Hydrogeological investigation of water for export from Nordland county, Norway

ARVE MISUND, DAVID BANKS & PATRICE DE CARITAT

Arve Misund[i], David Banks[ii] & Patrice de Caritat[i]
[i]Geological Survey of Norway, P.O. Box 3006-Lade, N-7002 Trondheim, Norway.
[ii] Present address: Department of Earth Sciences, University of Sheffield, Dainton, Building, Brookhill, Sheffield, S3 7HF, England.

Introduction

In northern Norway, a region remote from English industrial smokestacks and with an 'ultraclean Arctic' image, the Geological Survey of Norway (NGU) has initiated a one-year monitoring programme of 7 water sources in Nordland county (Fig. 1), with sampling on a monthly basis. The sampling procedure is in accordance with the Norwegian legislation on sale of bottled water (Sosialdep. 1977). Three of the sources are near-coastal high-mountain lakes, remote from human activity; two springs emerge from Quaternary deposits; the remaining two are Palaeozoic limestone karst springs. The fieldwork was carried out from November 1992 to February 1994, covering water sampling, field investigation and continuous monitoring of water discharge and temperature. At the Kattdalen karst spring, electrical conductivity was also continuously monitored.

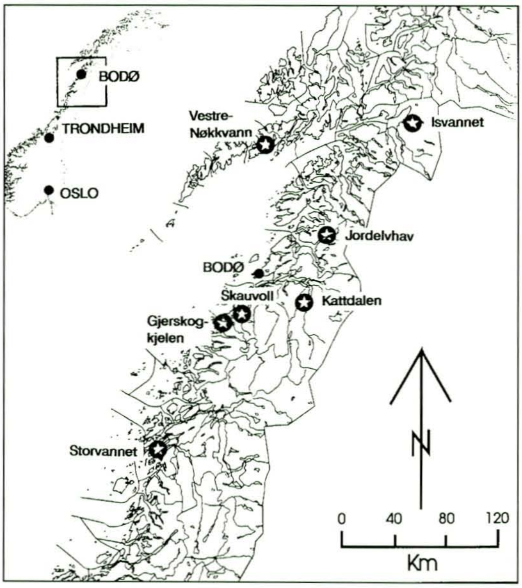

Fig. 1. Location of the sites of the water monitoring programme in Nordland county.

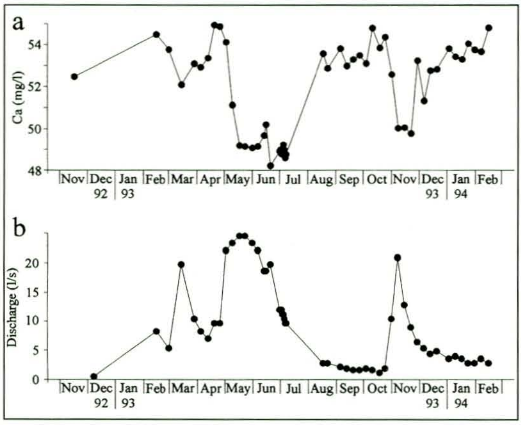

Fig. 2. Time-series for calcium concentrations (a) and discharge rate (b), Kattdalen spring (November 1992 to February 1994), Norway.

During spring 1993, it became clear that the three sources from the coastal high-mountain lake areas could not be recognised as 'natural mineral water', due to lack of natural protection (not groundwater). Because of this, the sampling programme was terminated for these three sites in August 1993, and site investigations were not completed.

Results

The time-series water quality data from this study show a strong negative correlation between water discharge and the concentrations of Ca and Mg, reflecting the interplay between water residence time and mineral-water interaction and dilution. For the karst spring at Kattdalen the Ca concentration fluctuates between 48 and 55 mg/l, which in Norway is regarded as high (Fig. 2). The bacteriological quality is excellent at all sites, including the high-mountain lakes. Table 1 shows summarised results of water quality monitoring.

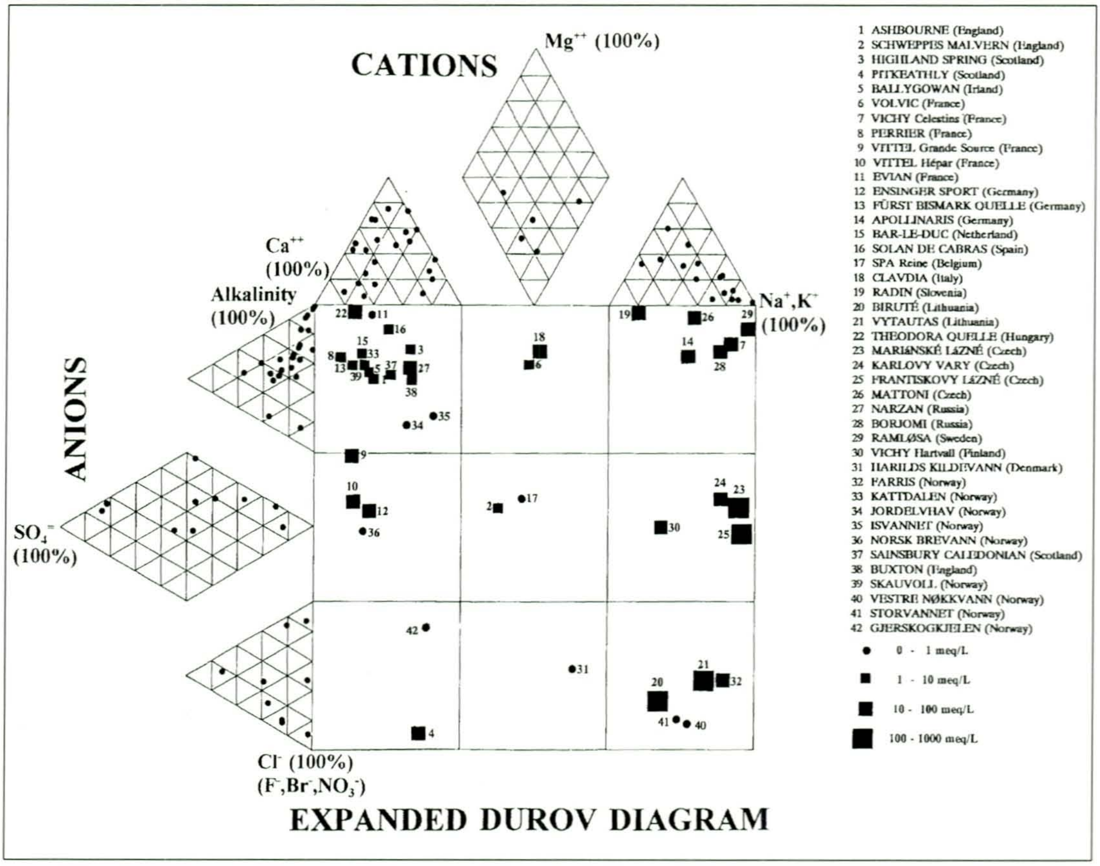

Fig. 3. Durov diagram showing cations (as percentages) along the top and anions along the side (modified after Misund & Banks, 1994). Total mineral content ([cations + anions]/2) is indicated by the symbol size. This diagram allows distinction between the 'end-member' water types, i.e. calcium-bicarbonate (e.g., from carbonate rocks, top left), sodium-calcium-bicarbonate (e.g., typical of granitic/acidic rocks, top right) and sodium-chloride (e.g. influenced by seawater, bottom right), and intermediate types. Data for the more famous mineral water types are from Green & Green (1985). The Nordland waters described in this study are nos. 33, 34, 35, 39, 40, 41 and 42.

Discussion and conclusions

The EEC Mineral Water Directive emphasizes that: "The composition, temperature and other essential characteristics of natural mineral water must remain stable at source within the limits of natural fluctuation; in particular, they must not be affected by possible variations in the rate of flow." This Directive is mainly concerned with bacterial pollution. The values of the major cations, for which no upper limits are stipulated, may far exceed the standards enshrined in the Drinking Water Directive (80/778/EEC). For the Kattdalen spring, the fluctuation in discharge throughout the year varies from 1 l/sec to 25 l/sec. In arctic Norway, in contrast to most temperate lands, groundwater recharge (and thus groundwater levels and discharges) often reaches a minimum in winter due to the frozen ground and accumulation of precipitation as snow cover (Kirkhusmo 1986, Haldorsen et al. 1992). A seasonal variation of the chemical parameters is also observed, and whether these variations are within the limits of the term 'stable' of the Mineral Water Directive is an open question. These variations are, in any event, effected by "the rate of flow".

The monitoring programme has shown that all the analysed springs meet the standards set by the EEC Drinking Water Directive. Taking into consideration water quality, location and flow rate, the Jordelvhav spring stands out as the most promising candidate for commercial production of bottled water. The Kattdalen spring is very well investigated (e.g. Misund et al. 1994), but has a low flow rate in winter and is not so favourably located from a logistical point of view.

Table 1. Major components at the monitored sources in Nordland county, sampled between 15 February 1993 and 15 February 1994 (all values in mg/L, except discharge in l/sec, conductivity in μS/cm and alkalinity in mmol/l). Q = Quaternary, K = Karst, L = Lake. For the first four sites n (no. of samples) =14, for the last three n=8.

	Jordelvhav		Kattdalen		Skauvoll		Gjerskog-kjelen		Isvannet		Vestre Nøkkvann		Stor-vannet	
	min	max	min	max	min	max	min	max	min	max	min	max	min	max
Type	Q		K		K		Q		L		L		L	
Discharge	6.7	40	1	24	> 10		1	30						
Conductiv.	38.3	99.2	315	386	94.8	159	79.9	104	15.3	23.2	35.7	61.4	43.5	63.5
pH	7.5	7.8	7.7	8.4	7.7	8.1	6.9	7.6	6.4	6.9	5.6	6.4	5.4	5.8
Alkalinity	0.3	0.6	2.6	3.1	0.5	1.2	0.3	0.5	0.06	0.08	0.01	0.03	0	0.02
Ca^{2+}	3.5	10.7	48.8	54.8	11.6	23.9	7.7	11.4	1.2	1.7	1.0	1.2	0.9	1.8
Mg^{2+}	1.1	3.5	8.3	15.2	0.2	1.7	1.1	1.4	0.2	0.4	0.5	1.1	0.7	1.0
Na^+	1.7	4.6	4.1	6.9	4.9	11.4	5.0	5.9	0.9	1.5	4.3	8.6	5.5	8.5
K^+	<0.2	0.6	<0.2	1.9	<0.2	1.1	<0.2	1.8	<0.2	0.7	<0.2	<0.2	<0.2	<0.2
HCO_3^-	16.5	37.8	160	191	30.5	75.6	17.7	31.7	3.7	4.9	0.6	1.8	0	1.2
Cl^-	2.1	17.4	6.8	20.9	7.1	26.9	9.1	16.8	1.3	3.3	6.2	15.9	8.2	16.8
SO_4^{2-}	1.2	2.5	7.8	50.5	3.0	4.7	3.5	5.4	1.3	1.5	2.2	3.3	2.4	3.5
NO_3^-	0.1	0.5	0.1	0.4	0.1	0.5	0.2	0.5	0.2	0.4	0.1	1.9	0.5	0.6

Generally speaking, the waters that have been monitored in Nordland county have very low total mineral contents. This is not necessarily a disadvantage; different water types suit different cultures. While East Europeans are used to drinking semi-seawater, low salinity waters, such as those from Nordland, are preferred by the Japanese. Kattdalen and Jordelvhav spring waters are classified as calcium-bicarbonate waters with low mineral content, and many Scandinavians may find it preferable to the more mineral-rich Norwegian mineral water, Farris. For a sodium-chloride type of water with a lower mineral content than Farris, possible candidates are the Vestre Nøkkvann water or the Storvannet water (nos. 40 and 41 in Fig. 3).

The three sources from coastal high-mountain lakes are not to be recognised as natural mineral water, thus there is no need for raw water quality documentation. Water from these lakes can be commercialised as 'packaged water' or 'general water'. Indeed, the EEC Drinking Water Directive allows the packaging and marketing of water "from any source, including water which is known to be bacterologically unsafe in its raw state and which has a significant proportion of waste water in its make-up, as long as it can satisfy the chemical and bacteriological standards after treatment" (Finlayson 1992). The analyses of these lake waters indicate a very high quality, although the pH is somewhat low.

Acknowledgements
This study in Nordland county has been funded by the 'Nordlandsprogrammet' at the Geological Survey of Norway (NGU). Thanks are due to Stein-Erik Lauritzen, Bergen University, who has been involved in the work at Kattdalen spring.

References

Finlayson, D.M. 1992: Chemical standards applied to natural mineral waters and packaged waters. *Soc. Chem. Industry Symp.'Natural Mineral Waters and Packaged Waters', 26/11/92, London*, 20 pp.

Green, M. & Green, T. 1985: The good water guide. *Rosendal Press, London*, 172 pp.

Haldorsen, S., Englund, J-O., Jørgensen, P., Kirkhusmo, L.A. & Hongve, D. 1992: Groundwater contribution to a mountain stream channel, Hedmark, Norway. *Nor. geol. unders. Bull. 422*, 3-14.

Kirkhusmo, L. A. (ed.) 1986: The use of Groundwater Monitoring Data from the Nordic countries. *Nordic Hydrological Programme, NHP-Report 19*, 36 pp.

Misund, A. & Banks, D. 1994: The Hydrogeochemistry of Bottled Water. *Geoscientist 4*, 20-23.

Misund, A., Caritat, P.de., Lauritzen, S.E. & Bakke, S. 1994: Monitoring of water quality in Nordland County, Norway. *IAH-Conference: Down Under 94, Adelaide, Australia*. Extended abstract, 7 pp.

Sosialdepartementet 1977: Foreskrift om omsetning av drikkevann. (Directive on monitoring and sampling of water for consumption). *Sosialdepartementet, Oslo*, 8 pp.