ASSESSMENT OF GROUNDWATER QUALITY WITH SPECIAL REFERENCE TO FLUORIDE AND ITS IMPACT ON IQ OF SCHOOLCHILDREN IN SIX VILLAGES OF THE MUNDRA REGION, KACHCHH, GUJARAT, INDIA

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SUMMARY: Sixty groundwater (GW) samples from bore and dug wells averaging 560 feet deep were collected from the six villages of Baroi, Chhasara, Gundala, Mundra, Pragpar, and Zarpara in the semi-arid Mundra region of Kachchh, Gujarat, India. The mean temperature of the GW collection samples was 32.11ºC, and the average slightly alkaline pH was 8.2, which is characteristic of GW in this semi-arid region. Average turbidity was 7.7 NTU, and the total dissolved solids (TDS) average was 1141.19 mg/L. Zarpara had the highest total alkalinity level of 620.84 mg/L, whereas the average was 392.01 mg/L. The average total water hardness level was 267.71 mg/L, which falls under a normal range. The average biological oxygen demand (BOD) was less than 6 mg/L, and the dissolved oxygen (DO) was 7.6 mg/L. The average levels of calcium, magnesium, and chloride were within permissible limits. Fluoride (F) concentrations were higher in Chhasara, Gundala, and Mundra villages with values of 3.42, 1.8, and 1.9 mg/L (ppm), respectively. The socio-economic scale of the area was essentially low and equal, i.e., category E in a scale of A–E. Urine samples of 34 schoolchildren from high F and 50 from low F villages were collected and analyzed for F: 2.25 ppm in urine samples from villages having higher F levels in the GW, which was highly significant ($p \leq 0.01$) as compared to 0.42 ppm F in the low F villages. The average IQ level of schoolchildren (N = 50) from the low F villages was 97.17, which is significantly higher ($p \leq 0.001$) than 92.53 of schoolchildren (N = 34) from the high F villages.

Keywords: Fluoride in water; Groundwater contamination; Mundra region of Gujarat, India; Physico-chemical analysis of groundwater; IQ of schoolchildren; Urinary fluoride.

INTRODUCTION

Fluoride (F) has been found to have adverse effects on the structure and functions of the animal nervous system.[1-2] Over the last two decades more subtle injuries from human F exposure in the form of lower intelligence have been reported in several countries.[3-17] This effect of F may be due to its ability to cause CNS (central nervous system) cellular injury through several mechanisms including free radical generation and excitotoxicity.[18]

Gujarat state in India has a very high rate of groundwater depletion. In the past two decades, it has lost about 27 percent of its groundwater resources, which indicates a serious “water stress” situation.[19] In the semi-arid region of Kachchh, where the availability of fresh water by precipitation is rare, and geomorphological expression groundwater is high in dissolved minerals, the chances of getting high F cannot be overlooked. Reconnaissance surveys reveal a possible impact of high F consumption on IQ of schoolchildren from different geological locations around

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the world. Moreover, Choi et al.[20] in their recent review of 27 epidemiological studies have revealed possible adverse impact of fluoride on children's neurodevelopment.

Therefore, the present investigation was designed to assess the groundwater quality in a semi-arid region of Kachchh with special reference to F contamination as one part of the study. As a second part of the investigation, the impact of F on IQ of schoolchildren with same socio-economic status in the Mundra region of Kachchh, Gujarat, was also included.

MATERIALS AND METHODS

This research was conducted in the semi-arid region Mundra region of Kachchh in Gujarat measuring 3 on a scale of 1–4 with a mean 1932–2001 annual rainfall of 366 mm, which is often irregular and erratic. As a consequence, the quality and availability of drinking water has a great influence on the health and psychology of the residents. The present study was undertaken therefore to assess the physico-chemical parameters of the groundwater (GW) with special emphasis on fluoride (F) contamination. The education level in the Mundra region is around 64.09% according to the 2011 census of India. GW samples from bore and dug wells were collected from six villages, namely, Baroi, Chhasara, Gundala, Mundra, Pragpar, and Zarpara in the Mundra region. The locations were selected to cover major parts of the taluka and represent overall groundwater quality of the taluka. Sixty GW samples of bore and/or dug wells of average depth of 560 feet in the area were collected during March through May 2011 using precleaned plastic sample containers and were stored under refrigeration until analyzed.

For physico-chemical analysis, temperature (ºC), pH, turbidity, total dissolved solids (TDS), total alkalinity (TA), total hardness (TH), calcium and magnesium dependent hardness, biological oxygen demand (BOD), dissolved oxygen (DO), and fluoride (F) were determined according to the methods prescribed in 1998 by the American Public Health Association (APHA).[21] F in the GW was measured by ion exchange chromatography.

The intelligence quotient (IQ) of representative samples of the children in the villages was measured as in our earlier study.[10] Regular students (having attendance more than 80%) of standard 6th and 7th were selected for the present study from six villages. The socio-economic status and iodine consumption of the population was analyzed using a questionnaire designed and standardised on the basis of the 2011 census of India.[22]

Statistical analysis: Data are expressed as Mean ± S.E.M. Paired sample T test was calculated using SPSS 17 software for the analysis of data and values were considered significant at $p \leq 0.05$.

RESULTS

Table 1 shows the average temperature of GW samples ranged from 29.0ºC in Pragpar to 35.0ºC in Baroi. It also shows that the average pH was slightly alkaline, varying between 7.77 and 8.30. Turbidity ranged from 4 to 12 NTU, with an average value of 7.67 NTU.

Table 1. Groundwater quality assessment with special reference to fluoride contamination (Mean ± S.E.M)

Anal. No.	Parameter	DL	PL	Chhasara (N = 10)	Gundala (N = 10)	Baroi (N =10)	Mundra (N =10)	Zarpara (N =10)	Pragpar (N =10)
1	Temperature (ºC)	--	--	31.00 ± 0.57	32.33 ± 0.33	35.00 ± 1.73	32.67 ± 1.33	32.67 ± 1.20	29.00 ± 1.29
2	pH	6.5–8.5	NR	7.87 ± 0.03	8.30 ± 0.10	7.85 ± 0.23	8.30 ± 0.20	7.77 ± 0.16	8.07 ± 0.20
3	Turbidity (NTU)	5	10	8.00 ±1.26	12.00 ± 0.98	4.00 ± 0.64	7.00 ± 1.87	8.00 ± 1.54	7.00 ± 1.02
4	TDS (mg/L)	500	2000	733.33 ± 336.91	1280 ± 567.77	1420 ± 505.04	1053.33 ± 437.68	1933.33 ± 899.16	426.67 ± 96.26
5	Total alkalinity (mg/L)	200	600	403.96 ± 108.98	298.22 ± 47.56	368.03 ± 45.68	306.37 ± 30.59	620.84 ± 342.98*	355.17 ± 50.26
6	Total hardness (mg/L)	300	600	105.33 ± 16.15	149.78 ± 20.28	185.12 ± 77.57	173.67 ± 82.73	875.61 ± 678.83*	116.79 ± 30.99
7	Calcium (mg/L)	75	200	81.2 ± 14.06	106.67 ± 13.54	149.3 ± 69.39	136 ± 75.53	736.93 ± 587.37*	76.93 ± 22.82
8	Magnesium (mg/L)	30	100	5.86 ± 0.81	10.48 ± 1.81	8.70 ± 2.01	9.16 ± 1.90	33.70 ± 22.22	9.68 ± 2.11
9	Chloride (mg/L)	250	1000	4.96 ± 0.02	4.83 ± 0.08	4.94 ± 0.01	4.97 ± 0.01	4.46 ± 0.31	4.95 ± 0.01
10	BOD (mg/L)	6	NR	0.20 ± 0.10	0.40 ± 0.10	0.38 ± 0.11	0.23 ± 0.12	0.17 ± 0.08	0.53 ± 0.17
11	DO (mg/L)	>6	NR	8.1 ± 0.06	7.9 ± 0.06	8.47 ± 0.11	6.97 ± 0.13	7.17 ± 0.12	7.17 ± 0.22
12	Fluoride (ppm)	1	1.5	3.42 ± 1.21*	1.6 ± 0.82*	0.98 ± 0.47	1.88 ±0.58*	0.7 ± 0.45	0.62 ± 0.32

DL: Desirable Limit; PL: Permissible Limit; *Higher than permissible limit

The TDS, alkalinity, and total hardness of the GW were fairly high, with Zarpara being exceptionally high. However, calcium dependent hardness was exceptionally high in all the studied villages, averaging 300.83 mg/L, which may in part be responsible for the high incidence of renal disorders, since it promotes formation of calcium oxalate kidney stones. The average magnesium dependent hardness was 211.83 mg/L, which is significantly higher than the permissible limit. The mean BOD was 0.26 mg/L, which is significantly below the desirable level of at least 6 mg/L, but no biological contamination seems to be present. On the other hand, the DO ranged from 6.97 to 8.47 mg/L, which is above the minimum desirable level of 6 mg/L, indicating the presence of a fairly good amount of oxygen in the GW. As also seen in Table 1, the average F concentration in the GW of the Chhasra, Mundra, and Gundala village areas exceeded the permissible limit of 1.5 mg/L as well as the desirable limit of 1.0 mg/L.[23-24] On the other hand, the F concentration in the village areas of Baroi, Zarpara, and Pragpar fell below 1.0 mg/L.

Table 2 compares the mean F levels in the GW drinking water and urine samples of the 84 schoolchildren who were tested. Results reveal a significantly higher F level ($p \leq 0.05$) in drinking water correlated with higher F levels in the urine and vice versa for the lower F drinking water and urine samples.

Table 2. Drinking water and urinary F level of children living in low F villages and high F villages (Mean ± SEM)

Village	Number of children examined	Level of F in GW drinking water (ppm)	Urinary F level (ppm)
Low F villages	50	0.84 ± 0.38	0.42 ± 0.23
High F villages	34	2.3 ± 0.87*	2.69 ± 0.92*

*p≤0.05 (Compared to low F contaminated villages)

Table 3 shows that the concentration of F in urine of the 84 schoolchildren and distribution of their IQ scores were inversely related. The average IQ score of the 34 students drinking the high F water was significantly lower ($p \leq 0.05$) than among the 50 students drinking the low F water.

Table 3. IQ scores of school children living in low F and high F villages (Mean ± SEM)

	Low F villages	High F villages
Male	99.97 ± 2.10	94.88 ± 2.96*
Female	94.37 ± 2.98	90.18 ± 3.319*
Total	97.17 ± 2.54	92.53 ± 3.13*

*p≤0.05 (Compared to low F contaminated villages)

Table 4 shows the distribution of IQ scores of the schoolchildren according the high and low F villages.

Table 4. IQ distribution of children in low F villages and high F villages

IQ	High F villages				Low F villages			
	Male	Female	Total	%	Male	Female	Total	%
≥ 130	0	0	0	0	0	0	0	0
120–129	0	0	0	0	2	0	2	4.0
110–119	3	1	4	11.76	6	1	7	14.0
90–109	10	9	19	55.88	21	11	32	64.0
80–89	3	2	5	14.71	5	3	8	16.0
70–79	2	4	6	17.65	0	1	1	2.0
≤ 69	0	0	0	0	0	0	0	0
Total	18	16	34	100	34	16	50	100

DISCUSSION

Overall physico-chemical parameters of GW from six villages of Mundra are pristine for consumption except in three villages where fluoride concentration is higher than permissible limit.[23-24] Intensive and long-term irrigation in the district is probably one of the factors that causes weathering and leaching of fluoride from the soils/weathered rocks, contributing F to the surface water and GW.[25-26] Moreover, Kachchh has unique geological features, mainly made up of alkali, silicate, igneous, and sedimentary rocks, so that weathering contributes a major portion of fluorides to GW.

As the kidney is the principal organ for the excretion of F, the rate or degree of exposure to F was checked by analyzing the urinary F level.[27] For the IQ testing, the majority of the students scored less than 109 which represents normal or below normal score of IQ. Further, the overall difference in the mean IQ was 4.64%, which is statistically significant. This difference is mainly due to 4% superior students (IQ Score > 119) in low F villages whereas no students represent the superior class in high fluoride villages (Table 4), which is in accordance to our previous study. It thus appears that elevated F exposure reduced higher levels of intelligence even more than it affects normal and below normal intelligence of the children.[10] Our study results are also in agreement with those of Poureslami et al.[16] for 180 school children in Iran, which revealed that the percentage of students ranked in the ranges of average, above average and excellent were higher in low F Baft than the percentage of students in the same ranks in high F Koohbanan. Likewise, the percentage of the students ranked in the ranges of below average and borderline were higher in Koohbanan than in Baft.

It is now clear from many reported studies that excessive intake of F can produce harmful effects on the developing brain,[12] the detailed mechanism by which F influences IQ is not clear. However, there is evidence that F may involve in alteration of membrane lipid and reduction in cholinesterase activity in the brain. Guan et al.[28] demonstrated that the contents of phospholipids and ubiquinone are altered in the brain of rats affected by chronic fluorosis, and therefore changes in membrane lipids could be involved in the pathogenesis of this disorder. A few studies on effect of NaF on neurotransmitter and neurochemical levels revealed alterations in dopamine, serotonin, 5-hydroxyindoleacetic acid, homovanillic acid, norepinephrine, acetylcholine esterase, and epinephrine in the hippocampus and neocortex regions of the rat and mice brain.[29-30] Earlier, Yu et al.[31] also demonstrated changes in neurotransmitters and their receptors in human fetal brain from an endemic fluorosis area. Moreover, it is well established that F can pass through the placenta to the fetus, and with subsequent continuous exposure to F during childhood, it may have adverse effects on the developing brain, thereby causing decreased IQ in children.[32-34]

Therefore, the present investigation concludes that the three villages of Chhasara, Gundala, and Mundra, are F-contaminated villages. Because of high F concentrations in the GW, children in these villages have greater exposure to F that may lead in to low IQ as compared to the nearby villages of Baroi, Zarpara, and Pragpar, which have low F in their GW.

ACKNOWLEDGEMENTS

We extend our special thanks to the Gujarat Council of Science and Technology (GUJCOST), Gandhinagar for the financial support. Also we would like to express our gratitude to the late Professor NJ Chinoy and Dr RJ Verma, Department of Zoology, School of Sciences, Gujarat University, Ahmedabad, for their invaluable guidance and support.

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