Research Article

Endemic Fluorosis in Vellore District, Tamil Nadu – A Bio-geochemical Approach

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ABSTRACT

Fluoride is the most electronegative of all the elements and is ubiquitously present in the environment. It is considered as a double-edged sword. It has a remarkable prophylactic effect at low concentrations by inhibiting dental caries, while at higher concentrations it causes dental and skeletal fluorosis. Endemic fluorosis is prevalent in many parts of the world. In India, endemic fluorosis has been reported from 20 states spreading over 65% of the total rural habitations. About 120 million people in India are affected and more than 200 million are exposed to the risk of developing endemic fluorosis. In Tamil Nadu state, Vellore is reported to have high fluoride contamination and the prevalence of dental and skeletal fluorosis is endemic. Hence, the present study was undertaken to assess the quality of groundwater samples meant for human consumption and their implications on human health in three panchayats in Tirupattur block and two panchayats in Jolarpet block, Vellore district. The study area was chosen based on the prevalence of dental and/or skeletal fluorosis in the local population. The data obtained revealed that the fluoride content in the drinking water samples was found to range from 2.15 to 4.91 mg/L which readily accounts for the increased incidence of dental and skeletal fluorosis in the study area.

Keywords: Fluoride, Dental Fluorosis, Skeletal Fluorosis.

INTRODUCTION

Water is a natural resource essential for sustaining life and is considered as nature's most precious gift. It was once viewed as an infinite and abundant resource; nowadays it often defines the limits of human, social and economic growth of a region. Water is rightly described as a major supporter and elixir of life [1]. Earth without water would have been deprived of flora and fauna. In the liquid state, water acts as the media for most of the chemical and biochemical reactions taking place in nature and biological systems. However, the sustainability of good health of living things mainly depends upon the quality of water [2]. Water must be free from disease-causing microorganisms or any other harmful chemical substances. Being a universal solvent, water can dissolve a wide array of substances leading to distinguished changes in its quality [3].

Drinking water must be pure to the possible extent. Globally about 97.2% of the water has been distributed in the oceans as salt water and the remaining 2.8% exists as fresh water. Unfortunately, out of this fresh water, about 2.2% is fastened in the polar ice caps and the balance 0.6%, is available as fresh water which is being used for human consumption [4]. The major source of freshwater for sustaining human life on earth is groundwater. However, the groundwater is either being increasingly depleted for irrigation of crops, industrial or other uses or is becoming contaminated by various lithogenic or anthropogenic pollutants [5].

Among the various lithogenic pollutants, the presence of fluoride as a contaminant of groundwater has become a worldwide concern [6]. The occurrence of fluoride in groundwater is mainly due to weathering and leaching of fluoride-bearing minerals from rocks and sediments and its distribution may vary widely over geographical and geopolitical boundaries [7]. Although the food items rich in fluoride are also a source of fluoride for human consumption, the fluoride present in water is often considered for its toxicity as it is readily absorbed from the intestine [8].

Fluoride was once considered as an essential trace element which promotes dental health by reducing dental caries and strengthens the enamel [9]. This widely propagated dental caries protection effect of fluoride was later established as erroneous because it has not been supported by long-term control double blind scientific investigations on a large cross-section of the population. In fact, the decline in the incidence of dental caries in fluoridated areas has resulted due to simultaneously increased dental health facilities, increasing number of dental clinics and hospitals, besides education and raising community awareness on oral health as well as hygiene, calcium and vitamin D nutrition and the deleterious effects of excess consumption of the sugary and starchy foods on dental health.

Fluoride is considered as a double-edged sword due to its harmful effects when its level exceeds the permissible limits. According to WHO, the permissible limit of fluoride concentration in drinking water is 1.5 mg/l. Fluoride concentrations in the range of 1.5–4.0 mg/L may result in dental fluorosis whereas with prolonged exposure at still higher concentrations (4–10 mg/L) dental fluorosis progresses to more severe skeletal fluorosis. Being a most electronegative element, fluoride readily forms complexes with other elements and elicit toxicity [10].

More than 200 million people of 29 countries worldwide rely on water source contaminated with high fluoride content and the occurrence of dental and/or skeletal fluorosis is endemic in several countries which include India, China, U.S.A, Japan, Canada, Pakistan and Bangladesh. In India, endemic fluorosis has been reported from 20 states spreading over 65% of the total rural habitations of the country [4]. About 120 million people in India are affected and more than 200 million are exposed to the risk of developing endemic fluorosis. In Tamil Nadu state, Vellore, Salem, Erode, Dharmapuri, Krishnagiri, Madurai and Virudhunagar districts are reported to have high fluoride contamination and the prevalence of dental and skeletal fluorosis is endemic. In the affected areas, the residents are mainly dependent on the groundwater source for their drinking purpose [11].

Recent studies have revealed that the incidence of fluorosis is endemic in Vellore district, Tamil Nadu, India. The total population of Vellore district is around 40 lakhs. Hence, the present study was undertaken to assess the quality of groundwater samples meant for human consumption and their implications on human health in three panchayats in Tirupattur block and two panchayats in Jolarpet block, Vellore district. The study area was chosen based on the prevalence of dental and/or skeletal fluorosis in the local population.

MATERIALS AND METHODS

Geographical and other details of the study area

The Geographical area constituting the present Vellore District lies between 12^{o} and 13^{o} 15′ of the Northern latitude and 78^{o} 2′ and 79^{o} 50′ of Eastern longitude (Figure 1). It slants from East to West. In general, the region has a long spell of hot climate with a short spell of the rainy season. The mean maximum daily temperature recorded during the hot season in the month of May is 38^{o}C and the low temperature in the month of January is 16.1^{o}C. The district often receives sporadic rainfall from the month of June to December, with occasional rains in other months. The major groups of soils that are found in the town are black and red varieties. The red soil constitutes 90 percent and the remaining constitutes the black soil. The present Vellore district constitutes of 20 panchayat union (Block) which in turn comprises 743 village Panchayats.

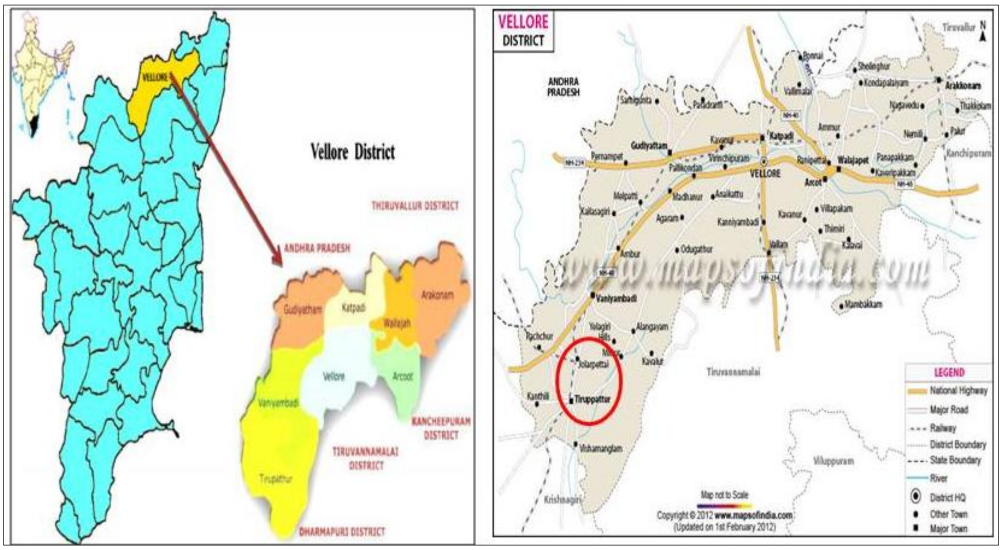

Figure 1: Location map of Study area

Analysis of groundwater samples

Fifteen groundwater samples meant for human consumption from each panchayat and totally seventy-five water samples were collected covering the entire area of Karuppanur, Annandapatty, Palanamkuppam of Tirupattur block and Pachal, Vettapattu of Jolarpet block, Vellore District and Tamil Nadu. The water samples were collected from hand pumps and bore wells and stored in plastic bottles, which were pre-cleaned with 1 N hydrochloric acid and rinsed 3–4 times with de-ionized distilled water.

Physical parameters such as color and odor were analyzed and the chemical parameters like total dissolved solids (TDS), total hardness (TH) and total alkalinity (TA), sodium, potassium, calcium, magnesium, chloride and sulphate were analyzed according to the standard methods prescribed by American Public Health Association [12]. The pH and Electrical conductivity were measured in the field itself using portable pH and EC meter. Cations such as Calcium and Magnesium and anions such as Chloride and Bicarbonate were analyzed by volumetric analysis while Sodium and Potassium were analyzed using a Flame Photometer. The levels Nitrate and Sulfate were estimated by turbidity method. All other chemical analyses were carried out following APHA method [13]. Fluoride content was determined using an ion analyzer (Orion modal 720 – pH-FLURIMETER, USA) equipped with a fluorine selective electrode. All parameters are expressed in milligrams per liter (mg/l), except pH. The electrical conductivity is expressed in microsiemens/cm at 25^{0}C. Statistical analysis was carried out using statistical package for social sciences (SPSS).

RESULTS AND DISCUSSION

The analytical data obtained for all the ground water samples collected from Karuppanur, Annandapatty, Palanamkuppam of Tirupattur block and Pachal, Vettapattu of Jolarpet block, Vellore District, were presented in Table 1-5.

Table 1: Physico-chemical properties of groundwater samples collected from Karuppanur, Tirupattur Block, Vellore District, Tamil Nadu.

Sample No.	pH	EC	TDS	TH	HCO_3^-	Ca^{2+}	Mg^{2+}	Na^+	K^+	Cl^-	SO_4^-	NO_3^-	F^-
1.	8.10	870	1200	150	350	120	50	120	22	210	34	15	**4.79**
2.	7.15	450	465	240	260	71	84	50	3	130	35	15	4. 46
3.	7.90	920	1400	300	450	25	60	160	50	141	19	26	4.15
4.	8.20	250	790	110	300	35	20	135	25	121	20	28	3.95
5.	8.15	110	300	200	330	20	38	175	20	73	25	45	3.80
6.	7.80	850	1150	210	420	140	78	210	12	136	38	16	3.76
7.	7.25	935	1445	515	192	154	48	95	1	75	27	37	3.58
8.	8.50	340	800	250	260	90	60	160	10	45	18	22	3.50
9.	8.20	930	1500	215	305	100	110	190	25	122	26	12	3.41
10.	7.45	960	1220	276	248	170	56	130	5	105	56	48	2.95
11.	8.50	340	800	250	260	90	60	160	10	45	18	22	2.50
12.	7.05	820	1024	525	148	208	101	120	7	118	90	73	2.45
13.	7.25	575	950	403	372	165	84	96	12	190	29	8	2.31
14.	7.40	1900	1216	330	376	176	64	204	12	131	24	54	2.25
15.	7.10	944	2475	198	215	108	79	187	10	78	50	20	2.15

All the values are in mg/l, except pH and EC. Units of EC are mmhos/cm.

Table 2: Physico-chemical properties of groundwater samples at Annandapatty, Tirupattur Block,vellore District, Tamilnadu.

Sample No.	pH	EC	TDS	TH	HCO_3^-	Ca^{2+}	Mg^{2+}	Na^+	K^+	Cl^-	SO_4^-	NO_3^-	F^-
1.	8.30	875	1080	160	270	120	30	120	6	105	35	45	**4.91**
2.	8.15	1300	2300	158	210	42	60	230	15	148	30	70	**4.85**
3.	8.35	855	1150	170	340	80	40	108	11	89	70	28	4.65
4.	7.90	550	996	298	315	155	90	98	14	180	30	9	3.97
5.	7.10	904	1090	460	245	148	70	87	6	155	35	21	3.80
6.	8.10	810	1100	190	215	160	35	190	14	125	58	50	3.73
7.	7.45	185	560	250	160	156	50	98	2	80	28	35	3.60
8.	7.30	1810	2130	340	290	110	75	90	8	80	55	21	3.51
9.	7.15	650	880	380	280	81	89	55	5	120	36	17	3.30
10.	7.16	420	500	131	160	65	35	165	20	52	14	11	2.87
11.	7.05	580	930	290	250	201	60	110	7	75	74	19	2.78
12.	8.05	1085	1480	380	360	140	120	183	7	130	33	11	2.65
13.	7.15	140	460	221	260	90	80	180	9	139	21	58	2.58
14.	7.80	730	570	172	240	92	65	98	16	110	17	27	2.45
15.	7.25	1749	970	454	248	204	58	105	6	195	79	16	2.43

All the values are in mg/l, except pH and EC. Units of EC are mmhos/cm.

Table 3: Physico-chemical properties of groundwater samples at Palanamkuppam, Tirupattur Block,Vellore District, Tamilnadu.

Sample No.	pH	EC	TDS	TH	HCO_3^-	Ca^{2+}	Mg^{2+}	Na^+	K^+	Cl^-	SO_4^-	NO_3^-	F^-
1.	8.30	875	1080	160	270	120	30	120	6	105	35	45	**4.81**
2.	8.15	1300	2300	158	210	42	60	230	15	148	30	70	**4.66**
3.	7.80	1730	3240	215	310	40	42	160	16	71	21	40	4.54
4.	8.35	855	1150	170	340	80	40	108	11	89	70	28	4.47
5.	8.20	1000	1310	380	400	50	75	150	45	140	13	22	4.05
6.	8.40	1995	3150	135	295	154	70	180	18	98	95	35	3.80
7.	8.30	570	990	140	305	187	40	120	13	80	80	22	3.75
8.	8.30	680	930	210	210	190	44	160	9	120	55	44	3.56
9.	8.20	360	780	110	180	190	125	205	12	160	35	21	3.27
10.	7.80	1005	1460	210	290	110	130	180	15	112	24	10	2.75
11.	8.10	1330	920	270	300	53	85	75	7	130	42	19	2.60
12.	7.50	770	980	128	280	180	105	150	13	122	98	75	2.58
13.	7.80	940	1120	360	280	128	40	99	9	170	40	23	2.56
14.	8.10	980	1050	175	330	145	62	10	18	190	32	10	2.25
15.	8.30	1095	1590	280	410	105	98	195	9	135	36	13	2.10

All the values are in mg/l, except pH and EC. Units of EC are mmhos/cm.

Table 4: Physico-chemical properties of groundwater samples at Pachal, Jolarpet Block, Vellore District, Tamilnadu.

Sample No.	pH	EC	TDS	TH	HCO_3^-	Ca^{2+}	Mg^{2+}	Na^+	K^+	Cl^-	SO_4^-	NO_3^-	F^-
1.	8.15	110	300	200	330	20	38	175	20	73	25	45	**4.63**
2.	8.20	250	790	110	300	35	20	135	25	121	20	28	**4.43**
3.	7.90	920	1400	300	450	25	60	160	50	141	19	26	**4.38**
4.	7.15	450	465	240	260	71	84	50	3	130	35	18	4.26
5.	7.90	920	1400	300	450	25	60	160	50	141	19	26	3.96
6.	8.20	1000	1310	380	400	50	75	150	45	140	13	22	3.87
7.	8.50	340	800	250	260	90	60	160	10	45	18	22	3.64
8.	8.10	810	1100	190	215	160	35	190	14	125	58	50	3.45
9.	8.20	1001	1600	120	290	150	100	160	18	129	100	80	3.38
10.	7.20	510	1390	320	328	80	95	128	32	125	10	20	3.20
11.	8.10	1110	2150	280	310	96	55	105	10	85	60	25	2.80
12.	7.90	1240	1570	168	190	68	70	200	12	145	25	60	2.75
13.	7.65	1405	1075	230	240	133	149	153	9	104	23	9	2.63
14.	7.25	960	1150	240	245	130	150	160	11	110	21	9	2.41
15.	7.45	960	1220	276	248	170	56	130	5	105	56	48	2.37

All the values are in mg/l, except pH and EC. Units of EC are mmhos/cm.

Table 5: Physico-chemical properties of groundwater samples at Vattapattu, Jolarpet Block, Vellore District, Tamilnadu.

Sample No.	pH	EC	TDS	TH	HCO_3^-	Ca^{2+}	Mg^{2+}	Na^+	K^+	Cl^-	SO_4^-	NO_3^-	F^-
1.	8.20	875	1080	160	270	120	35	122	8	107	34	47	**4.89**
2.	8.15	110	300	200	330	20	38	175	20	73	25	45	**4.76**
3.	8.20	250	790	110	300	35	20	135	25	121	20	28	**4.69**
4.	7.80	1730	3240	215	310	40	42	160	16	71	21	40	4.54
5.	7.15	450	465	240	260	71	84	50	3	130	35	15	4.36
6.	8.15	110	300	200	330	20	38	175	20	73	25	45	3.75
7.	8.20	930	1500	215	305	100	110	190	25	122	26	12	3.61
8.	8.20	1001	1600	120	290	150	100	160	18	129	100	80	3.42
9.	8.20	520	940	100	195	140	110	225	6	165	39	24	3.38
10.	7.10	490	885	178	255	210	121	130	11	117	93	72	3.25
11.	7.90	1100	1280	420	350	85	93	130	39	135	11	20	2.76
12.	7.20	320	570	380	240	140	81	130	3	38	11	16	2.69
13.	8.05	1085	1480	380	360	140	121	184	9	130	34	12	2.57
14.	7.15	310	650	190	210	90	61	100	18	115	16	24	2.45
15.	7.45	970	1230	286	250	180	65	140	12	125	56	50	2.32

All the values are in mg/l, except pH and EC. Units of EC are mmhos/cm.

Hydrogen ion concentration (pH)

The pH is a measure of the hydrogen ion concentration in the medium and it indicates whether the medium is acidic or basic. Most of the biological and chemical reactions are influenced by the pH of the medium because pH determines the solubility and biological availability of chemical constituents. The pH of water is an important criterion indicating the quality and provides information in many types of geochemical equilibrium or solubility calculations [14]. If the pH is not maintained within the physiological range, it may lead to alterations in the biochemical pathways including damage to the cellular membranes. Additionally, the taste of the water depends on its hydrogen ion concentration [15]. The standard value of pH for drinking water according to the Bureau of Indian Standards (BIS) is between 6.5 - 8.5, while the World Health Organization (WHO) is between 7.0-8.5. The pH value of the drinking water close to 7.0 is considered as economically feasible.

The pH value of the groundwater samples collected for the present study was found to range from 7.05 to 8.50 depicting the weak alkaline conditions dominant within the groundwater system in the study area. The pH of the ground water samples collected from Karuppanur, Annandapatty, Palanamkuppam, Pachal and Vattapattu was found to range from 7.05 to 8.50, 7.10 to 8.35, 7.50 to 8.35, 7.15 to 8.10 and 7.10 to 8.20, respectively. A positive correlation between fluoride concentration and pH is reported in different parts of the world. Fluoride in groundwater is associated with a pH >7.0. A moderate positive correlation of fluoride and pH observed in the present study revealed that fluoride in the groundwater samples may originate from leaching of fluoride-containing minerals [16]. The hydroxyl ions in groundwater with a high value of pH can replace the exchangeable fluoride of clay minerals which in turn may increase the concentration of fluoride in groundwater. At higher pH, ionic exchange occurs between F and OH ions (illite, mica and amphiboles) resulting in an increase of F ion concentration in groundwater [17].

Though a good correlation exists between fluoride and pH, a few water-soluble components also contribute to the increase in pH value. The fluoride solubility is lowest in the pH range of 5.0–6.5 [18]. It was observed that the groundwater samples in the study area were alkaline as the pH value of groundwater in the study area varied from 7.05–8.50. The solubility of fluoride-bearing minerals increases due to the alkaline nature of the groundwater. In an alkaline environment, the fluoride ions are desorbed thus supplementing the dissolution of fluoride-bearing minerals [19]. The results obtained on the pH value indicate that the fluoride concentration in groundwater is mainly governed by the geochemical composition of rocks, such as metamorphic granites and sedimentary rocks, alkaline hydrogeological environment, climatic conditions, high temperature and lesser rainfall and geochemical processes such as weathering, evaporation, dissolution and ion exchange.

Electrical Conductivity (EC)

The ability of a solution to conduct electrical current is termed as electrical conductivity which in turn is governed by the nature and number of the ionic species present in the solution. When the water is pure without any dissolved solutes, it conducts electricity naturally. Ions conduct electricity due to their positive and negative charges. When electrolytes dissolve in water, they split into positively charged (cation) and negatively charged (anion) particles. As the dissolved substances split in water, the concentrations of each positive and negative charge remain equal. Thus, the electrical conductivity (EC) of a solution is a measure of its ability to carry an electric current; the more dissolved ionic solutes in water, the greater its electrical conductivity [20]. For example, seawater's conductivity is one million times higher than deionized water, because there are a lot of ions dissolved in the seawater. However, univalent cations such as Na+ are more mobile than multivalent ions such as Ca^{2+} and Al^{3+}. Similarly, univalent anions such as Cl^- are more mobile than multivalent ions such as sulphates and carbonates, which are in turn more mobile than charged humic substances. Based on electrical conductivity values, the water quality can be classified as poor, medium or good.

Generally, ground water tends to have high electrical conductivity due to the presence of a high amount of dissolved salts. As ionic concentration increases, the conductance of the solution increases, therefore the measurement of conductance provides an indication of ion concentration. This capacity depends on the concentration of ions, ionic mobility, valence of ions and temperature. Conductivity can be regarded as a crude indicator of water quality for many purposes since it is related to the sum of all ionized solutes or total dissolved solids (TDS) content. The relationship between conductivity and TDS is not directly linear, however, since the conductive mobility of ionic species is variable.

Electrical conductivity is a very important parameter for determining water quality for drinking and agricultural purposes based on the total concentration of various ions. Conductance can be used for assessing the effect of diverse ions on chemical equilibrium, physiological effects on plants or animals, corrosion rates etc. Environmentalists can use conductivity to track the movement of water systems in order to predict and solve problems with marine life. Conductivity tests demonstrate the association between soil conditions and drought, heavy rain and other environmental conditions that could affect farming and crop yield. It takes the guesswork out of whether to irrigate or fertilize [21].

The WHO permissible limit for electrical conductivity in water is 600 µS/cm. The EC value of the collected samples was found to be in the ranges 110 to 1995 mmohs/cm.

There was a large variation in electrical conductivity even in the samples collected from the same block which may due to the presence of various ions present in the samples. The electrical conductivity reflects the activity of electrically charged ions and it follows that higher the conductivity the greater will be the potential for electrochemical action.

Total Dissolved Solids (TDS)

Dissolved solids refer to any minerals, salts, metals, cations or anions dissolved in water. Total dissolved solids (TDS) comprise inorganic salts (principally calcium, magnesium, potassium, sodium, bicarbonates, chlorides and sulfates) and some small amounts of organic matter that are dissolved in water. Thus TDS stands for total dissolved solids and represents the total concentration of dissolved substances and general quality of the water.

The TDS concentration is considered as a secondary drinking water standard and, hence it is regulated aesthetically rather than a health hazard. An elevated TDS may cause the water to be corrosive, salty or brackish taste, result in scale formation, and interfere and decrease the efficiency of hot water heaters. The TDS from natural sources has been found to vary from less than 30 mg/litre to as much as 6000 mg/litre, depending on the solubility of minerals in different geological regions. TDS in water less than 1000mg/l has been classified as non-saline. Total dissolved solids in a water sample include all solid materials in solution whether ionized or not. It does not include suspended sediments, colloids or dissolved gases. If all dissolved solids were determined accurately by chemical tests, TDS would be the numerical sum of those constituents. The values of TDS of groundwater samples ranges from 300 to 2475mg/litre in Karuppanur , 460 to 2300 mg/litre in Annandapatty, 920 to 3240 mg/litre in Palanamkuppam, 300 to 1600 mg/litre in Pachal and 300 to 3240 mg/litre in Vattapattu. The high values of TDS often causes gastrointestinal disturbances in human beings and chronic use of water with high TDS can cause kidney stone formation and development of cardiovascular diseases. The observed increase in the levels of TDS in groundwater samples can enhance the ionic strength and leads to an increase in fluoride solubility [22].

Total Hardness (TH)

Hardness of water is an aesthetic quality of water and is caused by carbonates, bicarbonates, sulphates and chlorides of calcium and magnesium. It prevents the lather formation with soap and increases the boiling point of water. According to the BIS, the maximum permissible limit of total hardness for drinking purpose is 300 mg/l. It also states that the water having hardness up to 75 mg/l is classified as soft, 76 - 150 mg/l is moderately soft, 151-300 mg/l as hard and more than 300 mg/l as very hard. Total hardness more than 300 mg/l may cause cardiovascular complications and renal dysfunction. In general, the total hardness of water is characterized by contents of calcium or magnesium or both [22]. In the present study, the total hardness of groundwater samples ranges from 110 to 525 mg/l in Karuppanur, 131 to 460 mg/l in Annandapatty, 110 to 380 mg/l in Palanamkuppam, 110 to 380 mg/l in Pachal and 100 to 380 mg/l in Vattapattu which in turn may be due to the presence of excessive amounts of calcium and magnesium or both.

Bicarbonate (HCO_3^-): Total alkalinity of water is mainly arisen due to the presence of carbonate and bicarbonate ions in the water. It is also associated with the calcium and magnesium contents in water. The total alkalinity of groundwater samples was found to range from 148 to 450 mg/l in Karuppanur, 162 to 360 mg/l in Annandapatty, 180 to 410 mg/l in Palanamkuppam, 190 to 450 mg/l in Pachal and 210 to 360 mg/l in Vattapattu.

Calcium (Ca^{2+}): Calcium is an important major constituent present in the natural water and the usual range is less than 100 mg/l. The calcium content of groundwater samples ranges from 25 to 208 mg/l in Karuppanur, 42 to 201 mg/l in Annandapatty, 42 to 190 mg/l in Palanamkuppam, 20 to 170 mg/l in Pachal and 20 to 210 mg/l in Vattapattu. The calcium content was found to be not related to fluoride in the water samples collected from five villages. The calcium salts are re-dissolved by rains and thus constitute a semi permanent reservoir of easily dissolvable fluorine.

Calcium abundantly exists in the earth's crust and present in water naturally. Seawater contains approximately 400 ppm calcium while river water contains 1-2 ppm. However, in lime areas, the river waters may contain calcium concentrations as high as 100 ppm and it gives water a bitter taste. Calcium content determines the hardness of water. Because of the buffering qualities, calcium is considered as a pH stabilizer. Calcium is a dietary requirement for all organisms apart from some insects and bacteria. Calcium carbonate is a building stone of skeletons of most marine organisms and eye lenses. Calcium phosphate is required for bone structure and teeth structure of terrestrial organisms.

Calcium is a dietary mineral that is present in the human body in amounts of about 1.2 kg and no other element is more abundant in the body. Inadequate intakes of calcium have been associated with increased risks of osteoporosis, nephrolithiasis (kidney stones), colorectal cancer, hypertension and stroke, coronary artery disease, insulin resistance and obesity. Calcium is unique among nutrients, in that the body's reserve is also functional; increasing bone mass is linearly related to the reduction in fracture risk. Osteoporosis is one of the most prevalent of age-related diseases. Calcium and vitamin D are jointly beneficial in increasing bone mass. Calcium present in the muscle tissue and blood is partially responsible for muscle contractions and blood clotting. It is also required for cell membrane development, cell division, regulation of membrane activity in addition to nerve impulse transfer and hormone release. Calcium carbonate works as a stomach acid remedy to resolve the digestive failure. In order to stimulate these body functions a daily intake of about 1000 mg of calcium is recommended for adults. However, Metallic calcium oxidizes the skin when it comes in direct contact with skin, eyes and mucous membranes. Removing calcium and magnesium ions from water is carried out by water softeners.

Magnesium (Mg^{2+}); Magnesium is one of the main constituents in natural water and ranks eighth among the elements in order of abundance. It is an important contributor for the hardness of water and general range of limit in natural water is 50 mg/l. The highest desirable limit is 30 mg/l and the maximum permissible range is 100 mg/l. The magnesium content of groundwater samples ranges from 20 to 110 mg/l in Karuppanur, 30 to 120 mg/l in Annandapatty, 40 to 130 mg/l in Palanamkuppam, 20 to 149 mg/l in Pachal and 35 to 110 mg/l in Vattapattu. The magnesium content was found to be lower and had a negative correlation with fluoride in the water samples collected from five panchayats. In high doses, magnesium toxicity causes nausea, muscular weakness and paralysis in humans and other mammals.

Magnesium is the fourth most abundant cation in the human body and the second most abundant element in the intracellular fluid. It acts as a cofactor for more than 350 cellular enzymes, many of which are involved in major metabolic pathways. Further, it is involved in protein and nucleic acid synthesis and is needed for normal vascular tone and insulin sensitivity. The total body storage of magnesium is about 25 g of which about 60% is present in the bones [23]. Low magnesium levels are associated with endothelial dysfunction, increased vascular reactions, elevated circulating levels of C-reactive protein and decreased insulin sensitivity. Low magnesium status has been implicated in hypertension, coronary heart disease, type 2 diabetes mellitus and metabolic syndrome. In humans, there is evidence for an inverse relationship between magnesium and coronary heart disease mortality.

Oral magnesium supplementation improves insulin sensitivity and metabolic control in type 2 diabetes mellitus. Alcoholism and intestinal malabsorption are conditions associated with magnesium deficiency [24]. Some drugs, such as certain diuretics, some antibiotics and some chemotherapy treatments, increase the loss of magnesium through the kidney; therefore, those patients should have magnesium supplementation as part of their therapy. On the other hand, the increased intake of magnesium salts may cause a temporary adaptable change in bowel habits.

Sodium (Na^+): Sodium occupies the sixth position among the elements in the order of abundance and therefore it is present in most natural water [25]. The ratio of sodium to total cations is important in agriculture and human pathology. Generally, 100 mg/l of sodium is present in natural water. The recommended desirable limit is 200 mg/l. The sodium content of groundwater samples ranges from 52 to 204 mg/l in Karuppanur, 55 to 230 mg/l in Annandapatty, 10 to 230 mg/l in Palanamkuppam, 50 to 200 mg/l in Pachal and 122 to 225 mg/l in Vattapattu. Sodium was higher than the WHO acceptable limit of 50 mg/l in all the water samples.

Potassium (K^+): Potassium is an important secondary constituent and it ranks seventh among the element in order of abundance. Generally, the natural water contains potassium less than about 10 mg/l and the desirable amount of potassium in drinking water is 20 mg/l. The potassium level of ground water sample ranges from 01 to 50 mg/l in Karuppanur, 02 to 20 mg/l in Annandapatty, 06 to 45 mg/l in Palanamkuppam, 03 to 50 mg/l in Pachal and 03 to 25 mg/l in Vattapattu. There was a positive correlation between fluoride and potassium in all the five panchayats.

Chloride (Cl^-): Chloride is a minor constituent of the earth's crust but a major dissolved constituent of most natural waters. Chloride in the form of chloride ion is one of the major inorganic anion present in the water. In potable water, the salty taste produced by chloride concentration is variable and dependent on the chemical composition of the water. The highest desirable value for chloride is 200 mg/l and the maximum permissible limit is 600 mg/l. The chloride concentration of groundwater samples ranges from 45 to 210 mg/l in Karuppanur, 52 to 195 mg/l in Annandapatty, 71 to 190 mg/l in Palanamkuppam, 45 to 145 mg/l in Pachal and 38 to 165 mg/l in Vattapattu.

Sulphate (SO_4^-): Sulphate occurs in water largely in oxidized form. The concentration of sulphate from less than 0.2 ppm is more than 1, 00,000 ppm is found in nature. In combination with other ions it gives better taste. The highest desirable limit is 150 mg/l. The maximum permissible limit is 400 mg/l. The sulphate concentration of groundwater samples range from 18 to 90 mg/l in Karuppanur, 14 to 79 mg/l in Annandapatty, 13 to 98 mg/l in Palanamkuppam, 10 to 100 mg/l in Pachal and 11 to100 mg/l in Vattapattu.

Nitrate (NO_3): Nitrate is mainly derived from chemical fertilizers, plants or sewage. Some plants fix atmospheric nitrogen and form nitrates. Ground water in the pure stage contains less than 5 mg/l of nitrate, but polluted water may contain 100 mg/l or even more. Excessive amount (> 50 mg/l) of nitrate leads to an illness known as infant methemoglobinemia (Blood becomes blue). A limit of 20 mg/l to 50 mg/l nitrate accordingly been imposed on drinking water. The nitrate content of groundwater samples ranges from 08 to 73 mg/l in Karuppanur, 09 to 70 mg/l in Annandapatty, 10 to 75 mg/l in Palanamkuppam, 09 to 80 mg/l in Pachal and 12 to 80 mg/l in Vattapattu. The high value of nitrate in the study area might be due to excessive use of nitrogen rich fertilizers in the area. The high salinity as well as high conductivity might be on account of precipitation of salt in groundwater. The precipitation of salt to a great extent is being caused by over-saturation of the topsoil on account of availability of water in plenty.

Fluoride (F^-): Fluorine as fluoride ion is widely distributed in rocks and is in constant movement and cycles. Rocks of different types are the ultimate source of fluoride in the groundwater. When released into the soil and groundwater, the fluoride concentration may increase until the solubility of fluoride is attained. The impact of fluoride in rocks on the environment depends on not only its concentration but also its modes of occurrence and chemical mobility.The fluoride content in the drinking water samples collected from all the seventy five sources was found to be varied from 2.15 to 4.91 mg/L. which is above the permissible limit of 1.0 mg/L. The drinking water is the major contributing factor for the development of fluorosis and all the residents in the study area mainly dependent on the ground water sources for their drinking utility. The residents who were residing in the study area since their birth had severe fluorosis than those who settled in the recent past. Additionally, women are exposed to the high incidence of fluorosis than men due to chronic exposure to high fluoride content. Likewise, older people are affected with both dental and skeletal fluorosis than the youngest due to chronic exposure to high fluoride ingestion.

More than 90% of the ingested fluoride is absorbed from the gut and approximately 50% of the fluoride absorbed is deposited in the bones and teeth. The remaining is excreted in the urine. On account of the greater affinity of fluoride for calcium phosphate, nearly 99% of the fluoride is absorbed is stored in the mineralized bones and teeth. Fluoride ions are taken up by the bones more rapidly by replacing hydroxyl ions in the bone. The main source of fluoride in ground water is fluoride-bearing rocks such as fluorspar, fluorite, cryolite, fluorapatite and hydroxylapatite [26]. Fluoride incorporation into hydroxyapatite results in spot wise production of fluoroapatite inducing alterations in the size and structure of bone crystals. The biological response and severity of fluorosis chiefly depend on the concentrations of fluoride in drinking water, the daily intake of fluoride, duration of exposure and vitamin D nutrition status. Additionally, the composition of foods with special reference to Ca, Mg, P and Al contents also influence the toxicity of fluoride.

The toxic effects of fluoride are more severe in children with growing bones and in labors with excessive drinking water that can be up to 6 to 8 liters in summer. The chronic fluoride toxicity in human was first reported by Eager [27] and endemic skeletal fluorosis was first described in India by Shortt et al. [28] in Nellore district, Andra Pradesh. Teotia and Teotia provides evidence that skeletal fluorosis is not confined only to adults but also affects the children as the growing bones are metabolically active, highly vascular and accumulate fluoride faster and greater than the older bones [29, 30]. Dental fluorosis occurs in children who are exposed to high levels of fluoride before the completion of dental mineralization which usually occurs at 12-14 years of age. Thus dental fluorosis is considered as the clinical index of the epidemiology of fluorosis. Several reports suggested that the intake of 2.5 mg of fluoride for more than 6 months results in the deposition of 4000- 6000mg/ kg of fluoride and causes detectable radiological changes of fluorosis.

The fluoride content in the ground water samples collected from five locations was presented in the descending order (Table 1 to5). The Fluoride concentration in the ground water samples collected from the five villages as ranges from 2.15 to 4.79 mg/litre in Karuppanur, 2.43 to 4.91 mg/litre in Annandapatty, 2.10 to 4.81 mg/litre in Palanamkuppam, 2.37 to 4.63 mg/litre in Pachal and 2.32 to 4.89 mg/litre in Vattapattu respectively. However, the fluoride content was found to be relatively higher in Karupannur village in Tirupattur block when compared to the other four villages.

In 1934, Dean developed a fluorosis index commonly known as the Community Fluorosis Index (CFI) to measure the burden of dental fluorosis in a population[32]. It takes into account both the overall prevalence and severity of fluorosis that is prevailing. This index is often used to measure enamel defects due to the chronic, accumulated ingestion of fluoride. The CFI index was modified by Thylstrup and Fejerskov [33] and later by Moller [34] which is calculated based on the following point scale for the different categories of dental fluorosis.

Questionable Fluorosis = 0.5 point; Very Mild Fluorosis = 1 point; Mild Fluorosis = 2 points; Moderate Fluorosis = 3 points; Severe Fluorosis = 4 points.

The Moller dental fluorosis index is widely used for assessing the severity of dental fluorosis and the data have been compared in several scientific articles.

Among the water quality parameters, fluoride ion exhibits unique properties as their concentrations in optimum dose in drinking water are advantageous to health and if the concentration exceeds the limit that affects the health [31]. Since there is hardly any cure for fluorosis, the only way to control is to reduce the fluoride levels in the drinking water. High fluoride concentration observed in the ground water samples analyzed readily accounts for the prevalence of dental and skeletal fluorosis in the study area.

CONCLUSION

From the data obtained on the levels of various elements, it may be concluded that the prevalence of dental and/or skeletal fluorosis the study area is mainly due to increased levels of fluoride concentration in the groundwater samples. The fluoride content is linked to various factors including rock chemistry, residence time, well depth, preferential pathways for the upward movement of deep groundwater and hydrologic condition of the pathways. Almost all the groundwater samples collected from the five panchayats from two blocks of Vellore District do not meet the water quality standards in terms of fluoride concentration and many other water quality parameters which in turn results in endemic fluorosis.

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