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Fluoride Contamination in the Ground Water of Two Villages of Visakhapatnam Industrial Area

G.V.S.R. Pavan Kumar*, Yerra Bharath[1] and M. Komal Avinash[1]

Department of Chemistry, M V G R College of Engineering, Vizianagaram – 535005 (A.P.), India
[1]Department of Chemical Engineering, M V G R College of Engineering, Vizianagaram – 535005 (A.P.) India
✉ sprs_ganti@yahoo.co.in

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Abstract: The present work of the authors is aimed at the assessment of water quality with special reference to fluoride contamination in the two selected villages Mulagada and Yeduruvanipalem. These two villages are situated in the industrial area of Visakhapatnam district of Andhra Pradesh, India. These two villages are surrounded by industries like BHPV, HPCL, Zinc smelter and Coromondel fertilizers. During a preliminary survey in the two villages it was found that the residents of the two villages were suffering from dental flourisis. In view of this, the authors carried out experiments on the determination of physico-chemical characterization. The results were compared with BIS standards. In the two villages, concentration of fluoride was found to be in the range 1.432-2.944 mg/L. Water quality index (WQI) for the two villages was found to be 101.1 for the village Mulagada and 87.5 for the village Yeduruvanipalem. A strong correlation between phosphate and fluoride in the water of the village Mulagada was observed. From the results obtained it was inferred that the water of the two villages is unfit for human consumption.

Key words: Water quality assessment, water quality index, fluoride contamination, Visakhapatnam, ground water.

Introduction

Ground water accounts for almost 99% of the available liquid fresh water resources on earth, leaving only 1% surface water found in rivers and lakes among few (Cavazza and Pagliara, 2000). Out of the global groundwater resources, it has been estimated that about 900 km^3 is pumped out annually for human activities (Nura Umar Kura et al., 2015). It has been estimated that almost one third of the world population relies on ground water for their day-to-day activities (Hiscock, 2011). Hence caution is required, as the pressure can make the matter worst through contamination and/or damage to the hydrological system if care is not taken (Jones, 2011). The effects of these problems were already being faced by the world, as the decline in the groundwater table, land subsidence and depletion in the groundwater reserves have been widely observed (Nura Umar Kura et al., 2015). The degrading state of urban water bodies is a worldwide environmental concern. This is of particular concern in developing countries where untreated industrial and municipal waste waters are directly discharged into rivers and lakes (Khadka, 2015). Most of the water bodies get contaminated through storm runoff, fertilizers, pesticides, vehicular exhausts, seepage from houses and industrial sewage (Khadka et al., 2015). In India only 12% of the population is getting good drinking water (Kudesia, 1980).

Ground water in several parts of India is affected by arsenic and fluoride pollution due to geo-genic contamination and anthropogenic activities (CGWB,

*Corresponding Author

2010). The fluoride accumulation in ground water varies according to the source of water, geological formulation of the area and amount of rainfall etc. In India, approximately 62 million people including six million children suffer from fluorosis, due to the consumption of high fluoride (Subba Rao et al., 2011). Statistics show that fluoride poisoning is spreading more than arsenic contamination in ground water in the country (Jaiprakash et al., 2007). The quality of ground water is steadily deteriorating at a faster rate due to pollution ranging from septic tanks, landfill leachates, domestic sewage, agricultural operations and industrial wastes (Byragi Reddy et al., 2013). The physico-chemical parameters of water and the dependence of all life processes on these factors make it necessary to determine the quality of water. Studies on groundwater quality with respect to drinking and domestic purposes have been carried out in different parts of the country (Kiranmai Reddy and Robert, 2014).

Visakhapatnam has been home for a number of large and medium industries such as the Hindustan Petroleum Corporation, Visakhapatnam steel plant, Bharat Heavy plants and vessels, Hindustan polymers, Coromandal fertilizers and Zinc smelter. Commensurate with the growth of industrial and allied activities in and around the city, its area grew from 30 sq. km in 1960 to over 80 sq. km presently (Srikanth Vuppala, 2012). The city's population according to 2011 census is about 1.8 million. The recent government plans to establish industrial corridor in the city, after the bifurcation of the state for creating economy and employability. In such situations it is necessary to supply fresh and pure water for domestic and industrial usage. Due to various factors as mentioned earlier, the quality of ground water gets deteriorated. In view of the decreasing quality and the increased level of pollution in ground water, the authors aimed at the water quality assessment of the two villages namely Mulagada and Yeduruvanipalem of Visakhapatnam district.

Study Area

The two villages Mulagada and Yeduruvanipalem are surrounded by HPCL, BHPV, Zinc and AluFlu (aluminum fluoride manufacturing company). Mulagada village is situated in the coordinates of 17.45 E and 82.35 N, where Yeduruvanipalem is situated in the coordinates of 17.65 E and 82.68 N.

The following are some of the reasons which made the authors to select these two villages for their study:

Figure 1: People suffering from dental fluorisis.

- Residents of the two villages were found to be suffering from dental fluorosis (Figure 1).
- In 1990 there were 200 families in the two villages; due to various health issues they were facing, now only 90 families are residing in Mulagada village and 85 families in Yeduruvanipalem village (data obtained from the residents when interacted with them).
- Most of the health issues are related to bone disorders, and kidney disorders which may be attributed due to the poor quality of water.
- It was found that the residents of the two villages are using ground water for domestic and drinking purpose though they are supplied municipal water.
- The two villages are situated 0.25 km away from BHPV and aluminum fluoride companies.

In light of the above mentioned facts the authors carried out experimentation to assess the quality of the water collected from the two selected vilages.

Sample Collection

Water from all the bore wells in the two villages were collected in pre-cleaned polyethylene bottles of volume 1000 ml. Composite sample collection procedures were adopted in collecting the samples. All the samples were brought to the laboratory for further analysis. Preservation of the samples was done by adding 2M nitric acid to each of the samples.

Methodology

Parameters such as pH, EC and TDS were determined on the spot. Concentration of fluoride in the water samples was determined by fluoride ion selective electrode. Total hardness of water, calcium and magnesium were determined by titrimetric analysis using EDTA. The concentration of sodium and potassium in water was

determined by flame photometric method. Nitrite in the water samples was determined by spectrophotometric method. All the methods employed were followed by the standards prescribed by APHA.

The following table illustrates the different instruments used for the determination of different physico-chemical parameters under study.

S.No.	*Name of the parameter*	*Instrument used*
1	Fluoride	Thermo Fischer Accumet fluoride ion selective electrode
2	Nitrite	JASCO V 750 UV VIS spectrophotometer
3	Sodium and potassium	Microprocessor based flame photometer

Results and Discussion

The complete result analysis of the physico-chemical parameters are presented in Table 1. Water quality index calculations and other details are presented in Tables 2(a) and 2(b). Correlation matrix data is presented in Table 3(a) and 3(b). Covariance matrix data is presented in Table 4(a) and 4(b).

The pH of water is an indicator of its quality and geochemical equilibrium for solubility calculation (Rosalin Das et al., 2015). pH of the water samples analyzed from the selected villages was found to be below the prescribed standard value. Among the fourteen samples analyzed seven samples were found to have a pH in the range of 6.5-7.06. Seven samples were found to have pH values in the range 6.14-6.43. From these data it was found that the water in the two villages was slightly acidic. The water with pH value less than 6.5 could be corrosive (water research.net).

Electrical conductivity is a measure of salt concentration in ground water. Among the fourteen samples analyzed twelve samples were found to have EC beyond the acceptable limit and two samples found to have EC beyond permissible limit prescribed by IS:10500. Highest values of EC are an indicative of the highest concentration of salts in the water. Total dissolved solids for the water samples analyzed were found to be very high. Among the samples analyzed six samples were found to be beyond acceptable limit and eight samples were beyond permissible limit. From these results it was found that the water of the two villages is unfit for human consumption either for domestic or for industrial purposes.

Total hardness for all the samples analyzed was found in the range 300-500 mg/L. The values were found to be beyond the acceptable limit prescribed and within the permissible limit. From the results it is found that the water analyzed collected from the two villages is hard and unfit for human consumption. The reason for higher

Table 1: Physico-chemical parameters of the two villages

S. No	*EC*	*TDS*	*pH*	*THW*	*Ca*	*Mg*	*Fe*	*Na*	*K*	*Cl*	*NO_2*	*PO_4*	*HCO_3*	*F*	
1	1212	775.68	6.14	400	220	180	ND	370	16	140	0.05	15	980	1.819	
2	1719	1100.2	6.51	380	190	190	1.8	492	58	192.5	0.1	18	1274	1.764	
3	2540	1625.6	6.26	300	200	100	1.6	286	25	157.5	0.1	25	980	2.944	
4	2300	1472	6.42	500	220	280	0.8	385	19	262.5	0.06	18	1617	1.859	
5	1776	1136.6	6.43	340	210	130	2.1	155	15	262.5	0.06	20	1519	2.229	
6	1756	1123.8	6.57	350	220	130	ND	485	55	157.5	0.1	18	1421	1.861	
7	1710	1094.4	6.48	370	210	160	ND	485	52	227.5	0.06	15	1372	1.785	Mulagada
8	1603	1025.9	5.97	340	210	130	2.1	330	15	227.5	0.06	18	1470	1.724	
9	1331	851.84	6.35	460	270	190	ND	485	56	245	0.06	20	735	1.745	
10	1116	714.24	6.64	360	220	140	ND	490	58	157.5	0.04	18	882	1.68	
11	1692	1082.9	6.69	450	200	250	ND	250	20	262.5	0.06	18	1127	1.442	
12	1212	775.68	6.62	350	200	150	ND	255	25	122.5	0.05	18	1029	1.871	
13	1255	803.2	6.51	370	210	160	ND	435	45	245	0.1	18	1078	1.502	
14	1220	780.8	7.06	410	220	190	ND	315	15	192.5	0.1	18	1127	1.547	Y V Palem
DL	**500**	**500**	**6.5-8.5**	**300**	**70**	**30**	**0.3**	**200**	**10**	**250**	**1**	**10**	**200**	**0.5-1.2**	
PL	**2000**	**1000**	**.....**	**600**	**100**	**50**	**.....**	**.....**	**.....**	**1000**	**.....**	**.....**	**.....**	**.....**	Standards

DL: Desirable limit; PL: Permissible limit

Table 2(a): Water quality index data for the village Mulagada

	1	*2*	*3*	*4*	*5*	*6*	*7*	*Vi*	*Si*	*Qi*	*Wi*	*WiQi*
pH	6.14	6.51	6.26	6.42	6.43	6.57	6.48	6.4014	8.5	95.2	0.056	5.3275
EC	12.12	1719	2540	2300	1776	1756	1710	1859	500	371.8	0.001	0.3537
TDS	775.6	1100.1	1625.6	1472	1137	1123.8	1094	1189.7	500	237.9	0.001	0.2264
THW	400	380	300	500	340	350	370	377.14	300	125.7	0.0016	0.1993
Ca	220	190	200	220	210	220	210	210	75	280	0.0063	1.7758
Mg	180	190	100	280	130	130	160	167.14	30	557.1	0.0159	8.8338
Na	370	492	286	385	155	485	485	379.71	200	189.9	0.0024	0.4515
K	16	58	25	19	15	55	52	34.286	12	285.7	0.0396	11.325
Cl	140	192.5	157.5	262.5	262.5	157.5	227.5	200	250	80	0.0019	0.1522
Fluoride	1.819	1.764	2.944	1.859	2.229	1.861	1.785	2.0373	1.2	169.8	0.3964	67.296
Nitrite	0.05	0.1	0.1	0.06	0.06	0.1	0.06	0.0757	1	7.571	0.4757	3.6015
TA	980	1274	980	1617	1519	1421	1372	1309	200	654.5	0.0024	1.5566
											WQI	101.1

Table 2(b): Water quality index data for the village Yeduruvabnipalem

	1	*2*	*3*	*4*	*5*	*6*	*7*	*Vi*	*Si*	*Qi*	*Wi*	*WiQi*
pH	5.97	6.35	6.64	6.69	6.62	6.51	7.06	6.5486	8.5	95.2	0.056	5.3275
Ec	1603	1331	1116	1692	1212	1255	1220	1347	500	269.4	0.001	0.2563
TDS	1026	852	714	1083	776	803	781	862.14	500	172.4	0.001	0.164
THW	340	460	360	450	350	370	410	391.43	300	130.5	0.0016	0.2069
Ca	210	270	220	200	200	210	220	218.57	75	291.4	0.0063	1.8483
Mg	130	190	140	250	150	160	190	172.86	30	576.2	0.0159	9.1358
Na	330	485	490	250	255	435	315	365.71	200	182.9	0.0024	0.4349
K	15	56	58	20	25	45	15	33.429	12	278.6	0.0396	11.042
Cl	227.5	245	157.5	262.5	122.5	245	192.5	207.5	250	83	0.0019	0.1579
Fluoride	1.724	1.745	1.68	1.442	1.871	1.502	1.547	1.6444	1.2	137	0.3964	54.319
Nitrite	0.06	0.06	0.04	0.06	0.05	0.1	0.1	0.0671	1	6.714	0.4757	3.1938
TA	1470	735	882	1127	1029	1078	1127	1064	200	532	0.0024	1.2653
											WQI	87.352

values of hardness is due to the mineral deposition in the area and found to have minerals such as apatite and quartz. Due to dissolution of these minerals by natural or chemical weathering processes in the groundwater aquifer, certain chemical parameters showed an increased concentration.

The concentration of calcium in the water samples analyzed was found to be in the range 190-270 mg/L. These values are beyond the permissible limits prescribed by BIS. This is due to the natural and chemical weathering processes in the aquifer causing dissolution of the minerals. The concentration of magnesium in the water samples of two villages under study was found to be in the range 100-280 mg/L. These values are six times higher than the standard values prescribed. Higher levels of calcium can cause cardiovascular disorders in human and higher concentration of magnesium in drinking water leads to bowel disorders (P. Sengupta, 2013). From the results obtained it was found that the water is “hard” in nature and unfit for human consumption.

The concentration of sodium in the water samples analyzed was found to be in the range 155-492 mg/L. These values are beyond the permissible limit prescribed. Higher levels of EC and TDS observed in the water of the area under study are an indication of

Table 3(a): Correlation matrix data for the parameters of the village Mulagada

	EC	*TDS*	*pH*	*THW*	*Ca*	*Mg*	*Fe*	*Na*	*K*	*Cl*	*NO_2*	*PO_4*	*HCO_3*	*F*
EC	1													
TDS	1	1												
pH	0.087499	0.087499	1											
THW	-0.04018	-0.04018	0.02339	1										
Ca	-0.3555	-0.2355	-0.14387	0.435955	1									
Mg	0.003257	0.003257	0.053278	0.984257	0.270031	1								
Fe	0.418845	0.418845	0.052445	-0.27944	-0.68351	-0.16474	1							
Na	-0.24091	-0.24091	0.4215	0.268873	-0.03456	0.294448	-0.59488	1						
K	-0.15012	-0.15012	0.714482	-0.1995	-0.37343	-0.1401	-0.22658	0.810473	1					
Cl	0.250352	0.250352	0.405793	0.422867	0.049164	0.442759	0.348261	-0.29958	-0.20406	1				
NO_2	0.399655	0.399655	0.387432	-0.49389	-0.56503	-0.41743	0.288675	0.292286	0.584209	-0.43741	1			
PO_4	0.785301	0.785301	-0.12486	-0.51411	-0.42344	-0.46687	0.66831	-0.54331	-0.25265	-0.07138	0.559025	1		
HCO_3	0.140044	0.140044	0.729563	0.470732	0.283589	0.447931	0.070485	0.015794	0.09896	0.8238	-0.19737	-0.21272	1	
F	0.675826	0.675826	-0.38202	-0.60524	-0.31342	-0.58598	0.508804	-0.62751	-0.39358	-0.16606	0.345337	0.926533	-0.41561	1

Table 3(b): Covariance matrix data for the village Mulagada

	EC	*TDS*	*pH*	*THW*	*Ca*	*Mg*	*Fe*	*Na*	*K*	*Cl*	*NO_2*	*PO_4*	*HCO_3*	*F*
EC	162307													
TDS	103877	66481												
pH	4.9114	3.1433	0.0194											
THW	-942.86	-603.4	0.1898	3391.8										
Ca	-1014.3	-649.1	-0.214	271.43	114.3									
Mg	71.429	45.714	0.4041	3120.4	157.1	2963.3								
Fe	145.16	92.901	0.0063	-14	-6.286	-7.714	0.74							
Na	-11258	-7205	6.8118	1816.3	-42.86	1859.2	-59.4	13454						
K	-1103.7	-706.4	1.8167	-212	-72.86	-139.2	-3.56	1715.7	333.1					
Cl	4797.9	3070.7	2.6895	1171.5	25	1146.5	14.25	-1653	-177	2263				
NO_2	3.4271	2.1934	0.0011	-0.612	-0.129	-0.484	0.005	0.7216	0.227	-0.44	0.0005			
PO_4	998.43	638.99	-0.055	-94.49	-14.29	-80.2	1.814	-198.9	-14.6	-10.7	0.0376	9.9592		
HCO_3	13027	8337.3	23.47	6330	700	5630	14	423	417	9048	-0.97	-155	53312	
F	108.31	69.319	-0.021	-14.02	-1.333	-12.69	0.174	-28.95	-2.86	-3.14	0.0029	1.1632	-38.174	0.158247

Table 4(a): Correlation matrix data for the village Yeduruvanipalem

	EC	*TDS*	*pH*	*THW*	*Ca*	*Mg*	*Fe*	*Na*	*K*	*Cl*	*Nitrite*	*Phosphate*	*HCO_3*	*F*
EC	1													
TDS	1	1												
pH	-0.43377	-0.43377	1											
THW	0.290571	0.290571	0.295394	1										
Ca	-0.21216	-0.21216	-0.16575	0.540526	1									
Mg	0.469221	0.469221	0.447737	0.869911	0.055259	1								
Fe	0.521631	0.521631	-0.76308	-0.46476	-0.15681	-0.45964	1							
Na	-0.48235	-0.48235	-0.21504	0.049383	0.680194	-0.34014	-0.15252	1						
K	-0.52447	-0.52447	-0.10324	0.124732	0.593173	-0.1997	-0.42654	0.900435	1					
Cl	0.666855	0.666855	-0.29752	0.57704	0.25294	0.536541	0.169791	0.122748	-0.01053	1				
Nitrite	-0.09103	-0.09103	0.345755	0.134371	-0.03767	0.181549	-0.13344	-0.04347	-0.25256	0.373838	1			
Phosphate	-0.0326	-0.0326	-0.2619	0.619677	0.940875	0.183855	-0.16667	0.509412	0.522435	0.318357	-0.13344	1		
HCO_3	0.565568	0.565568	-0.32197	-0.47229	-0.63952	-0.1856	0.780654	-0.57717	-0.79841	0.152544	0.217681	-0.6326	1	
F	-0.32494	-0.32494	-0.39037	-0.40981	0.234395	-0.62376	0.229866	0.073892	0.150943	-0.64508	-0.58153	0.290531	-0.17174	1

Table 4(b): Covariance matrix for the village Yeduruvanipalem

	EC	*TDS*	*pH*	*THW*	*CA*	*Mg*	*Fe*	*Na*	*K*	*Cl*	*Nitrite*	*Phosphate*	*HCO_3*	*F*
EC	40142													
TDS	25691	16442												
pH	-26.901	-17.22	0.0958											
THW	2630	1683.2	4.1306	2040.8										
Ca	-948.57	-607.1	-1.145	544.9	498									
Mg	3578.6	2290.3	5.2755	1495.9	46.94	1449								
Fe	76.8	49.152	-0.174	-15.43	-2.571	-12.86	0.54							
Na	-9238.6	-5913	-6.363	213.27	1451	-1238	-10.7	9138.8						
K	-1853.4	-1186	-0.564	99.388	233.5	-134.1	-5.53	1518.3	311.1					
Cl	6425.6	4112.4	-4.429	1253.7	271.5	982.23	6.001	564.33	-8.93	2313				
Nitrite	-0.3986	0.255	0.0023	0.1327	-0.018	0.151	0	-0.091	-0.1	0.393	0.0005			
Phosphate	-4.5714	-2.926	-0.057	19.592	14.69	4.898	-0.09	34.082	6.449	10.72	-0.002	0.4898		
HCO_3	24059	15398	-21.16	-4530	-3030	-1500	121.8	-11715	-2990	1558	1.01	-94	45080	
F	-9.2006	-5.888	-0.017	-2.616	0.739	-3.356	0.024	0.9983	0.376	-4.38	-0.002	0.0287	-5.153	0.019972

increased concentration of sodium in water. The spatial distribution of salts corresponds to increased levels of TDS and EC. High levels of sodium effects the functioning of kidneys and sometimes causes high blood pressure in human. The high concentration sodium in water causes increase in the fluoride ion concentration in water. It is due to ion exchange processes caused by natural weathering processes. The concentration of potassium in the water samples analyzed was also found to be beyond the permissible limit.

Concentration of phosphate in the water analyzed was found to be in the range 15-25 mg/L. These results are beyond the standard values prescribed by BIS. Higher concentration levels of phosphate in ground water is due to anthropogenic activities, household seepage and sewage. It was found that no proper drainage system exists in the two villages and most of the household seepage and sewage is fed into the ground.

Concentration of fluoride in water should not be below 0.5 mg/L and above 1.2 mg/L. Higher concentrations of fluoride than 1.2 mg/L causes cerebral fluorosis, leading to death. It was found that in the two villages that most of the people are suffering from dental fluorosis (Figure 1). From the results obtained, the concentration of fluoride in the ground water of the two villages was found to be in the range 1.432-2.944 mg/L. These values are beyond the permissible standard limit prescribed by WHO as well as BIS. In literature it was reported that most of the coastal villages of Prakasam district of Andhra Pradesh were found to have higher concentration of fluoride in the ground water (Subba Rao, 2015). The values of concentration of fluoride observed for the two villages under study resemble the values reported by earlier researchers. The correlation curves between bicarbonate-fluoride, calcium-fluoride, total hardness of water-fluoride, phosphate-fluoride and sodium-fluoride are presented in Figures 2-6. From these data it was found that positive correlation existed between total hardness of water-fluoride, phosphate-fluoride and sodium-fluoride in the village Mulagada. The R^2 values of the same were found to be as 0.366, 0.858 and 0.393 respectively. A

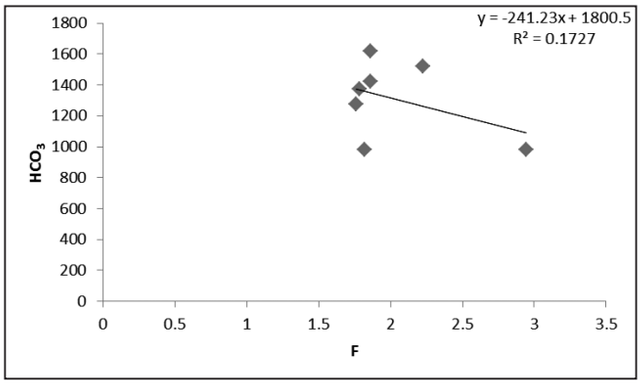

Figure 2(a): Correlation curve between bicarbonate and fluoride, Mulagda village.

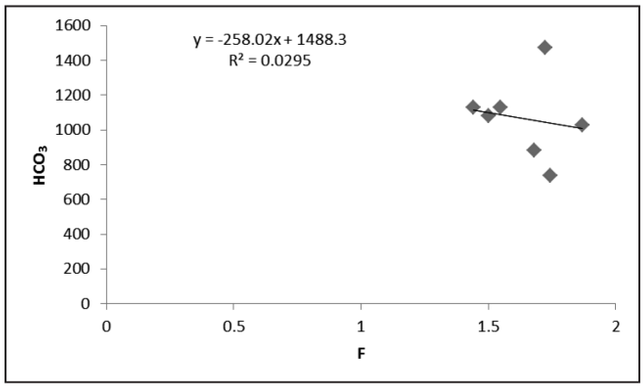

Figure 2(b): Correlation curve between bicarbonate and fluoride, Yeduruvanipalem village.

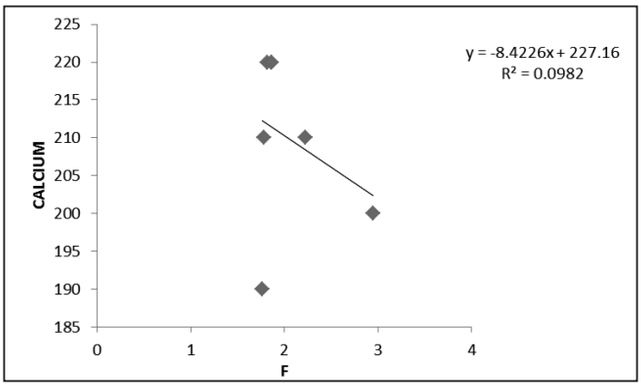

Figure 3(a): Correlation curve between calcium and fluoride, Mulagda village.

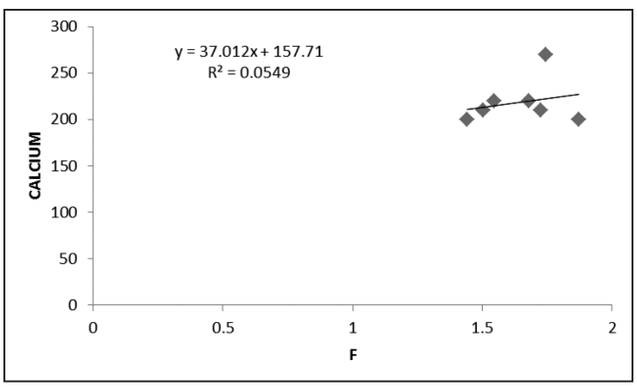

Figure 3(b): Correlation curve between calcium and fluoride, Yeduruvanipalem village.

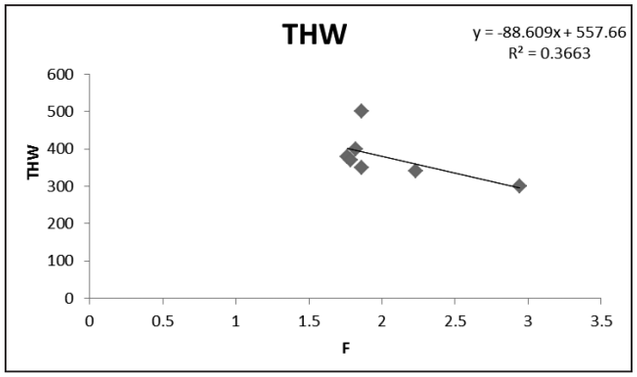

Figure 4(a): Correlation curve between total hardness of water and fluoride, Mulagda village.

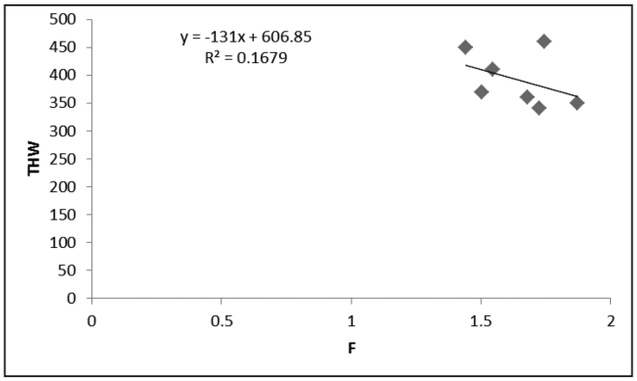

Figure 4(b): Correlation curve between total hardness of water and fluoride, Yeduruvanipalem village.

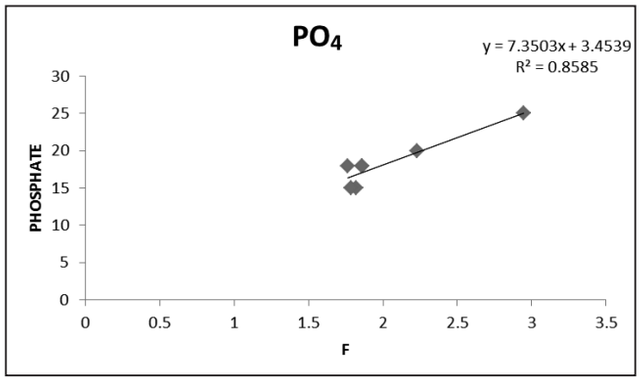

Figure 5(a): Correlation curve between phosphate and fluoride, Mulagda village.

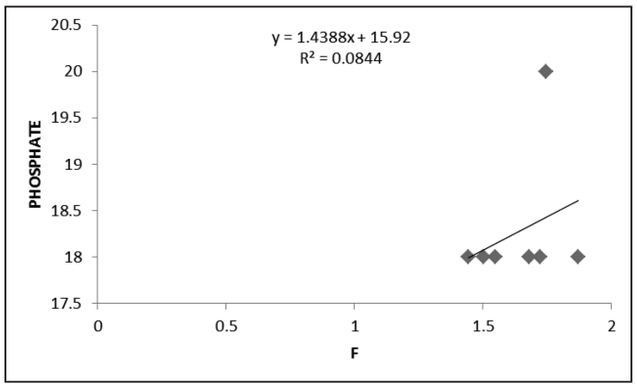

Figure 5(b): Correlation curve between phosphate and fluoride, Yeduruvanipalem village.

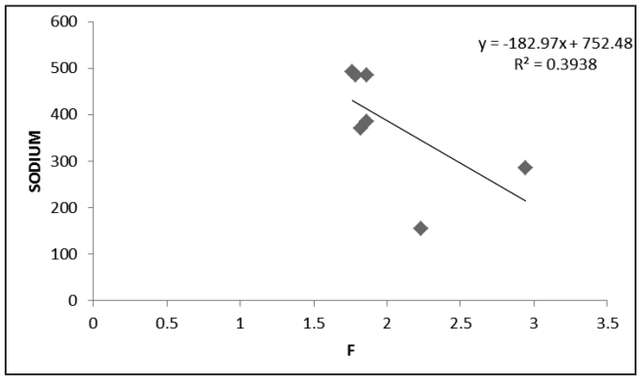

Figure 6(a): Correlation curve between sodium and fluoride, Mulagda village.

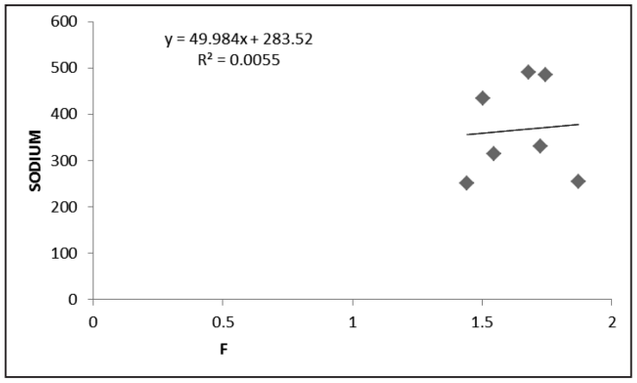

Figure 6(b): Correlation curve between sodium and fluoride, Yeduruvanipalem village.

high positive correlation existed between phosphate and fluoride. From these correlation data, it is inferred that sodium, phosphate and total hardness of water has an appreciable effect on the increased concentration of fluoride in the ground water of the village Mulagada. High fluoride ion concentration is due to the presence of apatite mineral deposits in the area under study. Due to natural and/or chemical weathering process and due to ion exchange and/or solubility of the salts fluoride entered the water. The ground water of the two villages is unfit for drinking with respect to the observed high concentrations of fluoride.

Concentration of nitrite in the two villages was well within the prescribed standard values. These values were found to be in the range 0.05-0.1 mg/L. Concentration of chloride in the two villages was found to be in the range 140-262 mg/L. These values were well within the prescribed standard limits. From this data it is inferred that nitrite and chloride have no effect on the quality of water.

Water quality index (WQI) for the two villages was calculated and found to be 101.1 for the village Mulgada and 87.5 for the village Yeduruvanipalem. From the WQI data it was found that the water of the two villages was graded as "poor" in its quality (Pavan Kumar and Rama Krishna, 2014). Hence, it is inferred that the water of the two villages was unfit for human consumption.

Correlation matrix analysis is to establish the relation between physico-chemical parameters of water samples, which can reveal the origin of solutes and the process that generated the observed water compositions. More precisely, the value of $r > 0.7$, the variables strongly correlated and r between 0.5 and 0.7 the variables are moderately correlated. From the correlation analysis data it was found that the parameters EC, TDS and phosphate have positive correlation with fluoride for the water samples of the village Mulagada. The p value for phosphate and fluoride was found to be 0.0027 which is less than 0.05 and hence a positive correlation was observed for these two parameters in the village Mulagda. A higher p value than 0.05 was observed for the two parameters for the water samples analyzed from the village Yeduruvanipalem. The value of p for all the other parameters in the two villages was found to be greater than 0.05. From these data it is concluded that there is a significant effect of phosphate on the concentration of fluoride. Regression statistical analysis data was presented in Table 5. Observed and predicted

Table 5: Regression statistical data for phosphate and fluoride in the village Mulagada

Regression Statistics	
Multiple R	0.926533
R Square	0.858464
Adjusted R Square	0.830156
Standard Error	1.404785
Observations	7

ANOVA

	df	*SS*	*MS*	*F*	*Significane F*
Regression	1	59.84719	59.84719	30.32663858	0.002700048
Residual	5	9.867099	1.97342		
Total	6	69.71429			

	Coefficients	*Standard error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	3.453912	2.770576	1.24664	0.267746532	-3.668080465	10.5759	-3.66808	10.5759
F	7.350299	1.334728	5.506963	0.002700048	3.91927085	10.78133	3.919271	10.78133

Residual Output

Observation	*Predicted PO*	*Residuals*
1	16.82411	-1.82411
2	16.41984	1.58016
3	25.09319	-0.09319
4	17.11812	0.881882
5	19.83773	0.162271
6	17.13282	0.867181
7	16.5742	-1.5742

concentrations of phosphate and fluoride are presented in Figures 7 and 8 for the two villages.

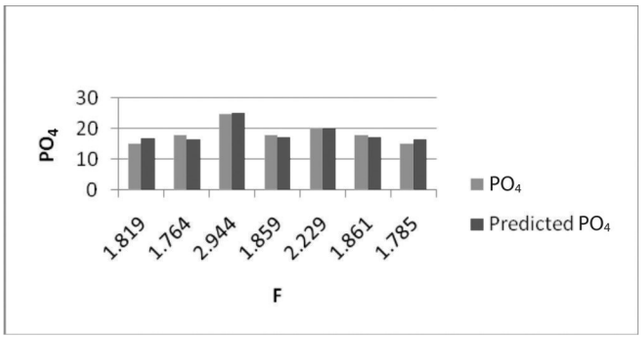

Figure 7: Line fit plot for fluoride and phosphate in the vilage Mulagada.

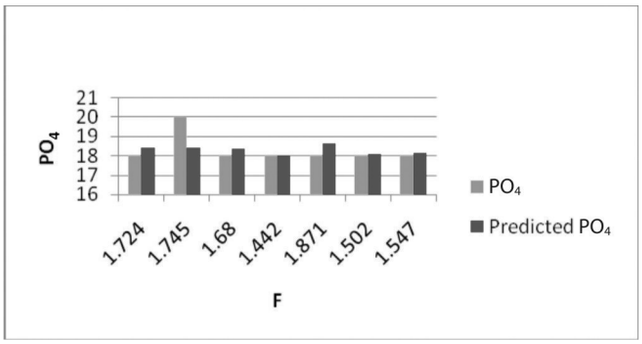

Figure 8: Line fit plot for fluoride and phosphate in the village Yeduruvanipalem.

Conclusions

Higher concentrations of fluoride in the water samples analyzed from the two villages were one of the findings of the present study. The concentrations of fluoride are beyond the permissible limits prescribed by BIS. A strong and significant correlation was found between phosphate and fluoride for the water samples of the village Mulagada with a *p* value of 0.027 and *R* square value of 0.89. The people suffering from dental fluorisis is also an evidence for this fact. EC and TDS were also beyond the acceptable limits prescribed. WQI calculated for the water of the two villages was found to be 101.1 and 87.25 for Mulagada and Yeduruvanipalem respectively. Nitrite and chloride concentration in the two villages was found to be well within the prescribed limits. From these data it is concluded that the water analyzed is unfit for human consumption.

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