological classification revealed that the dissolved river water values, underlying each category, were too variable to take account of and resulted in high standard deviations. Thus the results were statistically insignificant. More data are needed from rivers draining each single river category in order to add the river chemistry to the hydrological classification.

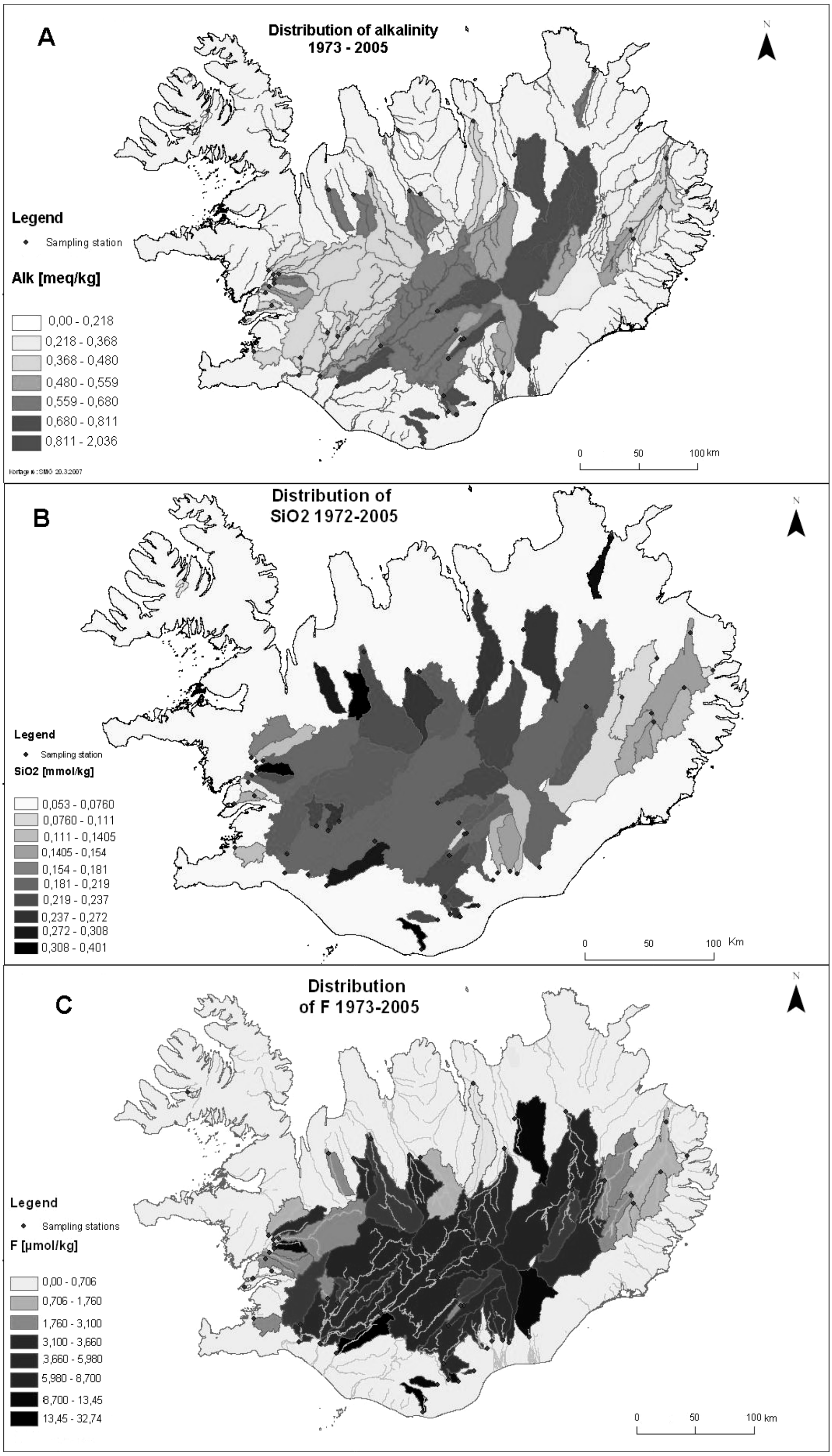

Figure 1. Spatial distribution of alkalinity (A), dissolved SiO_2 (B) and fluorine (C).

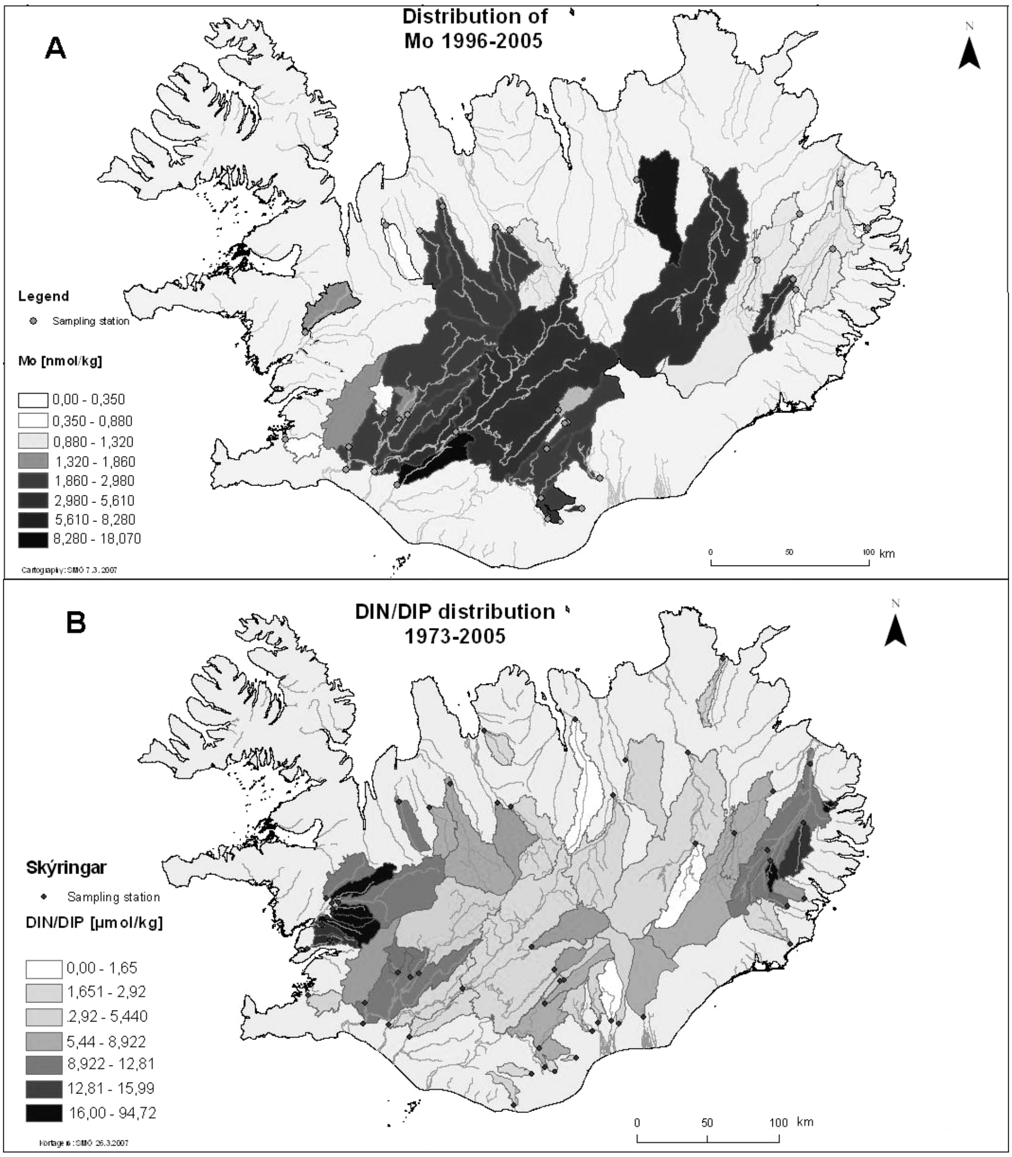

Figure 2. Spatial distribution of dissolved Mo (A) and DIN/DIP mol ratio (B).

The spatial distribution clearly revealed the difference between the two extremes, the volcanic rift zone and the old Tertiary terrain. However, more research and sampling needs to be undertaken in order to explain the concentrations in rivers at the margins of the two extremes, as well as to ascertain a more precise spatial distribution of dissolved constituents.

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