REGIONAL PATTERN DISTRIBUTION OF GROUNDWATER FLUORIDE IN THE SHUSH AQUIFER OF KHUZESTAN COUNTY, IRAN

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SUMMARY: The objective of this study was to investigate and map fluoride distribution patterns of groundwater in the Shush aquifer, Khuzestan County, located in western Iran. The aquifer was divided into four sub-regions according to topsoil type in relation to the direction of groundwater flow. A total of 168 groundwater samples were collected in 4 replicates from 42 wells during April, May, August, and September 2004. Fluoride concentrations measured spectrophotometrically by the SPADNS method ranged from 0.12 to 2.17 mg F/L (mean 0.6±0.44 mg F/L) with the highest levels in the southern-most part of the aquifer. Approximately 40% of the samples exceeded 0.68 mg F/L.

Keywords: Groundwater fluoride; Iran Shush aquifer; Khuzestan County, Iran; SURFER Software.

INTRODUCTION

The distribution of fluoride in drinking water and well water may vary widely over geographical and geo-political boundaries.[1] More than 50% of the world's population depend on groundwater for drinking water.[2] Variations occur with soil composition and with local political decisions to fluoridate water.[3,4] The use of wells of varying depths, commercial water products, home water purifiers and filtration systems also increase the variability of fluoride in drinking water and complicate estimates of intake.[5]

Information about water sources and constituents is of great importance in water quality management, but only limited data are available for the distribution of fluoride in the ancient Shush aquifer region of Khuzestan County, located in the western part of Iran. In this area, groundwater is the only available and widely used source of drinking water for rural and urban communities with the intensive agricultural activities.[6] The present study was therefore undertaken to investigate and map the regional pattern distribution of natural fluoride levels in the ancient groundwater sources known from 2500 BC in the Shush and Andimeshk plains.

MATERIALS AND METHODS

The study area involving the Shush and Andimeshk plains occupies approximately 1100 km^2 in Khuzestan County in western Iran (Figure 1). These plains are located in the northern part the county. The Shush aquifer is the primary source of groundwater, supplying nearly 100% of the total drinking water for about 180,000 people living in the region.[6] The groundwater levels are generally less than 2 m to more than 88 m below the surface.

According to topsoil type, the studied region was divided into four sub-regions: A, B, C, and D, according to the direction of groundwater flow. The dominant topsoil overlaying the aquifer consists of sand and gravel with mostly silt and loam in sub-region A and mostly silt and minor amounts of clay in sub-region B.

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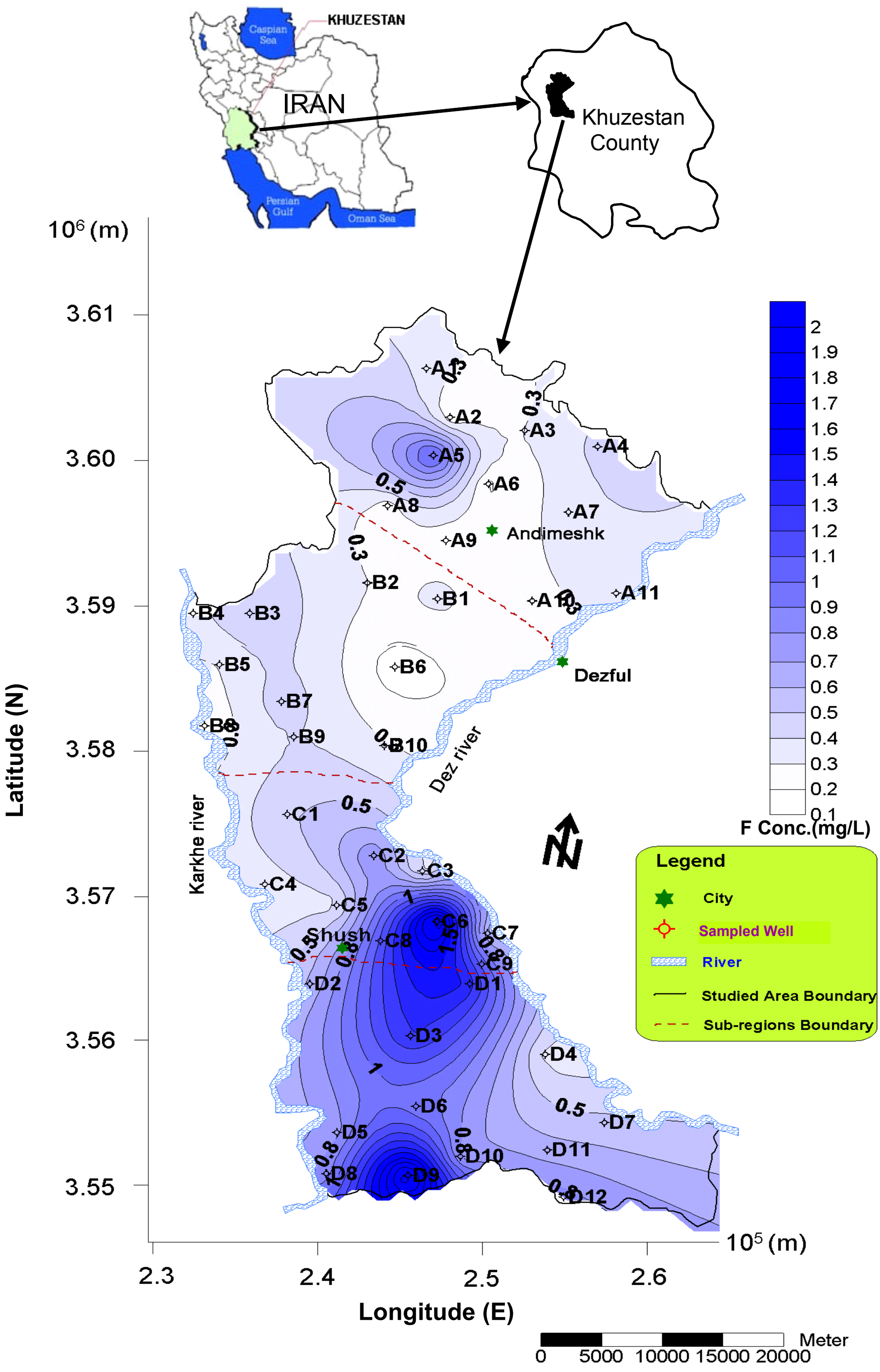

Figure 1. Distribution of F concentration in the Shush aquifer (mg/L).

The clay content of topsoil in sub-region C is higher than in sub-region B, and sub-region D has clayey topsoil.[6] From each of 42 wells, 4 replicates (168 groundwater samples) were taken for analysis during April, May, August, and September 2004. The analytical technique used for fluoride determination was the SPADNS method 4500-F^- D.[7] In addition, the samples were analyzed for pH, electrical conductivity (EC), alkalinity, Na^+, and K^+, following standard water quality analytical procedures. SURFER software was used for mapping of the fluoride content distribution pattern in the Shush aquifer.

RESULTS AND DISCUSSION

Fluoride concentrations of the 168 groundwater samples from different parts of the Shush and Andimeshk plains ranged from 0.12 mg/L to 2.17 mg/L with a mean of 0.6±0.44 mg/L. The mean fluoride contents in water samples from the four sub-regions A, B, C, and D are given in the Table.

Table. Distribution of fluoride in different region of Shush aquifer

Sub-region	No. of wells and samples	Fluoride concentration (mg/L)	
		Range	Mean
A	11* (11 × 4†)	0.15 – 1.17	0.37 ± 0.24
B	10 (10 × 4)	0.12 – 0.51	0.33 ± 0.10
C	9 (9 × 4)	0.33 – 2.03	0.79 ± 0.50
D	12 (12 × 4)	0.35 – 2.17	0.92 ± 0.44

*Number of wells; †4 replicates for each sample.

As seen in Figure 2, the four sub-regions exhibit different F concentrations with sub-region D having the highest average F concentrations.

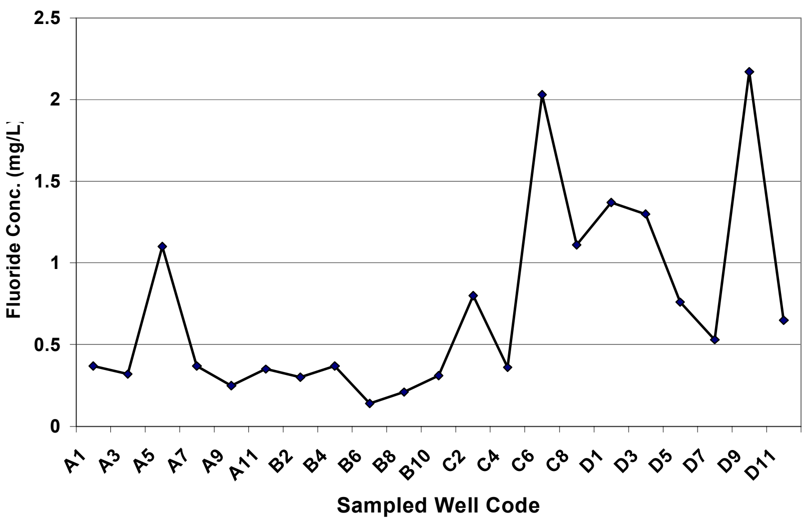

Figure 2. Average F concentrations in the studied wells during April - September 2004.

The low hydraulic conductivity of 1 to 3 m/hr for heavy clay to loamy soil, respectively, in sub-region A enables its groundwater to have a longer residence time with the aquifer materials in contrast to greater leaching of F in sub-region D with clayey soil. The connecting factors between sub-regions A and D are soil materials, soil porosity, and electrical conductivity. Moreover, clay materials, leading to greater leaching of F^- ions in place of OH^- ions, may be an additional source to circulating groundwater. During weathering of parent rocks, F^-/OH^- exchange-adsorption reactions occur in the clay minerals,[8] which could be responsible for higher F concentration in the shallow aquifer waters. On the other hand, the fractured zone is about 30% of total topsoil above the ground water having relatively greater hydraulic conductivity, which facilitates faster movement of groundwater and shorter contact time with the deep aquifer zones. Weathering is also retarded in deep layers, particularly below the water table, thereby leading to slower leaching of F in the capillary zone of the sub-region A.

A pie distribution of samples of different F concentrations is shown in Figure 3. There it can be seen that 84% of the samples have F concentrations not exceeding 1.0 mg/L, and 16% are above that level. As already noted, Figure 1 shows the locations of the sampled wells and regional pattern of F distribution in the Shush aquifer as prepared with SURFER software.

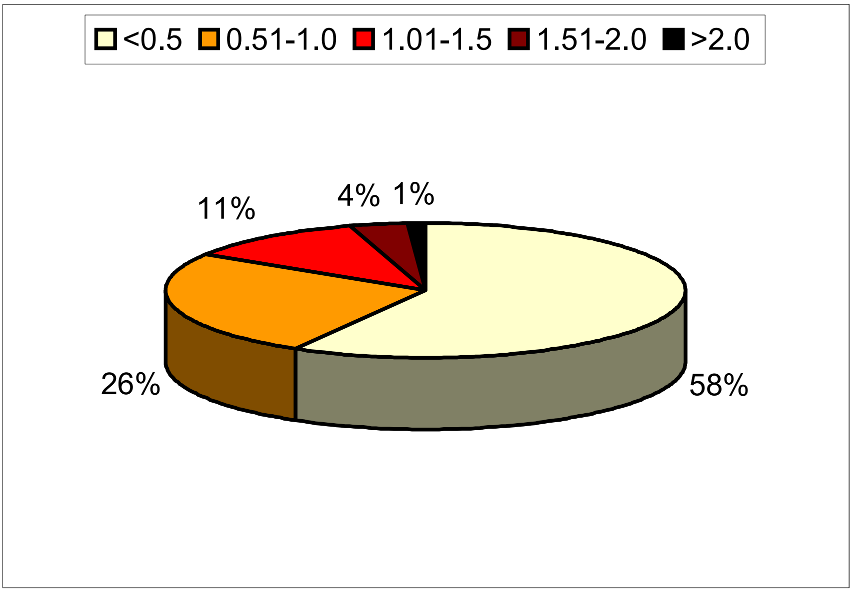

Figure 3. Percentage of groundwater samples in the Shush aquifer with different F concentration ranges.

Statistical analysis (ANOVA) demonstrated there was a significant correlation between groundwater fluoride content of the water table ($p = 0.012$ and $r = -0.384$) as well as groundwater F content and sampled well depth in the Shush aquifer ($p < 0.001$ and $r = -0.590$). This result is in agreement with the findings of Rao et al,[9] who reported that the F content of shallow aquifers was greater than that of deep aquifers. There was a significant negative correlation between fluoride content and pH of groundwater in the present study: $p = 0.045$ and $r = -0.311$. On the other hand, there was also a significant positive correlation between fluoride content and alkalinity of groundwater: $p = 0.004$ and $r = 0.438$. This study should therefore help to solve the problem of F in groundwater by using hydrogeological and geochemical information obtained from it by placing wells in more suitable locations rather than additional excavation of soils for F investigation.

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REFERENCES

1 Kariyanna, H. Geological and geochemical environment and causes of fluorosis – possible treatment – a review. In: Sahu KC, editor. Proceedings of the National Symposium on the Role of earth sciences in environmental planning at Salem Magnesite Mine areas; 1987 Dec 24–26; Bombay, India: Indian Institute of Technology; 1987.
2 Canter LW. Groundwater Quality Protection, Chelsea, MI: Lewis Publications; 1987.
3 McCaffrey LP, Willis JP. Distribution of fluoride-rich groundwater in the eastern parts of Bophuthatswana, relationship to bedrock and soils and constraints on drinking water supplies: a preliminary report. Africa Needs Ground Water. An International Ground Water Convention. 1993;1:1-8.
4 Fayazi M. Regional groundwater investigation on the Northern Springbok flats, Department of Water Affairs and Forestry. Geohydrology, GH Report No. 1994;3684:108-55.
5 Brown MD. The effect of point-of-use conditioning systems on community fluoridated water. Pediatr Dent 1991;13:35-8.
6 Water and Electric Organization of Khuzestan County, Shush Aquifer Data; 2000.
7 Clesceri LS, Greenberg AE, Eaton AD, editors. Standard methods for the examination of water and wastewater, 20th ed. Washington DC: American Public Health Association (APHA), American Water Works Association (AWWA), Water Environment Federation (WEF); 1998.
8 Hübner M. Geochemische interpretation von fluoride/hydroxide Austauschversuchen an Tonmineralen. Ber Deutsch Ges Geol Wiss B Miner Lagerstättenforsch 1969;14:5.
9 Rao NS, Rao KG, Devadas JD. Variation of fluoride in ground waters of crystalline terrain, Journal of Environmental Hydrology [The electronic journal of the International Association for Environmental Hydrology on the World Wide Web at http://www.hydroweb.com]1998;6(paper 3):1-5.