CORRELATION OF FLUORIDE WITH SOME INORGANIC CONSTITUENTS IN GROUNDWATER OF DASHTESTAN, IRAN

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SUMMARY: To determine the relationship of the previously measured fluoride (F) content to other inorganic constituents in groundwater samples from 14 different villages in the Dashtestan area of Bushehr Province, Iran, the levels of various inorganic constituents in the water such as pH, noncarbonate hardness, carbonate hardness, total hardness, alkalinity, Cl^-, SO_4^{2-}, NO_3^-, Ca^{2+}, and Mg^{2+} were determined. From correlation analysis, F was found to be positively related to total hardness, noncarbonate hardness, SO_4^{2-}, Ca^{2+}, and Mg^{2+}, but there appeared to be no significant association between the F concentration and other parameters.

Keywords: Dashtestan, Iran; Fluoride correlation; Groundwater; Inorganic constituents.

INTRODUCTION

Fluoride (F) in drinking water is usually the main source of F intake, and excessive consumption of F can cause a wide range of adverse health effects.[1-5] For this reason, it is important to determine the F concentration of groundwater and its correlation with other drinking water parameters. In this study, we examined the relationship between the F content of groundwater and other inorganic constituents such as pH, noncarbonate hardness (NCH), carbonate hardness (CH), total hardness (TH), Cl^-, SO_4^{2-}, NO_3^-, Ca^{2+}, and Mg^{2+} in villages of the Dashtestan area of Bushehr Province, Iran.

MATERIALS AND METHODS

This study was conducted between March and September 2007 in 14 villages of Dashtestan, Iran with groundwater as sources of drinking water. In a recent report, as the first part of this investigation, we showed a map of the location of the villages and noted the basis for their selection.[6]

As reported earlier,[6] the standard SPADNS method was used with a DR/2000_s spectrophotometer for the F determinations. Ca^{2+}, Mg^{2+}, and NO_3^-, also were measured with a DR/2000_s spectrophotometer (HACH Company, USA). Other parameters such as total hardness (TH), carbonate hardness (CH), alkalinity (ALK), Cl^-, and SO_4^{2-} were determined by standard methods,[7] and pH was determined using a pH meter. Since TH was greater than ALK, CH was considered to be equal to ALK, and noncarbonate hardness (NCH) was taken as the difference between TH and CH.[8]

RESULTS AND DISCUSSION

The F concentrations and the other inorganic parameters of groundwater in the 14 villages are shown in Table 1.

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Table 1. Analytical results of groundwater samples in 14 villages of Dashtestan (F, Cl^-, SO_4^{2-}, NO_3^-, Ca^{2+}, and Mg^{2+} values are in mg/L, and NCH, CH, TH, and ALK values are in mg/ L $CaCO_3^-$; maximum values are expressed as bold italics; minimum values as bold underlined)

Village[a]	F	pH	NCH	CH	TH	ALK	Cl^-	SO_4^{2-}	NO_3^-	Ca^{2+}	Mg^{2+}
1	***2.5***	7.11	635	205	840	205	60	740	1.5	216	73
2	2.12	7.15	1035	165	1200	165	38	980	7.8	272	127
3	2.11	7.15	***1480***	180	***1660***	180	***400***	***1100***	15.1	385	***171***
4	2.07	7.37	560	180	740	180	76	715	1.3	176	73
5	2.00	7.36	1400	160	156	160	44	880	1.4	***425***	122
6[b]	1.87	7.24	545	175	720	175	36	690	10	185	63
7[b]	1.87	7.24	545	175	720	175	36	690	10	185	63
8	1.80	**6.95**	900	200	1100	200	96	975	16	221	134
9	1.67	7.08	480	**140**	620	**140**	96	610	3.5	201	29
10	1.66	7.15	160	240	400	240	20	375	**1**	**96**	39
11	1.65	7.06	320	180	500	180	50	485	7.5	145	34
12	1.29	7.06	512	208	720	208	180	635	***22.8***	205	51
13	1.10	7.33	198	***250***	448	***250***	18	415	15.7	148	**19.5**
14	**0.99**	***7.82***	**105**	215	**320**	215	**16**	**310**	2	**96**	**19.5**

[a]Villages: 1: Khun, 2: Rud Faryab, 3: Dehrud-e Sofla, 4: Dalaki, 5: Tang-e Eram, 6: Shaldan, 7: Bushkan, 8: Dehrud-e Olya, 9: Kalmeh, 10: Kaftaro, 11: Talheh, 12: Emamzade, 13: Khairak, 14: Talkhab.[b]The source of drinking water in Shaldan and Bushkan is same.

Correlation analysis indicates there is no significant relationship between the F content of these waters with pH, alkalinity, Cl^-, and NO_3^- (Table 2).

Table 2. Correlation coefficient values of water quality parameters

Parameter	pH	NCH	CH	TH	ALK	Cl^-	SO_4^{2-}	NO_3^-	Ca^{2+}	Mg^{2+}
F	–0.417	0.621*	-0.491	0.607*	-0.491	0.208	0.703†	–0.305	0.533*	0.635*
pH		–0.260	0.185	-0.256	0.185	–0.299	–0.431	0.399	–0.194	–0.306
NCH			–0.528	0.998†	–0.528	0.574*	0.928†	0.136	0.966†	0.938†
CH				–0.473	1.00†	–0.172	–0.530	0.208	–0.523	–0.366
TH					–0.473	0.582*	0.923†	0.157	0.963†	0.946†
ALK						–0.172	–0.530	0.208	–0.523	–0.366
Cl^-							0.559*	0.475	0.539*	0.578*
SO_4^{2-}								0.249	0.826†	0.950†
NO_3^-									0.114	0.196
Ca^{2+}										0.823†

*Correlation is significant at the 0.05 level; †correlation is significant at the 0.01 level.

As seen in Table 1, because of high SO_4^{2-} levels, most of total hardness in the groundwater is due to NCH, not CH. In agreement with a study in Assam, India,[9] there is, however, a significant and direct correlation between F with Ca^{2+} and Mg^{2+}. Moreover, the F content of the water also has a significant and direct correlation with SO_4^{2-}, NCH, and TH (Table 2). In a report on groundwater in Tamil Nadu, India,[10] there was a positive correlation of F with TH and Ca^{2+}. On

the other hand, Gupta et al. in their study of groundwater in West Bengal found a weak inverse correlation of F with SO_4^{2-}, Ca^{2+}, Mg^{2+}, and TH, and a weak direct correlation with Cl^- and pH.[11] Karthikeyan et al. in their research have further reported both direct and inverse correlations of F with pH, TH, Cl^-, and SO_4^{2-} in the Tamil Nadu areas of South India.[12]

High concentrations of SO_4^{2-}, Ca^{2+}, Mg^{2+}, NCH, and TH in our water samples may be attributed to the aquifer soil texture in this area.[13] After multiple regression analysis of the data, the following equation was obtained:

$$F = 6.385 + 0.0012\ SO_4^{2-} - 0.0372\ NO_3^- - 0.714\ pH.$$

As indicated by the above equation, SO_4^{2-} has a positive association with F, but NO_3^- and pH have a negative relationship.

Recently we reported that the number of decayed permanent teeth (D_t) and deciduous teeth (d_t) in the 14 villages of Dashtestan showed no significant association with F content, but when Kuhn, the village with the highest water F level and the lowest caries scores is omitted, linear regression analyses showed weak increases of D_t and d_t with increasing water F levels.[6] In Table 3 correlation coefficient values of D_t and d_t with water quality parameters are presented for all 14 of the villages. Multiple regression analysis indicates that only Mg^{2+} has a significant and direct association with both D_t and d_t.

Table 3. Correlation coefficient values of D_t and d_t with water quality parameters

Parameters	F	pH	NCH	CH	TH	ALK	Cl^-	SO_4^{2-}	NO_3^-	Ca^{2+}	Mg^{2+}
D_t	0.163	0.088	0.537*	–0.368	0.530	–0.368	0.198	0.490	0.147	0.438	0.590*
d_t	0.151	0.031	0.524	–0.339	0.518	–0.339	0.263	0.535*	0.249	0.396	0.615*

*Correlation is significant at the 0.05 level.

Finally in view of the high F content of drinking water in certain parts of Iran,[14,15] along with extensive consumption of tea with a mostly modest F content,[16,17] we recommend the use of low F bottled drinking water in Iran.[18]

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