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Original Research Paper

Fluoride Toxicity in Groundwater and its Chronic Effect on Human Health: A Study in Tiptur Town and its Surrounding Areas in Karnataka State, India

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ABSTRACT

Groundwater is one of the boon provided by nature but indiscriminate urbanization, industrialization and overexploitation have led to its deterioration both in its quality and quantity. Fluorides are mainly found in groundwater derived by the solvent action of water on the rocks and the soil of the earth's crust. It is the most electro-negative of all chemical elements and is never encountered in nature in the element form. Imbalance of fluoride concentration causes effect on human life. A total of 50 groundwater samples were collected and analyzed for various physico-chemical parameters as well as fluoride content. The groundwater samples were collected in sterilized polyethylene plastic bottles and then immediately analyzed for pH, electrical conductivity, total dissolved solids, calcium, magnesium, total hardness, chloride and alkalinity. The fluoride concentration in some sample locations like S8, S10, S21, S32 and S48 were nearing the maximum permissible value of 1.5mg/L and in all other samples it ranged between 0.37 mg/L to 1.48mg/L. It was found that out of 50 samples, about 90% were within permissible limit while 10% had fluoride approaching maximal permissible limit (1.5mg/L). Fluoride is an essential mineral for human life and for animals within permissible limit. The present study becomes essential for the people of Tiptur town and its surrounding areas to lead a healthy life, as they depend on groundwater resources to a great extent.

INTRODUCTION

The fluoride in drinking water is considered to be a neurotoxin. It contributes to learning disabilities in children, including hyperactivity and attention deficit disorder. It also contributes to lower IQ, because the compounds used to fluoridate water cause the body to increase its uptake through the gut. It is fairly conclusive that chronic intake increases the risk of cancer, affects the immune system and hasten up the aging process. In high concentrations, soluble fluoride salts are toxic and skin or eye contact with the high concentration of many fluoride salts is dangerous. Referring to a common salt of fluoride, sodium fluoride (Na F), the lethal dose for most adult humans is estimated at 5 to 10 g, which is equivalent to 32 to 64 mg/kg elemental fluoride per kg body weight. A toxic dose that may lead to adverse health effects is estimated at 3 to 5 mg of elemental fluorides. Due to scarcity of surface water, Rajasthan has to depend on groundwater resources to a great extent. Groundwater fluoride contents in high levels are present in all the 33 districts and have become a serious health related issue in 23 districts of Rajasthan (Agrawal et al.1997, Maithani et al. 1998, Datta et al. 1999). Ingestion of fluoride can produce gastro intestinal discomfort at doses at least 15 to 20 times lower (0.2-0.3mg/L) than lethal doses. Although helpful for dental health in low dosage, chronic exposure to fluoride in large amounts interferes with the bone formation. In this way, the greatest example of fluoride poisoning arises from fluoride rich groundwater.

In India, an estimated 60 million people have been poisoned by well water contaminated by excessive fluoride which gets dissolved from granite rocks. The effects are particularly evident in the bone deformation of children. Dental fluorosis can alter the appearance of teeth (Fig. 1). Compared to un-fluoridated water, fluoridation to 1mg/L is estimated to cause fluorosis in one out of every 6-22 people. In general, excess consumption of fluoride may cause weakening of bones, bone fractures and wrist fractures at the consumption of 1-4 mg. Also it adversely affects kidney at the consumption of 12g/day, liver damage at 23mg/day and chromosomal damage and interference with the DNA repair. Epidemiological studies have noted a correlation between fluoride and low IQ (Wikipedia, the free e.fluoride toxicity). Fluorides, as with number of other trace elements (e.g., iodine, selenium), can therefore be considered as harmful or beneficial to humans and animals (Dissanayake 1991, Ozsvanth 2009) depending on the amount ingested on daily basis. Some hydro chemical conditions that may favor dissolution of fluorine from silicates include alkaline pH, anion

exchange (OH^- for F^-) capacity of aquifer materials, cation exchange capacity (N^{a+} for Ca^{+2}), long residence time of water in water rock interaction system and climate (Boyle 1992, Saxsena & Ahemd 2001, Ozsvath 2009). Trace elements are essential and beneficial for human body in minute concentrations, as they play an important role in many metabolic processes. However, excess intake of certain trace elements can have adverse effects on general body metabolism. One such trace element is fluorine in the form of fluoride, which is ubiquitously distributed in soil, earth and water. It is known that low amount of fluoride (0.3-1.0 mg/L) in drinking water helps in the prevention of dental caries and osteoporosis. However, high intake of more than1.5mg/L in drinking water for prolonged period can damage the teeth enamel and eventually lead to skeletal complications which ultimately can result in fluorosis (WHO 2006, ISI 1983). Thus, fluoride concentration is an important aspect of hydrogeochemitry.

The estimation of fluoride becomes important to lead a healthy life on this planet. Especially, 65% of the Indian villages are exposed to fluoride risk (UNICEF 1999). The present study was, therefore, undertaken to analyze the fluoride content and physico-chemical characteristics of groundwater in and around Tiptur town, Tumkur district, Karnataka.

STUDY AREA

Karnataka State is situated in the southern peninsular India. Tiptur town is about 75km from Tumkur district. It covers an area of 785 sq.km and situated at 13°16' north latitude and 76°29' east longitude at an altitude of 850.30 meter above sea level. The average temperature ranges from 11°C in winter and 38°C in summer. The average rainfall of Tiptur town is 503 mm.

MATERIALS AND METHODS

A critical perusal of the available literature has revealed that there is no systematic and scientific data on drinking water as the town depends on groundwater (bore wells) to meet the needs for drinking water. With this background, the present study was taken up to investigate the groundwater quality of Tiptur town and its surrounding areas. The samples were collected from February 2011 to May 2011 for four months comprising the pre-monsoon season.

Fifty samples were collected in 100mL plastic bottles and immediately taken to the laboratory to avoid impeditable changes in physico-chemical properties and analyzed for the parameters such as pH, alkalinity, total hardness, total dissolved solids, electrical conductivity, fluoride, calcium, magnesium and chloride. Temperature and pH were recorded on the spot by water analyzer kit (Global) and titration method following APHA (1992). From the collected data correlation were made. Fluoride concentration in all sampling locations was analyzed using visi-spectrophotometer 301 Global model at 570 nm.

RESULTS AND DISCUSSION

The results of physico-chemical characteristics of water samples including fluoride concentration are given in Table 1. Very high correlation was found between electrical conductivity and total dissolved, and total hardness and magnesium. Besides, there was good correlation between electrical conductivity, chloride, calcium and total dissolved solids, chloride, calcium (Table 2).

Fluoride concentration in the location S8, S10, S21, S32, and S48 ranged between 1.22mg/L and 1.48 mg/L as against the standard value of 1.5 mg/L as per WHO (2006). Study conducted in Rajasthan shows more than 40% area in Nagaur

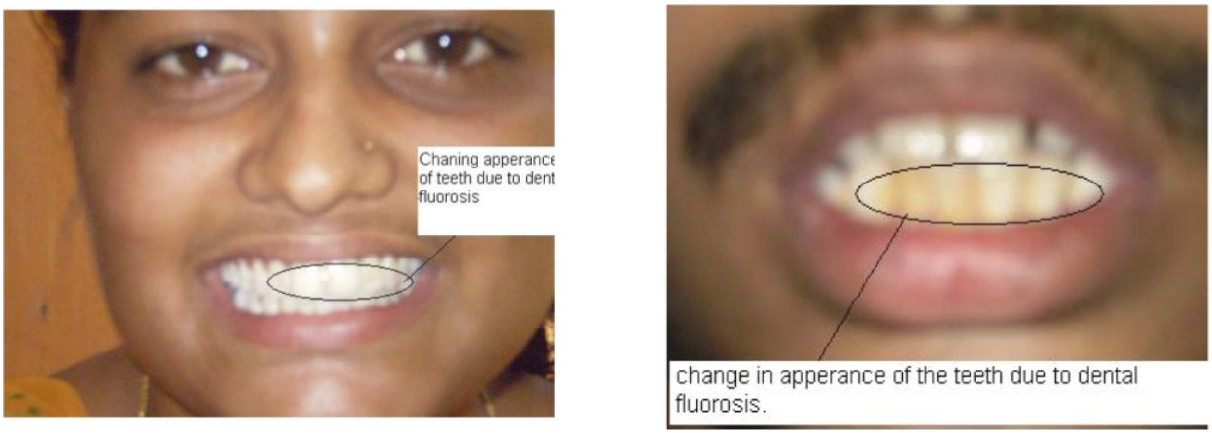

Fig. 1: Dental fluorosis.

Table 1: Physico-chemical properties of samples in and around Tiptur town and surrounding areas.

	Smapling Stations	pH	Alk mg/L	EC µmho/cm	TDS mg/L	TH mg/L	Ca^{+2} mg/L	Mg^{+2} mg/L	Cl^{-} mg/L	F^{-} mg/L
S1	Eralagre	7.48	520	932	622	240	39	34.6	160	0.48
S2	Chikkmarppanahalli	7.14	320	1079	720	175	74	2.37	220	0.37
S3	Doddamarppanahalli	6.98	230	319	213	310	8	70.4	52	0.53
S4	Ramenahalli	6.96	620	1169	780	315	83	26.1	305	0.78
S5	Huchgondnahalli	7.35	400	929	620	285	51	38.2	165	0.67
S6	Karadi	7.12	385	1019	680	205	68	8.54	270	0.86
S7	Kuppalu	6.24	430	959	640	195	57	13.2	180	1
S8	Gorgondanahalli	6.88	560	2079	1387	222	92	1.87	440	1.22
S9	Hedagarahalli	6.8	590	1370	914	100	69	17.5	187	0.98
S10	Bedagarahalli	6.89	540	1490	994	502	90	67.3	305	1.33
S11	Aldahalli	7.12	720	800	534	530	53	96.5	156	0.52
S12	Kannugatta	7.02	250	670	447	400	27	80.7	125	0.66
S13	Sugur	7.01	400	600	400	390	23	80.7	94	0.7
S14	Kodihalli	6.98	590	1529	1020	270	91	10.3	240	0.45
S15	Machegatta	7.12	330	509	340	570	13	130.5	76	0.97
S16	Tadasur	6.8	620	2049	1367	660	108	94.7	330	0.78
S17	Gurgadahalli	7.06	510	900	600	350	49	55.2	174	0.8
S18	Siddapura	7.1	330	390	260	310	11	68.6	78	0.73
S19	Honnavalli	6.63	490	1439	960	510	99	63.8	260	0.81
S20	Potarihalli	6.82	630	890	594	260	50	32.8	100	0.63
S21	Byrapura	7.05	450	900	600	500	24	106.8	125	1.38
S22	Halenahalli	6.92	610	1340	894	770	32	167.5	225	0.58
S23	Madenoor	6.8	720	2049	1367	1180	131	207.1	340	1.08
S24	Bidaregudi	7.12	430	719	480	480	19	105	115	0.96
S25	Shivara	6.98	490	2139	1427	750	153	89.3	400	0.96
S26	Manakikere	7.06	450	1269	847	335	44	54.6	185	0.61
S27	Nagatihalli	6.99	590	1218	813	670	56	128.7	195	0.58
S28	Idenahalli	6.99	380	860	574	415	35	79.5	183	0.57
S29	Marangere	6.9	355	949	633	390	56	60.7	171	0.45
S30	Anagondanahalli	7.1	500	790	527	560	29	118.4	114	0.65
S31	Madihalli	7.68	550	791	528	630	22	139.6	99	0.68
S32	Nagaragatta	7.11	640	900	600	625	27	135.4	170	1.28
S33	Echoor	6.9	630	1300	867	600	64	106.8	205	0.84
S34	Kanchegatta	7.45	510	878	586	400	47	68.6	127	0.77
S35	Kotanayakanahalli	7.28	415	850	567	485	42	92.3	172	0.78
S36	Lingadahalli	7.3	340	1030	687	510	45	96.5	152	0.51
S37	Gudigondanahalli	7.12	520	700	467	490	24	104.4	155	0.67
S38	Rangapura	7	630	1008	673	750	43	156	100	0.67
S39	Sarathavalli	7.35	440	540	360	305	18	63.1	85	0.44
S40	Kobredoddayyanna Palya	7.46	680	878	586	550	33	113.5	110	1.01
S41	Gandhi Nagar	7.73	480	570	380	260	13	55.25	75	0.68
S42	Chamundeshwari Badavane	6.93	675	1109	740	600	39	122	151	0.82
S43	Sharada Nagar	7.28	530	770	514	610	30	129.9	110	1.04
S44	Vidya Nagar	7.32	500	850	567	370	15	80.7	115	0.98
S45	H.B.Colony	6.9	490	929	620	495	36	98.4	120	1.01
S46	Govina Pura	7.3	540	1758	1173	1000	32	223.4	151	0.51
S47	Shankarappa Layout	7.14	560	1490	994	970	20	223.4	273	0.6
S48	Manjunatha Nagar	7.66	430	620	414	400	18	86.2	73	1.48
S49	Vinayaka Nagar	6.86	600	1520	1014	920	30	205.2	265	0.67
S50	Kote	7	620	1338	893	460	32	92.3	235	0.54
	WHO & ICMR Standards	7-8.5	200	750	500-1500	300-600	200	75-200	1.0	1.0

district having fluoride contamination between 1.5 and 13.5 mg/L (Seth 2005). Regular consumption of 1.5mg/L was medically found to be deleterious to health (Sinha & Musturia 2004). Few cases of fluoriosis were found in the study area.

In most of the drinking waters over 95% of total fluoride is the F^{-} ion, and magnesium fluoride complex (MgF^{+}) being the next most common. Because fluoride level in water is usually controlled by the solubility of fluorite (CaF_2), high

Table 2: Correlation coefficient between groundwater characteristics.

	pH	Alkalinity	EC	TDS	T. Hardness	Ca^{+2}	F^-	Cl^-	Mg^{+2}
pH	1	0.1263	-0.4079	-0.4079	-0.4045	-0.4611	-o.0723	-0.4535	0.1014
Alk.		1	0.4976	0.4975	0.4373	0.3104	0.1480	0.3435	0.3379
EC			1	1	0.4361	0.7824	0.1074	0.8806	0.1770
TDS				1	0.4362	0.7823	0.1073	0.8805	0.1771
TH					1	0.ii01	0.0610	0.2225	0.9393
Ca^{+2}						1	0.1328	0.8165	-0.2263
F^-							1	0.1381	0.2447
Cl^-								1	-0.0555
Mg^{+2}									1

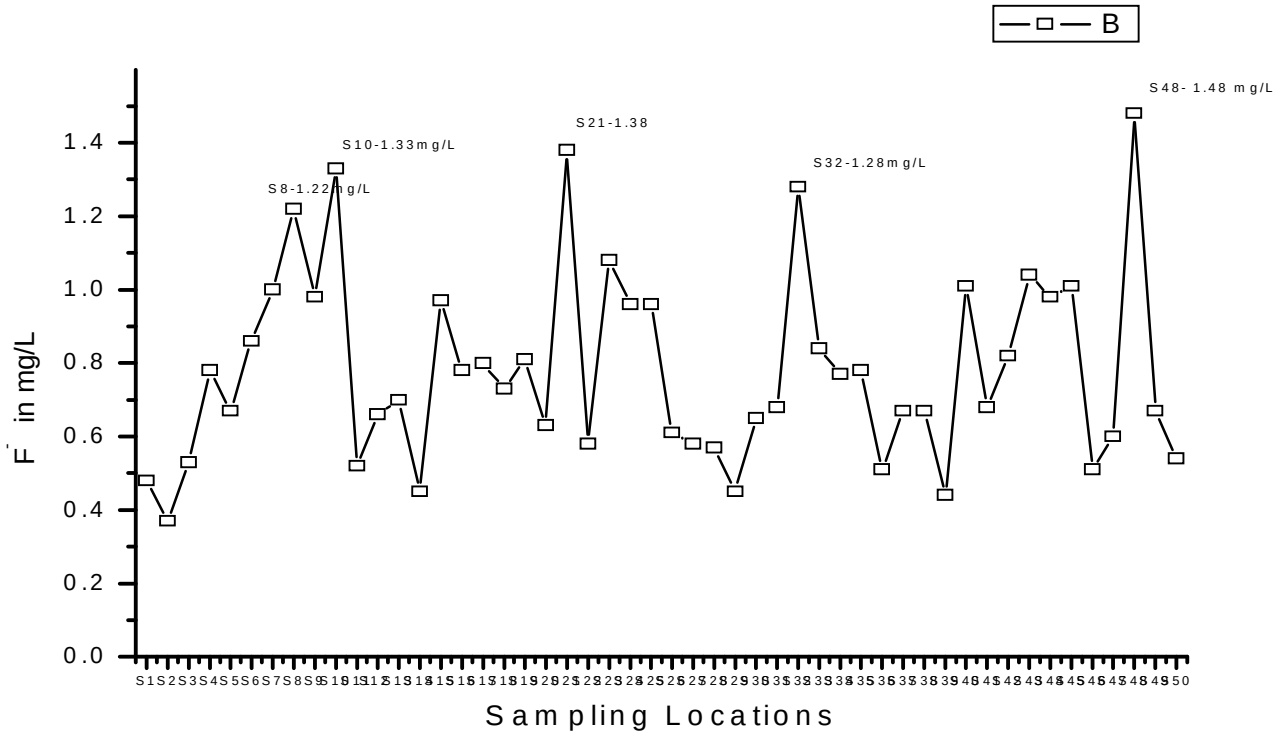

Fig.2: Fluoride concentrations in mg/L at different locations of Tiptur town.

natural fluoride levels are associated with calcium-deficient, alkaline and soft waters. Defluoridation is needed when naturally occurring fluoride level exceeds recommended limits. In the present study out of 50 samples about 10% were above 1.22mg/L but less than 1.5mg/L. Water fluoridation is effective in reducing cavities in both children and adults. Studies showed that water fluoridation led to reduction of 50-60% in childhood cavities; more recent studies show lower reduction (18-40%) likely due to increasing use of fluoride from other sources notably toothpaste and also the halo effect of food and drinks made in fluoridated areas and consumed in unfluoridated ones. The only clear adverse effect is dental fluorosis which can alter appearance of teeth at intake concentration of more than 1.5 mg/L (Fig. 2). In case the fluoride is less than 0.3mg/L fluoridation is required up to 1mg/L as per the WHO guidelines.

Like other water additives such as chlorine, hydro-fluorosilicic acid, sodium silicofluoride decrease pH and causes small increase in corrosivity, but problem can be solved by increasing pH. Change of pH corresponding to fluoride concentration is represented in Fig. 3 . The results of the present study are within the permissible limits of WHO.

Other physico-chemical properties such as pH, alkalinity, total dissolved solids, electrical conductivity, total hardness,

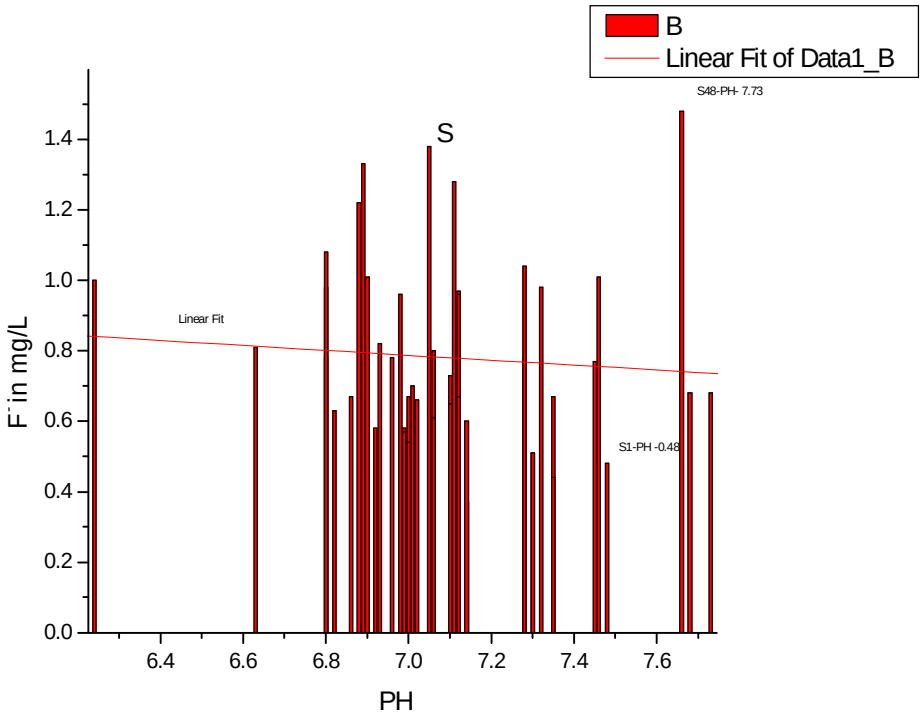

Fig. 3: F^- vs. pH.

chloride, calcium (Ca^{+2} and Mg^{+2}) were also studied. pH recorded in groundwater samples was between 6.63 and 7.73. A positive correlation (r = 0.893) was observed between fluoride and pH as reported by Teotia et al. (1981) and Trivedi (1988). Electrical conductivity ranged from 219 to 2139 µmho/cm. In Tiptur town and surrounding areas the groundwater contains varying concentration of total dissolved solids as a result of dissolution of materials in rocks, soil and decomposing plant materials. Total dissolved solids varied from 213mg/L to 1758mg/L. The principal ions contributing total dissolved solids are carbonate, bicarbonate, chloride, fluoride, sulfate, nitrate, sodium, potassium, calcium and magnesium (EPA 1976). Chloride varied between 52mg/L and 440 mg/L.

Research has been done regarding a strong negative correlation between Ca^{+2} and F^- in the groundwater that contains Ca in excess of that required for the solubility of fluoride minerals (Boyle 1992, Janardana et al. 2009). Hence, if calcium is present in higher concentration it is most effective in reducing the fluoride concentration. Calcium content in Tiptur town and surrounding areas ranged from 8- 153 mg/L, and magnesium from 2.37-223 mg/L.

Due to low fluoride solubility, hardness showed negative correlation with the fluoride content (Radha Gautam et al. 2010). In the present study hardness showed low correlation with the fluoride and also it was observed that with increase in the concentration of the fluoride in the groundwater hardness decreased while alkalinity increased. In sampling locations S_{10} fluoride was 1.33mg/L, hardness 502mg/L and alkalinity 540mg/L. Similarly in S_{48} fluoride was 1.48mg/L, hardness 400mg/l and alkalinity 430 mg/L.

The acceptable range for the alkalinity as per BIS (1991) is 200mg/L (maximum) and beyond this range (abve 600 mg/L) water becomes unpleasant. The results were in agreement with the findings of Susheelea (1999), Sinha & Musturia (2004) and Saini & Bhardwaj (2006). Similar observations were reported earlier by many investigators (Kaushik et al. 2004, Sabal & Khan 2008, Radha Gautam et al. 2011).

CONCLUSION

After looking into the overview of study it is concluded that groundwater of Tiptur town and surrounding areas contained no free acids as indicated by the pH value. All dissolved minerals like calcium, magnesium, chloride and fluoride in the groundwater were within the ICMR and WHO desirable limits. Study also revealed that groundwater in Tiptur town and its surrounding areas was free from fluoride toxicity and serious health hazards, except at few sampling locations (S_{10},S_{21} ,S_{48}) where fluoride was approaching maximum lim-

its. But few cases of dental and skeletal fluorosis were noted, because of regular consumption of the groundwater contaminated with fluoride at more than 1.5 mg/L according to medical research. Hence, in such sample locations defluoridation is required to reduce the incidences of dental and skeletal fluorosis.

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