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RESEARCH ARTICLE

Role of Alkalinity for the Release of Fluoride in the Groundwater of Tiruchengode Taluk, Namakkal District, Tamilnadu, India†

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Abstract: This work was undertaken to study the specific relationship between alkalinity and presence of fluoride ion in groundwater. Groundwater samples were collected from 24 different stations in Tiruchengode taluk, Namakkal district, Tamilnadu, India during the month of December 2011 and July 2012. The samples were stored in sterilized 2 L polythene containers and used to carry out the analysis of various physicochemical parameters. The alkalinity values were found to be more than the permissible limit. It plays an important role for the release of fluoride ion from its ore to the groundwater. It was observed that an increase in the alkalinity value made a similar increase in the amount of fluoride. In alkaline environment, the fluoride ion can be easily liberated from their ore because OH^- and F^- ions have similar radii. Hence they easily exchange with each other.

Keywords: Groundwater, Fluoride, Anthropogenic, Fluorosis, Namakkal District

Introduction

Fluoride is one of the most potent groundwater pollutant[1]. Fluoride exists in many forms and the harmful nature of the fluoride is contingent upon the type of fluoride it is. Depending on its concentration the fluoride in drinking water is known for both beneficial and detrimental effects on health, particularly to infants and young children. Fluoride is perhaps the only element whose deficiency (<0.5 ppm) as well as its presence in excess (>1.5 ppm) in drinking water has serious health implications. It is well known for its adverse health effects. It acts as an essential element up to 1.0 mg/L helping in teeth formation and strengthening of skeleton, beyond the limit it exerts negative impacts on the human health causing debilitating disease named "Fluorosis"[2].

Fluoride epidemic has been reported in as many as 19 Indian States and Union Territories. India is one among the 23 nations in the world, where fluoride contaminated groundwater is creating health problems. The state of art report of UNICEF confirms the fluoride problem in 177 districts of 20 states in India[3]. The high fluoride levels in drinking water and its impacts on human health have increased the importance of defluoridation studies[4-6]. The magnitude of the problem is sinking in and effects are being made towards defluoridation of drinking water, combating the debilitating fluorosis and taking steps to prevent and control the disease[7-9].

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Fluoride is well recognized as an element of public health concern. Fluoride is present universally in almost every water (Higher concentrations are found in groundwater), earth crust, many minerals, rocks *etc*. it is also present in most of everyday needs, *viz*, toothpastes, drugs, cosmetics, chewing gums, mouthwashes and so on[10]. An intake of more than 6 ppm of fluoride results in multidimensional health manifestations, the most common being dental and skeletal fluorosis[11,12]. Higher concentration of fluoride also causes respiratory failure, fall of blood pressure and general paralysis. Loss of weight, anorexia, anemia, wasting and cochexia are among the common findings in chronic fluoride poisoning. Continuous ingestion of non-fatal dose of fluorides causes permanent inhibition of growth. Fluoride ions inhibit a variety of enzymes often by forming complexes with magnesium ions and other metal ions[13-15].

This project work was undertaken to study the specific relationship between Alkalinity and presence of fluoride ion in groundwater. Tiruchengode Taluk, Namakkal district, was selected for our study. Groundwater samples were collected from 24 different stations in sterilized 2 L polythene containers during the month of December 2011 and July 2012 and carried out the analysis of various physicochemical parameters. We have carried out detailed hydrochemical studies in Tiruchengode Taluk, Namakkal district with a focus on fluoride occurrence and the findings are presented here. Besides offering a comprehensive status of fluoride concentration in groundwater in Tiruchengode Taluk, this paper also discusses fluoride distribution in relation to alkalinity.

Experimental

The samples were collected from various water sources during December 2011 and July 2012. First the water was left to run from sampling source for 4-5 min, before collecting sample. Samples were collected in pre-cleaned sterilized polyethylene bottles of 2 L capacity. The groundwater samples were analyzed to assess various chemical and physical water quality parameters such as pH, Electrical Conductivity(EC), Total Dissolved Solids(TDS), Ca^{2+}, Mg^{2+}, Cl^-, F^-, SO_4^{2}, NO_3^-,NO_2^- and PO_4^{2-} according to the standard method (APHA 1995). pH and temperature were determined *in situ* by portable pH meter and thermometer. Total hardness (TH) and Ca^{2+} were analyzed titrimetrically using standard EDTA. Mg^{2+} was computed, taking the difference between total hardness and Ca^{2+} values. Cl^- was estimated by standard $AgNO_3$ titration and SO_4^{2-} was measured by the volumetric method. Fluoride concentration was determined by Ion-selective electrode method.

Study area

The study area is situated at a distance of 45 km south-west of Salem and at a distance of 8 km from Sankaridurg, which is the nearest railway station. It lies between North Latitudes 11°20' and 11° 30' and East Longitudes70°50' and 78° 0' with a total extent of 25.20 sq km. This area experiences a tropical climate, with an average rainfall varies from 640 mm to 880 mm. Mornings in general are more humid than the afternoons with the humidity exceeding 78% on an average. In the period from June to November the afternoon humidity exceeds 66% on an average. In the rest of the year the afternoons are drier, the summer afternoons being the driest.

The hot weather begins early in March, the highest temperature being felt in April and May. Weather cools down progressively from about the middle of June and December; the mean daily maximum temperature drops to 30.2 °C.

Hydrogeology

Namakkal district is underlain entirely by Archaean Crystalline formations with recent alluvial deposits occurring along the river courses and Colluvium at the foothills. The depth

to water level in the district varied between 1.20 to 14.33 m bgl during pre-monsoon and the depth to water level varied between 0.86 to 16.60 m bgl during post monsoon. The seasonal fluctuation shows a rise in water level, which ranges from 0.03 to 3.51 m bgl. The piezometric head varied between 1.35 to 9.40 m bgl during pre-monsoon and ground level to 13.00 m bgl during post monsoon.

Results and Discussion

Table 1 presents the physicochemical parameters of groundwater of study area. Fluoride concentration in groundwater of 23 villages of Tiruchengode block was analyzed. The groundwater was free from colour, odour and taste and it was slightly saline. The pH of the groundwater in the study area was 6.9 to 10.0. EC and TDS signify the inorganic load of any water body. The EC of the groundwater varies from 153 to 4767 µs/cm. Higher EC may be attributed to high salinity and high mineral content in the sampling points. TDS a salinity indicator for the classification of groundwater varies between 500 and 2450 mg/L.

Table 1. Physicochemical characteristics of the groundwater of Tiruchengode Block, Namakkal District (*A-W are the different stations of study area; cf. Table 2)*

S.No	Parameter	Unit	A	B	C	D	E	F
1	pH	-	8.0	7.9	7.7	8.2	8.2	8.0
2	Color	-	Color less	Color less	Color less	Color less	Color less	Color less
3	Electrical conductivity	µs/cm^{-1}	4366	6810	6415	2628	1483	708
4	Temperature	ºC	27.1	26.0	25.8	31.1	31.1	31.1
5	Odour	-	Odour less	Odour less	Odour less	Odour less	Odour less	Odour less
6	DO	mg/L	2.42	1.21	0.80	3.43	4.44	10.90
7	TDS	mg/L	1530	1700	5450	1974	1146	557
8	COD	mg/L	11.6	10.0	7.6	46.8	28.8	6.4
9	BOD	mg/L	1.2	1.2	4.3	0.9	1.2	1.4
10	Total alkalinity	mg/L	465	675	560	835	595	415
11	Total hardness	mg/L	602	690	860	620	218	254
12	Chloride	mg/L	563.74	792.36	756.86	450.14	191.70	100.82
13	Calcium	mg/L	200.40	228.45	347.09	114.62	47.29	62.52
14	Magnesium	mg/L	401.6	461.55	512.91	123.31	41.65	46.72
15	Fluoride	mg/L	0.54	1.1	0.87	1.9	0.25	0.31

Table 1. Continued

S.No	Parameter	Unit	G	H	I	J	K	L
1	pH	-	8.0	6.9	7.7	7.8	7.8	9.5
2	Color	-	Color less	Color less	Color less	Color less	Color less	Color less
3	Electrical conductivity	µs/ cm^{-1}	1841	1085	1824	3260	3217	1265
4	Temperature	ºC	31.2	33.9	34.1	33.6	33.7	33.1

Contd…

5	Odour	-	Odour less	Odour less	Odour less	Odour less	Odour less	Odour less
6	DO	mg/L	3.03	3.03	4.84	8.28	3.63	4.04
7	TDS	mg/L	1432	893	1372	2655	2609	1024
8	COD	mg/L	8.4	14.8	4.8	8.4	13.2	22.4
9	BOD	mg/L	2.2	0.4	1.2	0.7	0.4	0.9
10	Total alkalinity	mg/L	790	550	630	860	40	700
11	Total hardness	mg/L	250	410	484	696	428	450
12	Chloride	mg/L	203.06	171.82	302.46	282.58	313.82	228.62
13	Calcium	mg/L	58.51	88.97	77.75	186.77	99.39	87.37
14	Magnesium	mg/L	46.72	45.83	70.72	56.03	43.87	56.56
15	Fluoride	mg/L	0.30	0.44	1.7	1.7	1.1	1.6

Table 1. Continued

S.No	Parameter	Unit	M	N	O	P	Q	R
1	pH	-	9.9	9.7	10.0	7.8	7.8	7.9
2	Color	-	Color less	Color less	Color less	Color less	Color less	Color less
3	Electrical conductivity	µs/ cm^{-1}	1453	1752	1796	1141	2327	2139
4	Temperature	ºC	33.5	33.0	33.1	32.4	32.0	31.9
5	Odour	-	Odour less	Odour less	Odour less	Odour less	Odour less	Odour less
6	DO	mg/L	2.77	5.05	6.26	5.85	6.86	5.45
7	TDS	mg/L	1174	1396	1421	904	1820	1681
8	COD	mg/L	30.8	10.8	25.6	34.8	31.6	27.2
9	BOD	mg/L	0.8	1.3	2.4	1.6	2.8	2.1
10	Total alkalinity	mg/L	700	650	850	350	670	390
11	Total hardness	mg/L	538	562	596	440	836	576
12	Chloride	mg/L	302.46	274.06	306.72	248.5	475.7	426
13	Calcium	mg/L	161.92	189.17	220.44	121.04	322.24	126.65
14	Magnesium	mg/L	32.62	21.87	11.11	33.61	7.65	63.38
15	Fluoride	mg/L	0.38	0.84	1.4	0.82	1.3	0.72

Table 1. Continued

S.No	Parameter	Unit	S	T	U	V	W
1	pH	-	7.5	7.3	7.7	7.9	7.6
2	Color	-	Colorless	Colorless	Colorless	Colorless	Colorless
3	Electrical conductivity	µs/ cm^{-1}	868	3215	825	2375	2821
4	Temperature	ºC	31.9	32.7	32.3	31.6	32.5
5	Odour	-	Odour less	Odour less	Odour less	Odour less	Odour less
6	DO	mg/L	2.82	1.61	1.81	2.62	1.41
7	TDS	mg/L	683	2543	655.80	1873	2232
8	COD	mg/L	7.2	99.2	30	50.4	16.8

Contd…

9	BOD	mg/L	0.7	0.5	0.2	1.9	1.1
10	Total alkalinity	mg/L	220	425	287.5	650	525
11	Total hardness	mg/L	330	1028	428	720	748
12	Chloride	mg/L	170.4	802.3	213	475.7	532.5
13	Calcium	mg/L	106.61	220.44	121.04	322.24	126.65
14	Magnesium	mg/L	15.56	70.72	56.03	43.87	56.56
15	Fluoride	mg/L	0.39	1.4	0.38	1.2	1.1

Table 2. Fluoride variations in the study area

S No	Stations	Fluoride, mg/L
A	Anangur	0.54
B	Devanankurichi	1.1
C	Srinivasampalayam	0.87
D	Pirithi	**1.9**
E	Molasi	0.25
F	Eryamangalam	0.31
G	Patlur	0.30
H	Chitalandur	0.44
I	Pudupuliyampatti	**1.7**
J	Sirumolasi	**1.7**
K	Animoor	1.1
L	Chickanaikanpalayam	**1.6**
M	T Goundampalayam	0.38
N	Emapalli	0.84
O	Andipalayam	**1.4**
P	Thaneerpandalpalayam	0.82
Q	Valrasapalayam	1.3
R	Modamangalam	0.72
S	Karuvepampatti	0.39
T	Vattur	**1.4**
U	Thirumangalam	0.38
V	T Kailasampalayam	1.2
W	Karumapuram	1.1

Ca^{2+} and Mg^{2+} are important ions for TH. In the study area, the Ca^{2+} concentration varies from 113.8 to 250.0 mg/L. Due to dissociation of $CaCO_3$, Ca^{2+} gets enriched in the water and it is possible that some fluoride are getting removed by the Ca^{2+} as CaF_2 or Fluoroapatite $[Ca_5(PO_4)_3F]$ in the medium. The Mg^{2+} in the study area varies from 38.1 to 176.2 mg/L. A concentration of 30 mg/L is recommended for Mg^{2+} in drinking water. Mg^{2+} is an essential indicator of many enzyme system but magnesium salts are cathartic and diuretic, and high concentration may cause laxative effect, while deficiency may cause structural and functional changes. The concentration of Cl^- in the study area ranges from 72.4 to 534.1 mg/L. The concentration of fluoride ranges from 0.12 to 1.9 mg/L. The fluoride content of groundwater varies greatly depending on the geological setting and type of rocks (Table 2). During weathering and circulation of water in Rocks and soils, fluorine can be leached out, and dissolved in groundwater. Fluorine transport in aqueous solutions is controlled mainly by the solubility of calcium fluoride[16]. High fluoride groundwater are mainly associated with $NaHCO_3$ type and

relatively low calcium and Mg concentrations. Such water types usually have high pH values (>7). It was observed that about 5 stations were having fluoride level more than the permissible limit. In alkaline environment, the fluoride ion can be easily liberated from their ore because OH^- and F^- ions have similar radii. Hence they easily exchange with each other.

Fluoride enrichment in the drainage basin from source rocks like fluoride-bearing granite and within the structural basin indicating geological-cum-tectonic control of the fluoride concentration in an area. The Quaternary sediments with volcanic ash containing high fluoride are geochemically reactive with Na replacing Ca in aqueous system resulting in enriched pockets. The Alkalinity values were found to be more than the permissible limit. It plays an important role for the release of fluoride ion from its ore to the groundwater. It was observed that an increase in the Alkalinity value made a similar increase in the amount of fluoride. In alkaline environment, the fluoride ion can be easily liberated from their ore because OH^- and F^- ions have similar radii. Hence they easily exchange with each other.

Conclusion

Our present study reveals that about 4 stations having fluoride level more than the permissible limit. The increased fluoride level in the groundwater of Tiruchengode taluk is due to some geological process such as dissolution of fluoride rich mineral (Fluorspar) in the environment of alkaline pH, excess of bicarbonates, evaporation, semi aridity and high temperature. Geochemical behavior of groundwater from the study area suggests that the high fluoride content groundwater contains low levels of Ca and has high alkalinity. Also the current management of acute and chronic fluoride poisoning relies on supportive care and effective treatment for chronic fluoride poisoning. Ground waters, on account of their high fluoride content, require defluoridation for which a number of simple and readily applicable techniques are available. The people using fluoride-contaminated water for drinking purpose are also advised to take balanced diet (rich of calcium, vitamins and proteins) to reduce the risk of fluorosis.

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