Fluoride contamination status of groundwater in Karnataka

S. Suma Latha, S. R. Ambika and S. J. Prasad

Abnormal level of fluoride in phreatic groundwater causes serious health hazards in humans and physiological damages in plants. This study showed that occurrence of fluoride is highly sporadic and localized in eastern and southeastern Karnataka and the concentration of fluoride varies from 1 to 7.4 mg/l. The geological strata near the wells influence the fluoride content in phreatic groundwater. Effective and cheap methods of defluoridation are few and hence biological defluoridation may be the best alternative to the conventional methods.

FLUORIDE is known to contaminate groundwater reserves globally. Sporadic incidence of high fluoride content in groundwater has been reported from India, China, Sri Lanka, West Indies, Spain, Holland, Italy, Mexico, and North and South American countries. In India, its occurrence in top aquifer system is endemic in many places of Andhra Pradesh, Tamil Nadu, Karnataka, Gujarat, Rajasthan, Punjab, Haryana, Bihar and Kerala. A high concentration of 5.2 mg/l has been reported in Medak district, Andhra Pradesh[1], 15 mg/l in Nawabganj Block, Uttar Pradesh[2] and 18 mg/l in Jaipur, Rajasthan[3] as against its critical limit of 1.5 mg/l in drinking water[4]. The levels above this pose serious health hazards to humans and irreversible damage to plants. High profile of fluoride in shallow zone groundwater is due to the geochemical disposition in the vicinity of the groundwater extraction structures. The toxicity of fluoride is also influenced by high ambient temperature, alkalinity, calcium and magnesium contents in the drinking water[5].

Geochemistry of fluoride

Abnormal level of fluoride in water is common in fractured hard rock zone with pegmatite veins. The veins are composed of minerals like topaz, fluorite, fluor-apatite, villuamite, cryolite and fluoride-replaceable hydroxyl ions in ferromagnesium silicates[6]. Fluoride ions from these minerals leach into the groundwater and contribute to high fluoride concentrations[7]. Occasionally, mica group of minerals like muscovite and biotite also contribute to water fluoride content[8].

S. Suma Latha and S. R. Ambika are in the Plant Physiology
Research Laboratory, Department of Botany, Bangalore University, Bangalore 560 056, India. S. J. Prasad is in the Central Ground
Water Board, Ministry of Water Resources, 31st Cross, 11th Main, 4th Block, Jayanagar, Bangalore 560 011, India.

Fluorospar occurs in structurally weak planes like shear fracture zones, joints and at the contact of host rock and vein quartz. Rock minerals weather and form calcium and magnesium carbonates, which serve as good sinks for fluoride ions[9]. However it is the leachable state of fluoride ions that determines the water fluoride levels. The leachability is governed by (i) pH of the draining solutions and (ii) dissolved carbon dioxide in the soil. The present study pertains to the fluoride in phreatic groundwater (the top aquifer system) and it is in this regimen that hand pumps, dug and borewells have been constructed.

Profile of fluoride in shallow groundwater zone

High profile of fluoride in groundwater is observed in 4.6% geographical area (8900 km^2) of Karnataka. The incidence of very high levels of fluoride is in the eastern and southeastern belt of

Karnataka, covering districts of Gulbarga, Raichur, Bellary, Chitradurga, Tumkur and Kolar and is scattered in rest of Karnataka as shown in Figure 1.

The present study includes 15 villages from each of the above mentioned six districts with noticeable levels of fluoride. The concentrations of fluoride vary from 1 to 7.4 mg/l. Occurrence of fluoride is very sporadic and marked differences in concentrations occur even at very short distances, sometimes even less than 2 to 3 km. Village Hathiguddur in Gulbarga district has a fluoride level of 7.4 mg/l, while 5.75 mg/l is seen in Farhatabad. Nimbala recorded 4.4 mg/l while in other villages, the level was less than 3 mg/l. District Raichur has non-permissible levels of fluoride prevailing in many villages. Gabbur and Lingasugu villages have 5 mg/l while in the rest of the villages, levels ranged from 1.2 to 4 mg/l. District Bellary showed a wide range of fluoride concentrations. Village Sanavaspur and Tekalakota have 7.4 mg/l while Kurugodu and Verupayur have as low as 0.95 mg/l. Fluoride levels are comparatively low in districts of Chitradurga and Tumkur. Bommianapalya has a

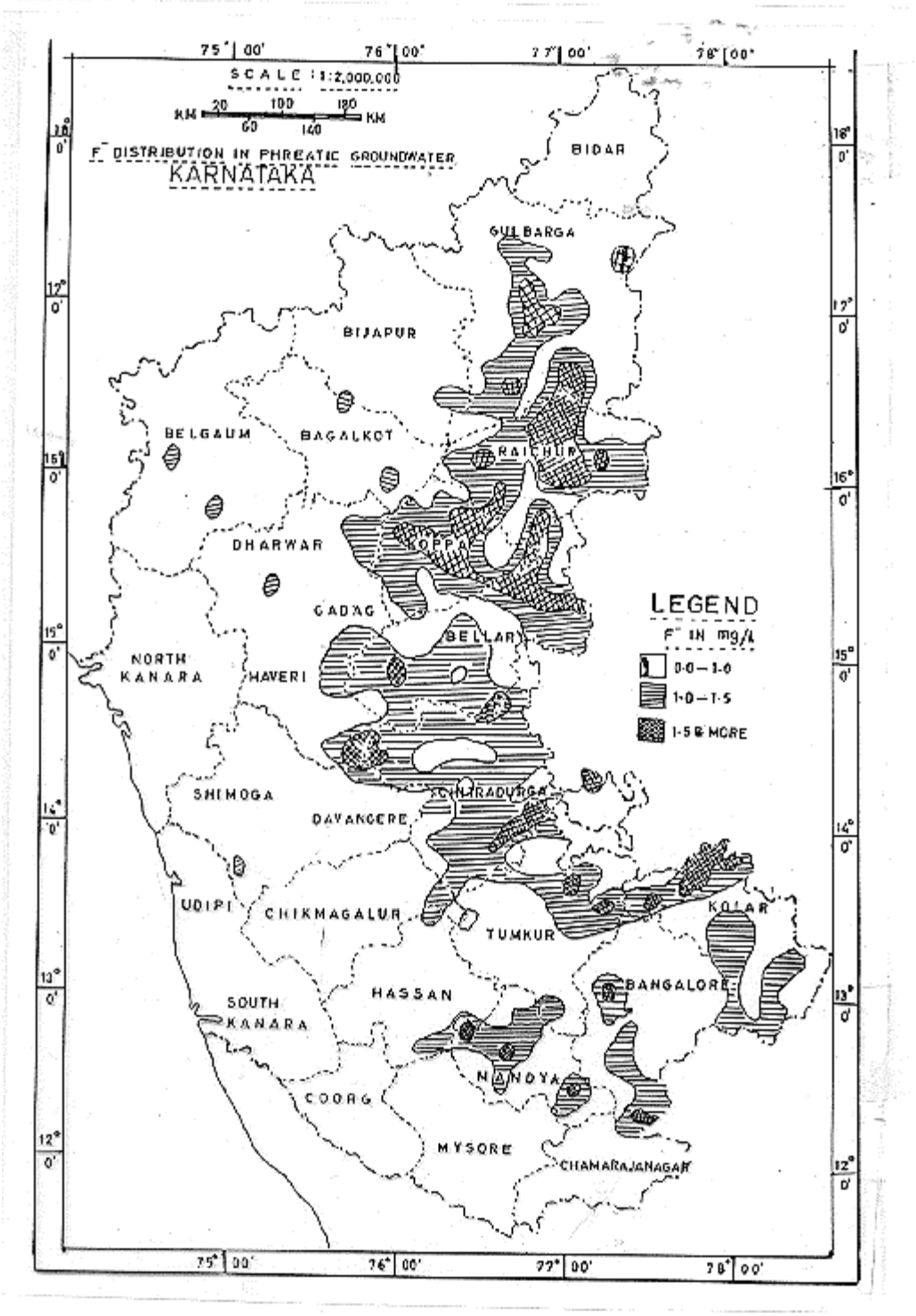

Figure 1. Map showing the distribution of fluoride in phreatic groundwater in Karnataka.

high of 3.2 mg/l while in the rest of the villages levels range from 0.45 to 2.5 mg/l. Villages in Kolar have comparable low levels of fluoride (1.5 mg/l to 3.4 mg/l) (Table 1).

The level of fluoride in phreatic groundwater, when compared over the years 1988, 1992, 1993, 1995 and 1996, exhibits wide variations (Table 2). Percentage of non-permissible level of fluoride

(2.5 mg/l and more) is the highest in District Raichur (13 to 31.9%). Gulbarga and Bellary districts follow, with a number of taluks afflicted with high fluoride levels (2 to 15 taluks). Tumkur, Chitradurga and Kolar have comparatively low percentage of regions with fluoride concentrations crossing the threshold level (1 to 9.4%). The number of taluks falling under high fluoride category in these three districts over the years, remain almost the same. High profile of fluoride in shallow groundwater is seen in the year 1995 in all the districts (3.9 to 31.9%) and quite low in the year 1993 (0 to 13%).

Table 1. Concentration of fluoride in phreatic groundwater in different villages in various districts of Karnataka State

District	Village	Fluoride* (mg/l)
Gulbarga	Farhatabad	5.75
	Firozabad	2.60
	Hathiguddur	7.40
	Kurkunde	2.76
	Nimbala	4.35
Raichur	Gangavathy	5.15
	Kalmali	4.50
	Kapgal	4.05
	Lingasugur	2.02
	Raichur	5.15
Bellary	Virupapur	1.05
	Tekalakota	7.40
	Sanavaspur	7.40
	Kurugodu	0.80
	Hagarnur	4.00
Tumkur and	Badavanahalli	1.82
Chitradurga	Koratagere	2.40
	Nagehanahalli	2.60
	Bommianapalya	3.20
	Hosakere	0.97
Kolar	Gulur	1.55
	Jagampalli	3.40
	Kaiwara	1.95
	Kammanpalli	2.60
	Mulbagal	1.55

*Concentration of fluoride (mg/l) in groundwater.

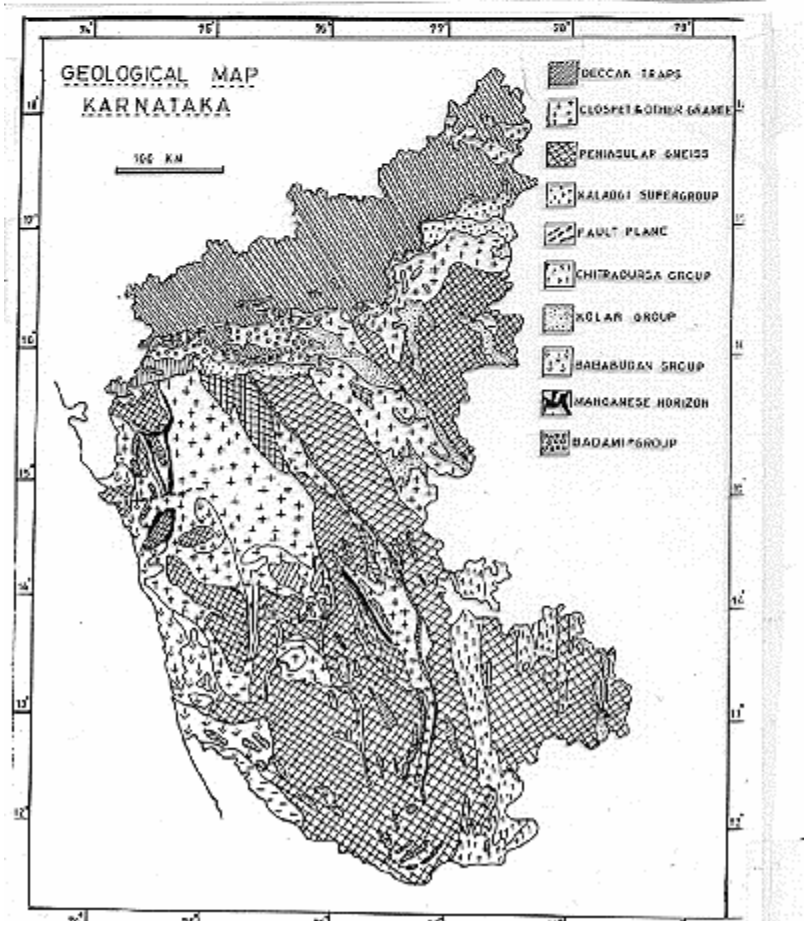

Figure 2. Map showing geological disposition and stratigraphy of Karnataka.

Table 2. Distribution of fluoride in phreatic groundwater in different villages in various districts of Karnataka State

District	Fluoride concentration (mg/l)	Year 1988 No. of villages with F^-	Year 1988 %	Year 1992 No. of villages with F^-	Year 1992 %	Year 1993 No. of villages with F^-	Year 1993 %	Year 1995 No. of villages with F^-	Year 1995 %	Year 1996 No. of villages with F^-	Year 1996 %
Gulbarga	0.0 – 0.5	4	17.4	15	35.7	18	24.3	1	1.9	23	39.7
	0.5 – 1.5	12	52.2	27	64.3	52	70.3	32	60.4	27	46.6
	1.5 – 2.5	3	13.0	0	0.0	4	5.4	14	26.4	6	10.3
	2.5 and more	4	17.4	0	0.0	0	0.0	6	11.3	2	3.4
Raichur	0.0 – 0.5	2	5.6	4	7.4	5	9.3	0	0.0	2	3.7
	0.5 – 1.5	19	52.8	33	61.1	30	55.6	24	51.1	34	63.0
	1.5 – 2.5	13	36.1	10	18.5	12	22.2	8	17.0	18	33.3
	2.5 and more	2	5.6	7	13.0	7	13.0	15	31.9	0	0.0
Bellary	0.0 – 0.5	10	31.3	2	7.1	5	14.7	2	7.7	5	19.2
	0.5 – 1.5	16	50.0	18	64.3	21	61.8	11	42.3	11	42.3
	1.5 – 2.5	4	12.5	5	17.9	5	14.7	5	19.2	5	19.2
	2.5 and more	2	6.3	3	10.7	3	8.8	8	30.8	5	19.2
Tumkur and Chitradurga	0.0 – 0.5	12	20.7	17	26.6	23	54.8	2	6.1	20	37.0
	0.5 – 1.5	38	65.5	37	57.8	17	40.5	28	84.8	26	48.1
	1.5 – 2.5	6	10.3	4	6.3	0	0.0	3	9.1	7	13.0
	2.5 and more	2	3.4	6	9.4	2	4.8	0	0.0	1	1.9
Kolar	0.0 – 0.5	26	29.5	20	28.2	14	21.2	13	16.9	7	15.9
	0.5 – 1.5	60	68.2	48	67.6	45	68.2	48	62.3	29	65.9
	1.5 – 2.5	1	1.1	2	2.8	4	6.1	13	16.9	8	18.2
	2.5 and more	1	1.1	1	1.4	3	4.5	3	3.9	0	0.0

The occurrence and fluctuation of fluoride can be better understood by studying the geological setting and stratification of the various districts.

Geological setting

The area under study is underlain by rock types ranging from Archaean to Recent. They can be classified as Peninsular gneissic complex, sedimentaries, Deccan Traps, laterite and alluvium (Figure 2). The gneissic complex is constituted by the Archaeans, pre-Cambrians/Dharwars and basic intrusives. The Archaean type of rocks are mainly granite gneisses, hornblende, biotite gneisses and unclassified crystallines.

High fluoride regions in Karnataka occur mostly in gnessic and granitic areas. Granitic gneisses are the oldest formations in the state and have undergone maximum weathering. The joints, fractures, faults and vertical openings in the formations are occupied by fluoride-bearing minerals. The leachable fluoride in these minerals is reflected in the top aquifer system.

The sedimentary formation of Bhima group is constituted by conglomerates, sandstones, shales and limestones. The formation in the Southern regions is subjected to tectonic disturbances and hence traversed by shear and fractured zones. These zones are occupied by pegmatite veins filled with fluorite-associated minerals.

The alluvium is of Recent age and is limited to certain river courses draining the districts[10]. It consists of unconsolidated sediments as gravel, sand, clay, silt and pebbles. These sediments contribute to the water fluoride content as listed in Table 3, in different locations of the districts.

District Gulbarga is predominated by Sargur and Bababudan group of Dharwars and sedimentaries of Bhima group. The Deccan traps occur in a limited extent in southern part of the district and the laterite occurs extensively[11].

The stratigraphy in Raichur district is shown in Figure 3. The oldest formation is the Sargur group consisting of amphibolites with acid volcanics, banded ironstone, meta-pelitic schist, quartzite and meta-ultrabasics. The peninsular gniesses underlie the Sargur group of rocks with an unconformity. The Hutti schist belt of rocks is spread over the peninsular gneisses with a marked unconformity. The younger grey and pink biotite granites, which occur as intrusives in the gneisses, are associated with fluoride-bearing minerals, tourmaline. Pegmatite veins occupy the fault zones and run east to west. Occasionally, pegmatites trending NS show displacement of the host rock. Fluorite-associated minerals like magnetite and apatite are seen in the quartz and pegmatite veins.

The geological disposition of District Bellary is shown in Figure 4. The oldest formations in the district are hornblende schists of Archaean age. The meta-

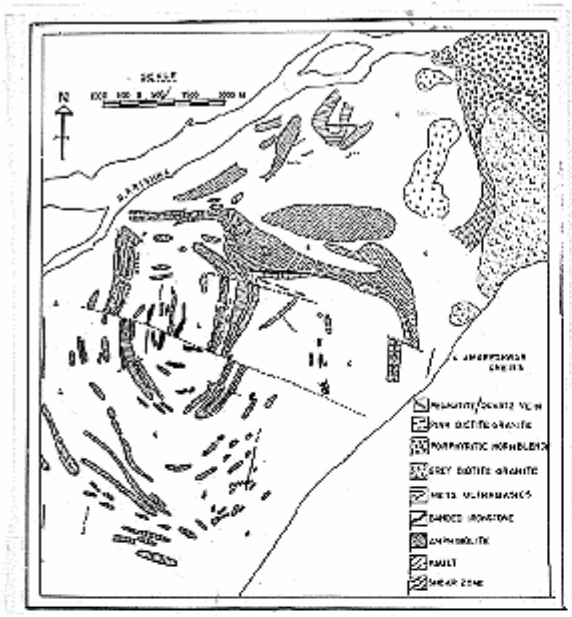

Figure 3. Map showing the geological disposition and stratigraphy of Raichur district, Karnataka.

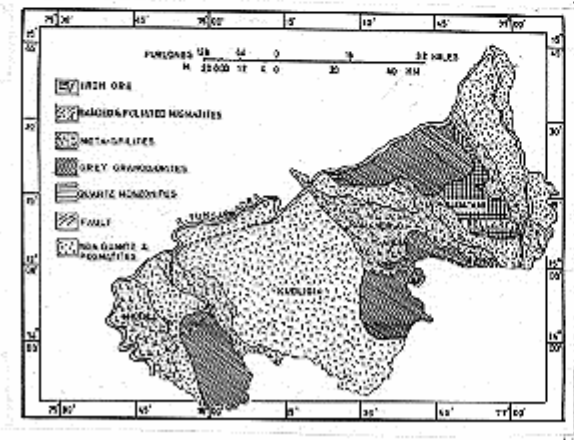

Figure 4. Map showing the geological disposition and stratigraphy of Bellary district, Karnataka.

Table 3. Fluoride concentration in the unconsolidated sediments of alluvium and their contribution of F^- to groundwater

Village	District	Soil type	Fluoride (mg/l)	F^- (mg/l)*
Kalavarahalli	Chitradurga	Sandy, mainly quartz	210	2.0
Machananahatti	Chitradurga	Sandy, mainly quartz	190	2.6
Ramanahalli	Chitradurga	Sandy	510	0.1
Sira	Tumkur	Sandy clay, loam medium black	190	0.4

*In soil drainage.

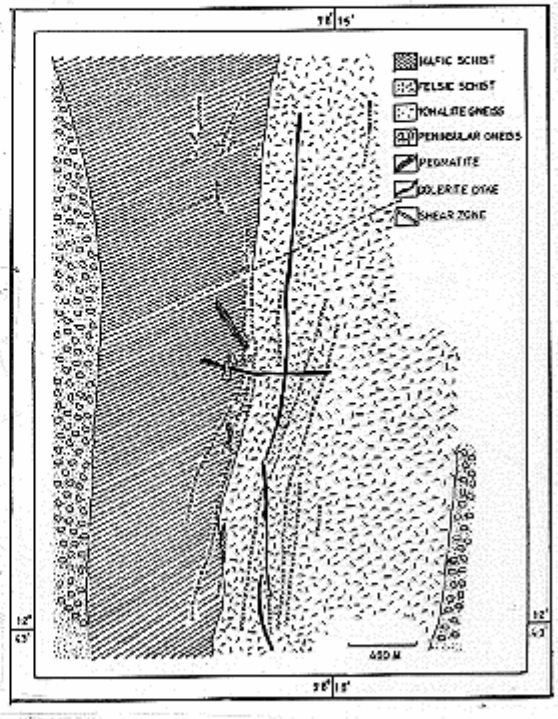

Figure 5. Map showing the geological disposition and stratigraphy of Kolar district, Karnataka.

in the groundwater with remarkable levels of fluoride,

Figure 3. Map showing the geological disposition and stratigraphy of Raichur district, Karnataka.

Figure 4. Map showing the geological disposition and stratigraphy of Bellary district, Karnataka.

Figure 5. Map showing the geological disposition and stratigraphy of Kolar district, Karnataka.

sedimentary rocks of banded ferrugenous cherty quartzites, phyllites, shales and acid tuffs overlie the Archaeans with a noted unconformity. The youngest formations are pegmatite and quartz veins cutting across the banded foliated migmatites and biotite gneisses. The predominant fluorite mineral is associated with haematite-quartzite.

The fluorite-bearing biotite gneisses have been noticed in Dwaralu village of Chitradurga district, also reflected in the groundwater with remarkable levels of fluoride. The same fluoride is noticed in chlorite schists, quartzites, granite gneisses and metavolcanics in Somarahatti, Puttanakatte, Naikanahatti, Hosur and Hireyur villages of Tumkur district.

The well-known Kolar schist belt which contains rich gold deposits also contains fluorite and fluor-apatite in the pegmatites as in Figure 5. The deep borewells drilled to a depth of 200 m cutting the belt have revealed high concentrations of fluoride to a tune of 6 mg/l in Bagepalli taluk[12].

Conclusions

Natural contamination of groundwater by fluoride causes irrepairable damage to plant and human health. High oral intake of fluoride results in physiological disorders, skeletal and dental fluorosis, thyroxine changes and kidney damage in humans[13]. High fluoride levels inhibit germination, cause ultrastructrual malformations, reduce photosynthetic capacities, alter membrane permeability, reduce productivity and biomass and inflict other physiological and biochemical disorders in plants[14]. Several physical and chemical defluoridation methods have been designed to treat high fluoride waters. However ion exchange and chemical treatments are cost intensive, while physical methods suffer limitations like frequent change of defluoridant beds and inability to reduce fluoride to non-toxic levels. Biological defluoridation can serve as a best alternative to the conventional methods of defluoridation. Such methods would be cost effective and material employed would be biodegradable. Efforts are on in this direction and the preliminary laboratory trials conducted in the Plant Physiology Laboratory, Department of Botany, Bangalore University, have yielded promising results.

1. Srikanth, R., Khanam, A. and Rao, A. M. M., *Fluoride*, 1994, **27**, 93–96.
2. Mukherjee, S., Pal, O. P. and Pandey, A. K., *Bhu–Jal News*, 1995, **10**, 1–6.
3. Agrawal, V., Vaish, A. K. and Vaish, P., *Curr. Sci.*, 1997, **73**, 743–746.
4. Bureau of Indian Standards, Drinking water specification (First Revision) IS 10500, 1991.
5. Singh, B. and Dass, J., *Bhu–Jal News*, 1993, **8**, 28–31.
6. Ramesham, V. and Rajagopalan, K. J., *J. Geol. Soc. India*, 1985, **26**, 125–132.
7. Karunakaran, Analytical informational on percentage fluorine content, 1974.
8. Handa, B. K., *Bhu–Jal News*, 1988, **3**, 31–37.
9. Jacks, G., Sharma, V. P. and Sharma, G. K., Hydrochemical Studies, SIDA-assisted groundwater project in Kerala – A Report, 1980, pp. 1–5.
10. Achuta Rao, Jagannathan, V. and Rama Rao, D. M., Ground-water Resources of Karnataka State – A Report, 1992, vol. 2, pp. 35–37.
11. Narasimha, S. and Hans, S. K., *J. Geol. Soc India*, 1983, **24**, 299–302.
12. Suryanarayana, K. R. and Gupta, B. K., Proceedings of a workshop on methodology of quality monitoring and information disseminated to the users, 1997, p. 1.
13. Grandjean, P., Olsen, J. H., Jensen, O. M. and Juel, K., *J. Natl. Cancer Inst. (Bethesda)*, 1992, **84**, 1903–1909.
14. Miller, G. W., *Fluoride*, 1993, **26**, 3–22.

ACKNOWLEDGEMENTS. We thank the Central Ground Water Board, Geological Survey of India and Bangalore University, for the laboratory and library facilities.

Received 31 March 1998; revised accepted 31 December 1998