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Original Research Paper

Fluoride Contamination in Groundwater from Bhadravati Tehsil, Chandrapur District, Maharashtra

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ABSTRACT

The groundwater quality from Bhadravati tehsil has been assessed and results are presented in the paper. A total of 46 samples were collected out of which 23 samples represent shallow aquifers while remaining 23 samples correspond to deeper aquifers. The fluoride concentration varies from 1.0 to 4.4 mg/L in phreatic aquifers and from 0.5 to 2.9 mg/L in deeper aquifers. The present investigation indicates that the fluoride concentration is higher in shallow aquifers than in deeper aquifers. This may be ascribed to leaching of fluoride in to groundwater from weathered zone. The physicochemical conditions like decomposition, dissociation as well as subsequent dissolution are also responsible for leaching of fluoride, though with limited residence time. The inhabitants consuming the fluoride contaminated water are suffering from different types of fluorosis.

INTRODUCTION

In rural and urban areas, the groundwater is main source of drinking water; however, more than 80% diseases of the mankind are waterborne (WHO 1984, Dev Burman et al. 1995, Subba Rao 2003). The concentration of fluoride between 0.6 and 1.0 mg/L in potable water protects teeth decay and enhances bone development (Apambire et al. 1997, Datta et al. 2000, BIS 2003). However, excessive fluoride intake through the drinking water causes awful disease of fluorosis. World Health Organization (WHO 1984) has suggested a tolerance limit of 1.5 mg/L. In India 15 States have been identified as endemic States and Maharashtra is one of them. UNICEF (1999) has pointed out that more than 62 million people from India are suffering from different kinds of fluorosis. Fluorosis is manifested in three main types (Kharb & Susheela 1994, Susheela 2001). Dental fluorosis manifests in the form of pitting of teeth, opaque patches, chalkiness, staining, chipping of enamel, etc. The skeletal fluorosis causes pain in the neck, joints, back, etc. With increase in severity of skeletal fluorosis pain becomes associated with rigidity and restricts movement of cervical and lumbar spine, shoulder joints as well as knee and pelvic joints (WHO 1984, 1994, Teotia & Teotia 1988, Susheela 2001). Ozha & Mathur (2001) have propounded non-skeletal fluorosis in the form of neurological, muscular, allergic, gastrointestinal ailments as well as headache and urinary tract infections.

In the present paper an attempt has been made to understand the hydrochemical composition of groundwater as well as fluoride concentration in shallow and deeper aquifers. The origin of fluoride content in water and the remedial measures for control of fluorosis are discussed.

STUDY AREA

Location and climate: The study area covers 15 villages of Bhadravati tehsil (Lat. 20°06’30’ N and Long. 79°07' 00’E), Chandrapur district, Maharashtra. The area experiences tropical dry subhumid climate. The summer months are much hot (max. temp. ~ 44°C) while, winter is mild (min. temp. ~ 11.6°C). The area receives an average rainfall of 1420 mm from south-west monsoon (June to September) with relative humidity of 70% during monsoon season.

Physiography and drainage: The area exhibits moderately dissected topography with a few isolated hills. It forms the part of the Penganga sub-basin (Deshpande 1998, Duraiswami 2007, GSI 2008). Bhadravati tehsil is drained mainly by southward flowing Erai river and its tributaries. The drainage network is dendritic to subdendritic with ephemeral drainages.

Hydrogeological set-up: In the area, the Penganga beds form the base for the disposition of rocks of the Gondwana Supergroup. The Talchir formation comprises lower unstratified tillites and upper stratified sandstones. Intercalation of shales and thin veneers of clays are also noted at places. The Barakar formation consists of fine to medium grained sandstones, shale, clay and coal seams. The Kamthi formation is composed of sandstones exhibiting fining upward cycles. Besides, shales and clay beds are also noticeable. The silicified sandstones, certified limestones and calcareous sandstones representing the Lameta formation cap, the Kamthi sediments. The soil cover and in some parts local alluvium cover up the area.

In the area under investigation, the stratified sandstones of Talchir formation as well as sandstones from the Barakar and the Kamthi formations form the good aquifers (Murkute & Badhan 2010, Murkute et al. 2010). The groundwater in these rocks mainly occurs under phreatic conditions; however the confined aquifers are also not uncommon. The alluvium deposits consist of different water bearing horizons. The most important amongst them are beds of sand, gravel and boulders, as these beds receive the recharge as well as store and transmit large quantities of groundwater. In general, the wells penetrating shallow aquifers range in depth between 5 and 15 mbgl and deeper aquifers at the depth varying from 25 to 40 mbgl upholding a discharge of 50 to 300 m^3/day (GSDA 2005, 2009). Murkute et al. (2010) have established the relationship between aquifer parameters and the petrological characteristics of Kamthi sandstone. According to them the values of transmissivity and specific yield for the arenites range from 104.85 to 412.72 m^2/day and 20 to 29 % respectively. These high values of transmissivity and specific yield in arenites aquifer are accountable for higher percentage of detrital grains, lesser amount of matrix and the moderate sorting of the grains. The values of transmissivity and specific yield for the graywackes grade from 59.82 to 146.43 m^2/day and 11 to 16 % respectively. The lower percentage of detrital grains, higher amount of matrix and the poor or very poor sorting of the grains are responsible for low values of transmissivity and specific yield in graywacke aquifer.

MATERIALS AND METHODS

The hydrochemical survey in the study area has been carried out during pre-monsoon season (May) of 2010. Fifteen samples from both the dugwells and borewells have been collected. The chemical parameters were analyzed using the standard chemical analytical techniques (APHA 1998).

RESULTS AND DISCUSSION

The results of the chemical analysis of waters are presented in Table 1. The groundwaters from the dugwells (pH: 7.12-7.87), and the borewells (pH: 7.01-7.57) are neutral to moderately alkaline. The values of electrical conductivity for the groundwaters collected from the dugwells range from 680 to 3878 μS/cm, and for the borewells from 800 to 3340 μS/cm. The TDS content from shallow aquifer ranges from 451 to 2479 mg/L, whereas in deeper aquifers it varies from 521 to 2162 mg/L. The calcium content in shallow aquifers range between 32 and 329 mg/L, and from deeper aquifer from 50 to 288 mg/L. The concentration of magnesium from the dugwells range from 19 to 261mg/L, and of borewells from 23 to 197 mg/L. The sodium and potassium contents in shallow aquifers range between 17 and 267 mg/L and 0.8 to 67 mg/L respectively. For the deeper aquifer sodium varies from 61 to 169 mg/L, and potassium from 1 to 57.9 mg/L. The bicarbonate content from shallow aquifer grades from 211 to 623 mg/L, whereas in deeper aquifers it varies from 211 to 399 mg/L. The nitrate and chloride contents in shallow aquifers range between 1 and 99 mg/L and 7 to 585 mg/L respectively. For the deeper aquifers nitrate varies from 1 to 19 mg/L and chloride from 25 to 520 mg/L. The sulphate content from shallow aquifers grades from 61 to 602 mg/L, whereas in deeper aquifers it varies from 103 to 533 mg/L. The fluoride content from shallow aquifer ranges from 1 to 4.4 mg/L, whereas in deeper aquifers it varies from 0.5 to 2.9mg/L.

In the study area, the fluoride concentration is more in Lameta aquifers than Gondwana aquifers. The higher concentration of fluoride in Lameta aquifers is ascribed to the presence of fluoride bearing minerals like fluorite and apatite in limestones or the clays, which absorb fluorine by fluoride to OH^- replacement (Kodate et al. 2007). In Gondwana sediments higher fluoride contents are observed in Talchir shales than sandstones of the Barakar and Kamthi formations. The principal source of fluoride in the Talchir shales is micas and the clay minerals (Wedepolh 1974, Deshmukh et al. 1995). The fluoride content in groundwater depends on the rocks through which it flows and increases along with the depth (Dev Burman et al. 1995). The correlation plots of pH versus fluoride have depicted the positive correlation (Fig. 1a and Fig. 2a), indicating that higher alkalinity of the water promotes leaching of fluoride and thus increasing the fluoride concentration (Saxsena & Ahmed 2001, Madhnure & Malpe 2007). The inverse relationship has been found between F^- and Ca^{++} concentration (Fig. 1b and 2b). In shallow aquifers, the positive relationship observed between F^- and Na^+ (Fig. 1c), indicates that Na^+ is released in that supports dissolution of F^- (Kodate et al. 2007). The negative relationship of F^- and Na^+ from deeper aquifers reveals no role of Na^+ in controlling F^- dissolution (Fig. 2c). The F^- and HCO_3^- show positive correlation in both shallow as well as deeper aquifers (Fig. 1d and 2d). However, higher concentration of HCO_3^- in shallow aquifers compared to deeper aquifers indicate release of more F^- in dugwells, where leaching process is dominant (Shivanna et al. 2003). Fluoride shows negative correlation with SO_4^{2-} and Cl^-, both from shallow as well as deeper aquifers (Fig. 1e, f and 2e, f). The weathering and pollution are the chief sources of SO_4^{2-} in groundwater. In shallow aquifers, SO_4^{2-}/Ca^{2+} ratio ranges from 0.79 to 6.16 whereas SO_4^{2-}/Ca^{2+} ratio in deeper aquifers varies from 1.14

Table 1. Chemical analysis of groundwaters from dugwells and borewells.

Sr.No	SampleNo.	pH µS/cm	EC mg/L	TDS	Ca^{2+}	Mg^{2+}	Na^+	K^+	HCO_3^-	SO_4^{2-}	NO_3^-	Cl^-	F^-
Dugwell													
1	NK1	7.54	680	451	75	34	17	0.8	289	61	10	7	2.6
2	NK2	7.76	699	456	64	32	18	1.0	293	70	12	8	2.4
3	NB3	7.42	970	621	79	38	55	12.6	233	234	13	38	1.1
4	NB4	7.41	975	632	76	37	53	12.0	235	233	15	41	1.3
5	B5	7.51	1990	1297	159	54	192	67.0	367	221	55	333	1.2
6	D6	7.87	1350	945	99	29	191	9.1	399	275	8	102	4.4
7	D7	7.87	1339	941	96	31	190	9.4	404	276	9	103	4.2
8	D8	7.81	710	487	52	21	67	1.9	275	89	8	22	3.9
9	V9	7.54	1010	619	53	33	116	3.7	281	199	3	26	3.2
10	M10	7.16	1670	1014	64	102	127	4.1	399	261	7	243	1.0
11	M11	7.20	1665	1011	59	99	131	4.3	402	263	8	244	1.1
12	P12	7.64	2950	2072	252	121	211	6.9	623	200	47	544	2.9
13	K13	7.82	2810	1779	118	83	267	16.2	431	317	2	367	2.9
14	M14	7.16	830	602	32	19	128	28.9	225	197	9	66	1.3
15	V15	7.14	3870	2479	325	253	68	41.1	436	601	99	585	1.1
16	V16	7.12	3878	2477	329	261	69	41.3	438	602	97	583	1.1
17	T17	7.61	1470	957	63	65	171	1.1	246	344	13	134	2.2
18	T18	7.61	1468	953	63	66	173	1.3	248	349	12	124	2.2
19	C19	7.34	1820	1231	107	79	143	1.7	311	428	1	156	1.0
20	S20	7.80	860	506	61	40	52	1.9	212	123	6	91	1.1
21	S21	7.81	869	508	63	38	54	1.9	211	122	6	93	1.1
22	D22	7.18	1310	768	53	31	168	5.6	301	264	14	87	1.8
23	D23	7.16	1308	771	55	30	171	5.3	298	262	13	86	1.7
Borewell													
24	NK1	7.57	970	670	82	25	67	1.0	261	161	8	42	1.6
25	NK2	7.55	970	659	84	27	61	1.1	264	160	8	39	1.4
26	NB3	7.30	910	627	84	26	63	13.3	234	104	0	83	0.6
27	NB4	7.31	920	633	82	27	61	13.5	236	103	1	82	0.5
28	B5	7.1	1290	842	150	33	64	3.4	233	171	15	153	0.6
29	D6	7.37	1370	889	68	50	65	8.1	303	135	6	177	2.4
30	D7	7.39	1360	891	70	46	67	8.4	300	136	7	174	2.5
31	D8	7.29	800	521	50	41	66	1.6	269	145	0	25	2.9
32	V9	7.09	1460	961	82	23	183	7.9	211	198	0	261	0.9
33	M10	7.01	2830	1843	96	193	170	2.3	234	404	8	520	0.5
34	M11	7.03	2840	1841	94	197	169	2.6	236	401	8	517	0.5
35	P12	7.35	1580	1021	56	67	168	2.8	373	218	12	144	1.9
36	K13	7.25	3000	1967	288	95	189	17.4	372	533	0	467	2.1
37	M14	7.04	2370	1543	198	92	122	56.6	369	269	13	426	1.1
38	V15	7.09	3330	2162	278	171	89	57.8	239	401	11	485	1.0
39	V16	7.07	3340	2157	280	167	92	57.9	399	403	11	483	1.0
40	T17	7.37	2050	1333	122	86	187	6.2	394	344	11	234	1.6
41	T18	7.34	2040	1334	120	83	183	5.9	370	349	12	233	1.8
42	C19	7.02	1250	832	56	48	129	7.8	372	230	1	139	1.0
43	S20	7.24	1230	801	88	39	100	2.5	257	157	3	111	1.0
44	S21	7.33	1220	799	90	43	97	2.9	314	159	5	109	0.9
45	D22	7.31	2430	1580	146	99	199	15.9	311	499	19	302	1.2
46	D23	7.29	2440	1576	144	102	203	16.1	278	501	19	299	1.3

to 4.27 (Table 2) indicating dissolution of sulphate bearing minerals in groundwater (Saini et al. 2006). The presence of coal and pyrite bearing rocks of the Barakar formation are responsible for the concentration of the SO_4^{2-} content in groundwater (Karanth 1997). Pophare & Dewalkar (2007), while working in sedimentary terrain have established the relationship between TDS content and fluoride concentration. They pointed out that when TDS is lower, the fluoride content is also low. This is in agreement with observation in the present investigation.

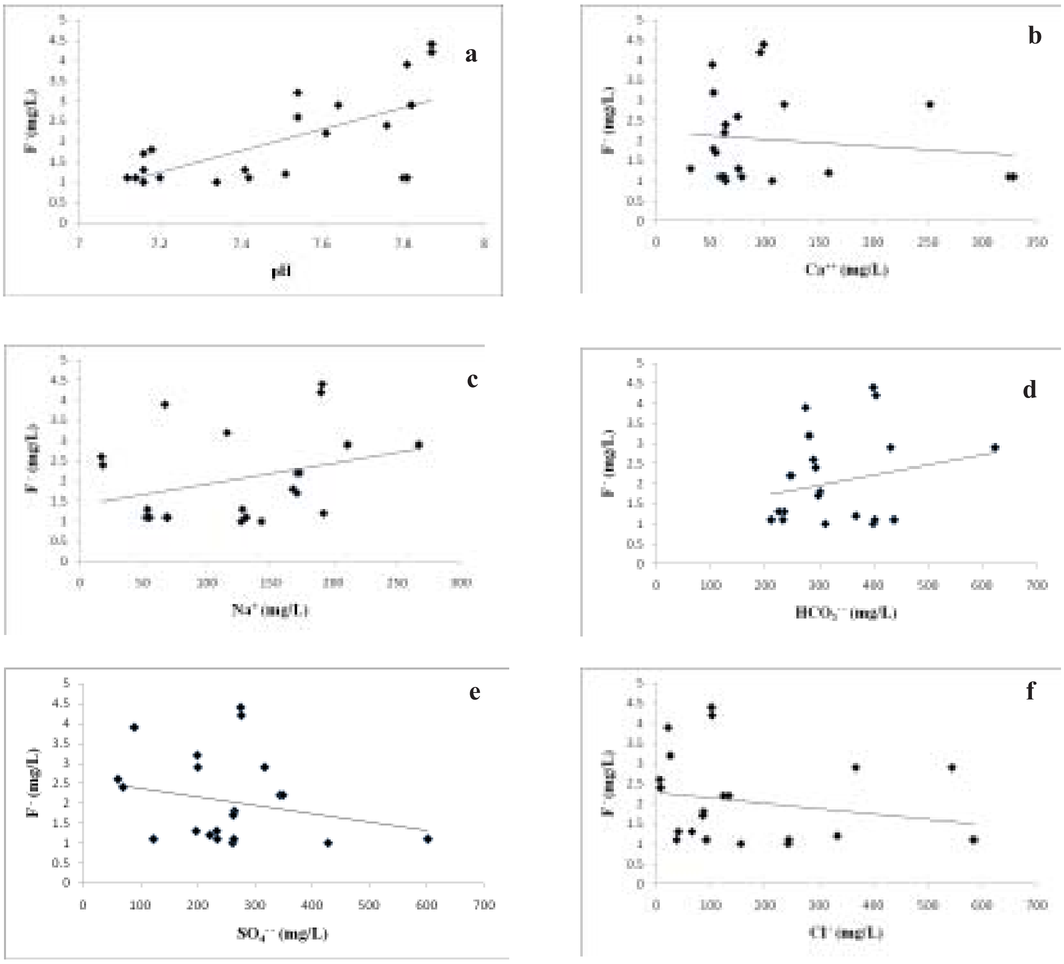

Fig.1: Correlation of fluoride with other chemical parameters from dugwell samples.

CONCLUSIONS AND REMEDIAL MEASURES

The rock-water interaction is the main process for the source of fluoride in groundwater of the area under investigation. The leaching of fluoride containing minerals from the weathered zone has contributed to the high fluoride concentration in shallow aquifers. This may be the sole reason for higher content of fluoride in the dugwells than the borewells. The higher concentration of fluoride in Lameta aquifers is ascribed to the presence of fluoride bearing minerals like fluorite and apatite in limestones or the clays. The principal source of fluoride in the Talchir shales is micas and the clay minerals.

The defluoridation, nutritional supplementation and artificial recharge are the common practices for prevention and control of the fluorosis. The flocculation method popularly referred to as Nalgonda technique, which involves addition of lime and alum powder to the water, also proved to be effective. Instead of lime the bleaching powder can also be added to disinfect the water (Madhnure & Malpe 2007). The supplementation by calcium rich, vitamin C and antioxidants to the diet may be beneficial for prevention of fluorosis. The artificial recharge of groundwater, perhaps, is the better remedial measure to control fluorosis (Gupta & Deshpande 2003).

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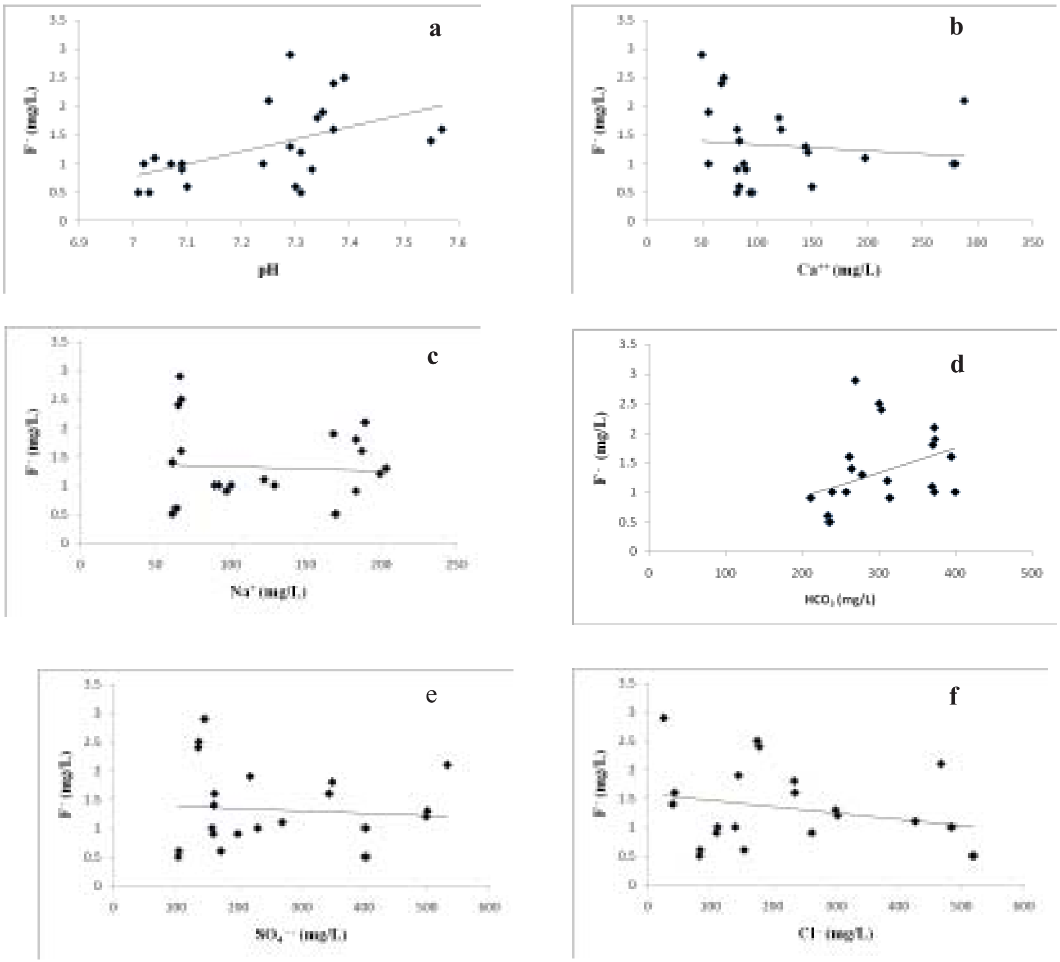

Fig.2: Correlation of fluoride with other chemical parameters from borewll samples.

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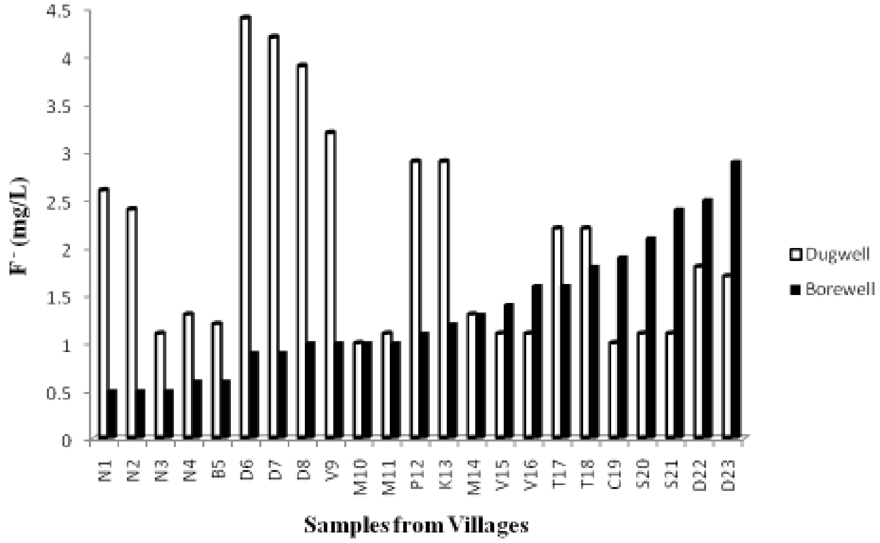

Fig. 3: Fluoride content from dugwells and borewells.

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