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VARIATION OF FLUORIDE IN GROUNDWATERS OF CRYSTALLINE TERRAIN

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Groundwater in shallow aquifers that supply water to dugwells in crystalline terrain of the Visakhapatnam region, Andhra Pradesh, have higher concentrations of flouride (F) than those of borewells from deep aquifers. Factors for variation in F content between the two aquifer water types are discussed. The relative merits of the shallow water for potability are pointed out with respect to F concentrations and public health.

INTRODUCTION

In view of the increased interest in recent years in fluoride (F) concentrations in groundwater and impact to human health, the present study is focused on factors determining F levels in the groundwater of shallow and deep aquifers in the crystalline terrain of the Visakhapatnam region, Andhra Pradesh, and the identification of appropriate aquifer zones for fluoride-safe drinking water.

METHODOLOGY

Twenty four samples, 12 each from shallow dugwells and deeper borewells in close proximity, were collected for comparative study (Figure 1). The dugwells range in depth from 2 to 14 m and the borewells range from 20 to 60 m with averages of 9 and 34 m respectively. The samples were analyzed for the chemical constituents Ca^{+2}, Mg^{+2}, Na^{+}, K^{+}, HCO_3^-, Cl^-, SO_4^{-2}, NO_3^-, and F^- following standard water quality procedures (Brown et al., 1974).

STUDY AREA

The area under study has a sub-humid to semi-arid climate with an average monthly temperature variation of 24° to 32° C and an average annual rainfall of 990 mm. The area is underlain by khondalites, charnockites and their variants, with the former as the dominant formation. Quartzite and pegmatite veins cut across the country rocks in some places. Important accessory minerals in the rocks, which are known as sources for F in groundwater, are apatite, biotite, mica and hornblende.

A soil-clay complex weathered zone corresponds to the shallow aquifer, and fracture zones make up the deep aquifers. The shallow aquifer yields groundwater at an average rate of 20 m^3/day through dugwells and the deep aquifer has average yields of 105 m3/day day through borewells, due to variations in their hydraulic conductivities (Subba Rao, 1992).

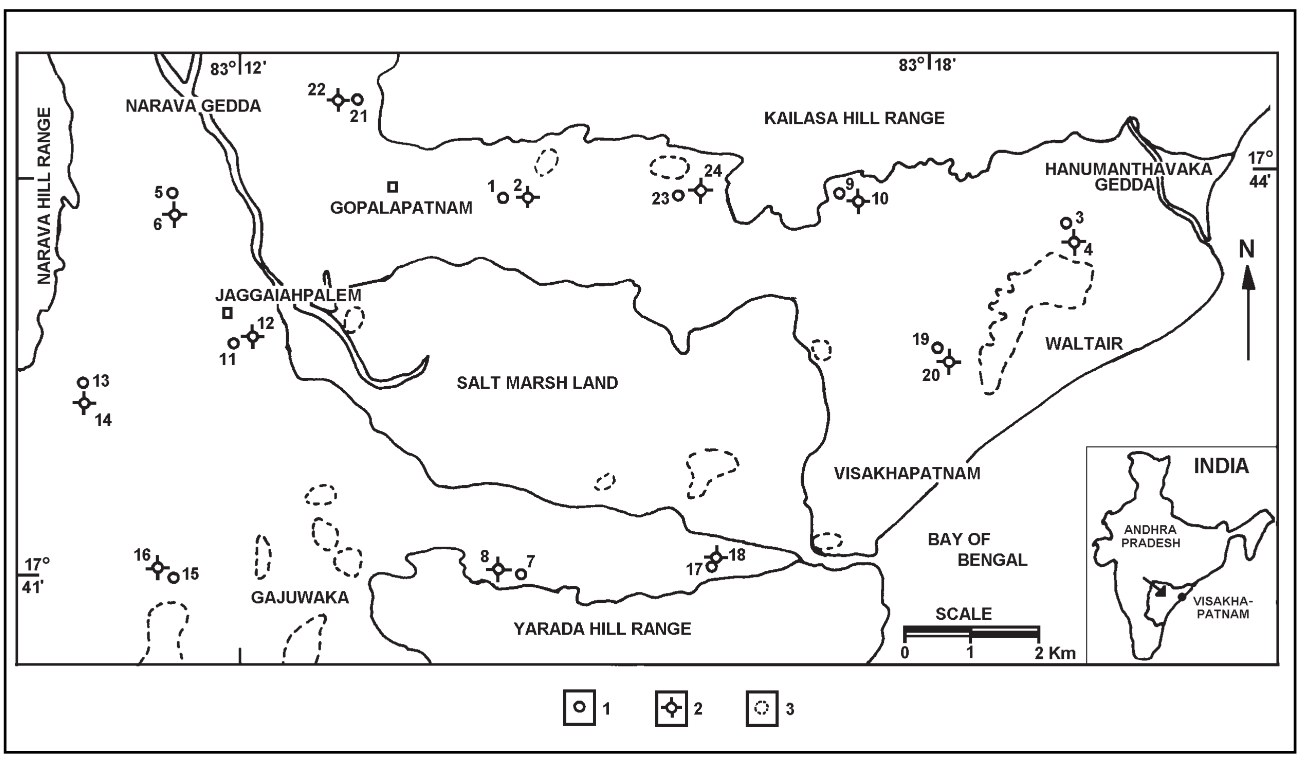

Figure 1. Study region. 1-Dugwell, 2-Borewell, 3-Hillock.

RESULTS AND DISCUSSION

Table 1 shows the chemical composition of groundwater from dugwells and borewells in the study area. As shown in this table, it is noted that the groundwaters of the shallow aquifer have a higher concentration of F than the deep aquifer. The variation in F content between the two aquifer waters is believed to result from the interplay of the following factors.

The vertical geochemical zoning in the groundwater as presented in Table 1 suggests that there is little hydraulic continuity between the shallow and deep zones. This is due to the fact that the recharge source for the deep zone is different from the shallow zone (Subba Rao et al., 1997). Otherwise both aquifers would have similar chemical quality.

The rate of groundwater flow influences F content in the groundwater. The low hydraulic conductivity in the weathered zones enables the waters to have a long residence time with the aquifer materials, leading to greater leaching of F in the soil-clay weathered zone. In addition, the clay minerals, which may contain F ions in substitution of part of OH ions, may be an additional source to circulating groundwater. During the weathering of parent rocks, F/OH exchange-adsorption reactions occur in the clay minerals (Hubner, 1969) which could be responsible for higher

Table 1. Chemical Composition of Groundwaters in the Study Region

Samples Nos. shown in figure	pH	TDS	Ca^{+2}	Mg^{+2}	Na^{+}	K^{+}	HCO_3^-	Cl^-	SO_4^{-2}	NO_3^-	F^-
1 D	7.8	960	20	49	95	2	600	240	22	8	1.1
2 B	7.1	440	15	21	61	2	210	100	15	Tr	0.7
3 D	8.0	1010	10	43	215	4	390	220	33	1	1.0
4 B	7.5	660	13	19	168	1	310	130	21	Tr	0.6
5 D	8.2	1250	15	47	311	3	460	480	16	11	1.4
6 B	8.1	720	15	21	193	1	340	230	15	1	0.8
7 D	8.1	1100	15	52	275	3	360	430	54	15	1.2
8 B	7.4	770	5	32	206	2	250	310	29	1	0.7
9 D	8.0	750	25	43	163	5	370	260	21	4	1.1
10 B	7.5	430	15	13	108	3	210	150	14	Tr	0.8
11 D	8.2	1750	8	29	530	10	820	520	63	10	7.5
12 B	8.0	1020	5	30	305	6	430	390	28	2	3.5
13 D	8.0	1160	25	41	283	5	400	420	15	9	1.2
14 B	6.9	630	10	21	180	2	290	250	4	2	0.7
15 D	7.5	1050	55	30	206	10	310	410	19	16	0.9
16 B	7.6	640	20	23	163	3	220	300	4	2	0.6
17 D	7.4	1100	30	51	155	12	460	400	30	14	1.3
18 B	7.5	830	25	33	208	4	320	230	17	1	0.9
19 D	7.2	1050	45	50	207	7	360	390	36	20	1.1
20 B	7.1	700	20	32	184	2	290	300	11	Tr	0.7
21 D	8.2	550	30	26	115	5	310	150	24	2	1.1
22 B	7.5	380	20	18	80	1	250	90	10	Tr	0.6
23 D	7.9	870	40	34	161	9	360	290	18	12	1.0
24 B	7.2	390	20	13	92	2	240	100	7	2	0.7

D = Dugwell B = Borewell Tr = 0.2

All concentrations are expressed in ppm except pH concentration of F in the shallow aquifer waters. It is also reported that the leachable F in the soils is of greater significance in contributing F to the groundwaters than its absolute content in the country rocks (Ramesam and Rajagopalan, 1985). On the other hand, the fractured zone with relatively higher hydraulic conductivity facilitates relatively faster movement of groundwater which results in less contact time with the deep aquifer zones. Weathering is also retarded in deep layers, particularly below the water table. Thus, leaching of F is low in this zone.

Investigations conducted in the crystalline terrains of Prakasam, Anantapur and Nalgonda districts of Andhra Pradesh, India have revealed that deep well waters contain less F than the shallow well waters (Ramamohana Rao and Rajyalakshmi, 1974) which is in conformity with the present study.

On the contrary, the concentration of F in the groundwater of the deep aquifer in crystalline rocks has been reported to be relatively greater than the shallow aquifer in the Peddavankahalla Basin of Karnataka (Wodeyar and Sreenivasan, 1996). But the actual nature of the aquifer tapped by the borewells was not mentioned in their study. In some cases, the borewells may be completed in the weathered zone itself, and in that case they do not differ much from the deep wells.

Another aspect of the concentration of F in groundwater is that it is not uniform over the entire study region (Table 1). This is attributed to variations in the availability of F source minerals. For instance the abnormal F concentration in the groundwater of the shallow and deep aquifers (Wells 11 and 12 respectively) at Jaggaiahpalem is due to the effect of apatite (Rao and Naidu, 1973), which has been causing fluorosis.

Elemental fluorine plays a vital role in higher life forms, especially in the skeletal systems. Both deficiency and excess of F might be harmful. Effects associated with the impact of the ion on human health greatly depend on total intake through various media such as water, air and food. For instance, the common food stuffs have fluorine contents as follows: milk 0.07 to 0.22 ppm, wheat 0.05 ppm, rice 0.7 ppm, eggs 1.2 ppm, tea 3.2 to 178.8 ppm, garlic and onion contain 10 to 17 ppm (Kariyanna, 1987). Under these circumstances, it is advisable to consume waters having a low concentration of F to prevent fluorosis problems. The desirable limit of F in water for drinking purpose is 0.6 to 1.2 ppm, while the optimal range for it in the present study area as per temperature conditions (Public Health Service, 1962) is 0.7 to 0.8 ppm. Therefore, the ideal concentration of F may be considered to be 0.6 to 0.7 ppm. Since nearly 73% of the deep aquifer water (except at Jaggaiahpalem) has an F concentration between 0.6 and 0.7 ppm compared to the shallow aquifer water, the former would be more suitable than the latter for drinking purposes.

Similar studies in other fluoride problem areas would help to identify safe aquifer zones for drinking water. However, the borewells sampled should tap the fracture zones only. A few exploration deep borewells are also advisable where even the shallow fracture zones which are in close proximity with the weathered zones are sealed to avoid the effects of vertical leakage. It is also recommended to compare groundwater from borewells in outcrop areas (no weathered zone) to areas with weathered zones to understand the behavior of fluoride concentrations. Such studies will help solve the fluoride problem in groundwater by using hydrogeological and geochemical information for well placement rather than spending huge sums of money on alternate supply schemes.

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