

THE FLUORIDE AND CHLORIDE ION LEVELS IN THE SEAWATER ALONG THE NORTHERN PART OF THE PERSIAN GULF IN BUSHEHR PROVINCE, IRAN

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ABSTRACT: The objectives of the present study were to determine the concentration levels of the fluoride (F) and chloride (Cl) ions, and the F to Cl (F:Cl) ratio, in the seawater adjacent to the industrial region of the Pars Special Energy Economic Zone along the northern part of the Persian Gulf in Bushehr province, Iran. Forty-five seawater samples from three different areas of the northern part of the Persian Gulf, Nakhle Taghi, Kangan, and Lavare Saheli, were collected during March-August 2016. The results showed that the ranges for the concentration levels of F and Cl were 0.35–2.79 mg/L and 19.99–35.49 g/L, respectively. The range for the F:Cl ratio was 1.34×10^{-5} – 11.50×10^{-5} .

Keywords: Bushehr province, Iran; Fluoride to chlorinity ratio; Iran; Pars Special Economic Energy Zone; Persian Gulf.

INTRODUCTION

The widespread presence of the fluoride ion (F) in the environment is a cause for concern because of the extensive range of harmful health effects associated with it.¹⁻² Various studies have been performed in Iran on the F concentration levels in drinking water, air, fish, ballast water, and seawater as well as on its removal from water and aqueous solutions containing high concentration levels of F.³⁻²² F is a major element in seawater and the specific geochemistry of F compared to the other halogens has been a focus in research. Recently, we reported on the F to Cl (F:Cl) ratios in Bushehr port coastal seawater as well as in the ballast water of commercial ships entering Bushehr port.^{5, 22} However, no reports have been made yet on the F:Cl ratio in the sea water adjacent to the industrial region of the Pars Special Energy Economic Zone, along the northern part of the Persian Gulf in Bushehr province, Iran, which is the biggest individual gas source in the world. Accordingly, the objectives of the present study were to establish base-line data for the concentration levels of F and Cl, and the F:Cl ratio, in the seawater adjacent to the industrial region of the Pars Special Energy Economic Zone along the northern part of the Persian Gulf in Bushehr province, Iran.

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MATERIALS AND METHODS

Fifteen seawater samples were collected, during March to August 2016, from each of three areas along the northern part of the Persian Gulf, Nakhle Taghi, Kangan, and Lavare Saheli, in the industrial region of Bushehr province, Iran, (Figures 1A-1D).

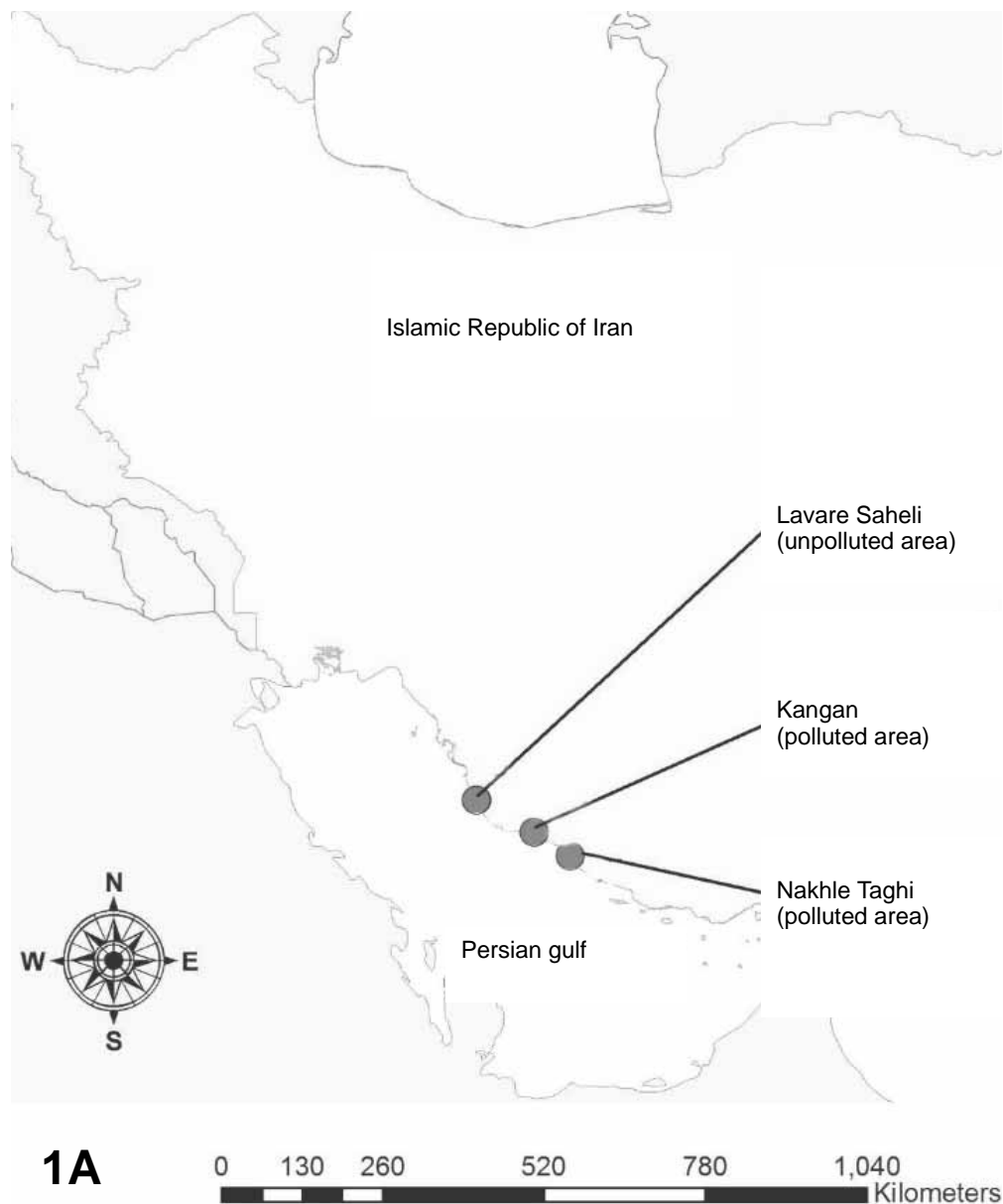
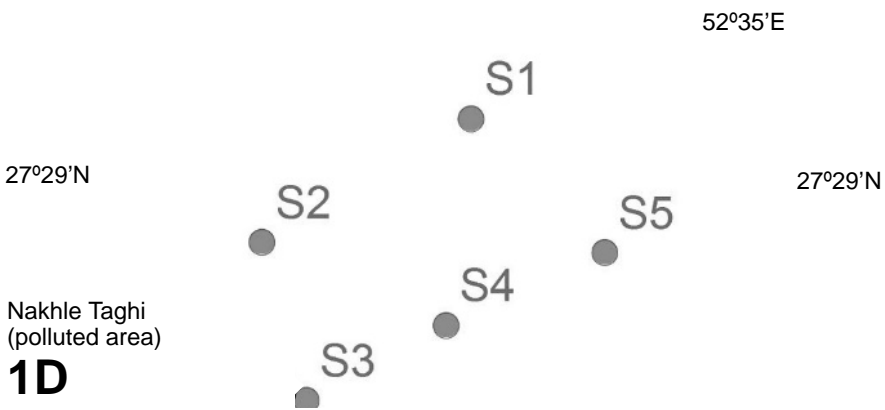
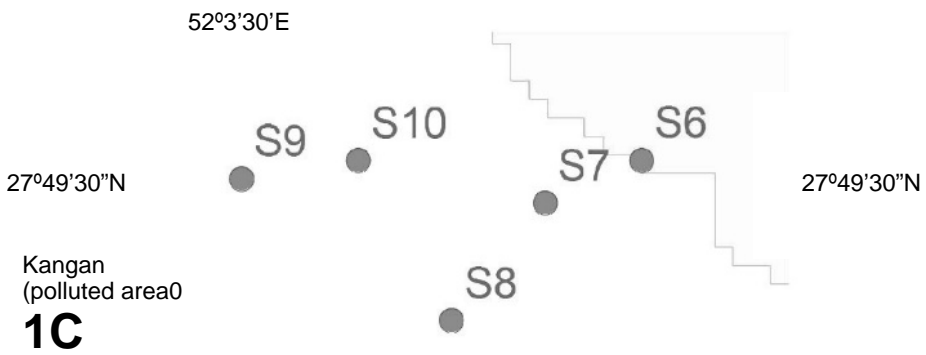
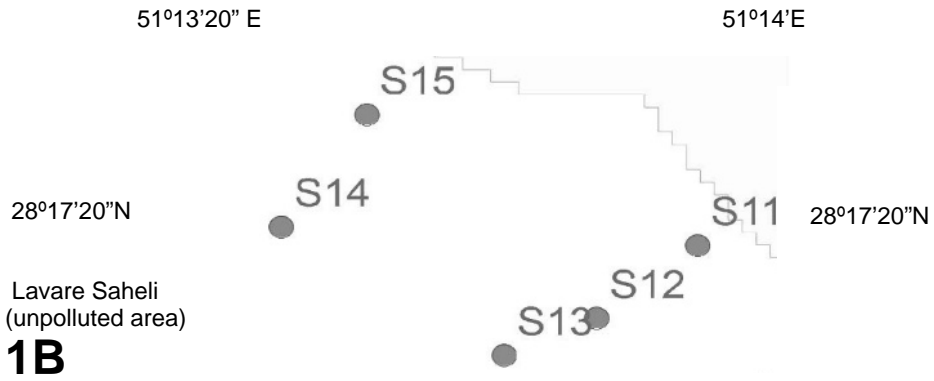


Figure 1A. The geographical location of seawater samples from the three locations, Nakhle Taghi, Kangan, and Lavare Saheli, adjacent to the industrial region of the Pars Special Energy Economic Zone along the northern part of the Persian Gulf in Bushehr province, Iran.



Figures 1B, 1C, and 1D. The geographical location of seawater samples from the three locations, Nakhle Taghi, Kangan, and Lavare Saheli, adjacent to the industrial region of the Pars Special Energy Economic Zone along the northern part of the Persian Gulf in Bushehr province, Iran.

The water temperature and the pH values were measured by using a water quality checker (Multi 340i Set 2, Germany), and the Cl concentration level was determined by the standard method.²³ For the measurement of the F concentration level in the seawater samples the standard SPADNS method was used with a UV-VIS spectrophotometer (model CAM spec M 501). As noted previously,^{5,22} although chlorinity is not equivalent to the Cl levels, the factor for converting a Cl content in seawater to include bromide, for example, is only 1.0045. So, for practical use, as well as here, the Cl content, in g/kg of solution, is nearly equal to the chlorinity in seawater.

RESULTS AND DISCUSSION

The results for the seawater samples of the water temperatures, pH, F and Cl concentrations, and the F:Cl ratios are shown in the Tables 1A and 1B.

Table 1A. The values for samples 1–23 for the water temperature (Temp, °C), the pH, the fluoride ion (F, mg/L) and chloride ion (Cl, g/L) concentrations, and the F:Cl ratio (value $\times 10^{-5}$) in the seawater at various sampling points in the Nakhle Taghi, Kangan, and Lavare Saheli areas of the industrial region of Bushehr

Sample code	Location	Station	Temp (°C)	pH	F (mg/L)	Cl (g/L)	F:Cl (value $\times 10^{-5}$)
S ₁	Nakhle Taghi	1	25.3	7.78	1.42	35.49	4.00
S ₂	Nakhle Taghi	2	25.2	7.35	1.34	24.99	5.36
S ₃	Nakhle Taghi	3	25.5	7.64	1.41	24.99	5.63
S ₄	Nakhle Taghi	4	25.4	7.42	1.37	25.99	5.25
S ₅	Nakhle Taghi	5	25.4	7.68	1.32	22.99	5.73
S ₆	Kangan	1	24.7	7.25	1.41	21.99	6.40
S ₇	Kangan	2	24.8	7.95	1.36	20.99	6.48
S ₈	Kangan	3	25.1	7.32	1.43	24.49	5.83
S ₉	Kangan	4	24.8	7.62	1.39	21.99	6.33
S ₁₀	Kangan	5	25.1	7.34	1.43	20.49	7.00
S ₁₁	Lavare Saheli	1	24.4	7.63	1.36	22.99	5.91
S ₁₂	Lavare Saheli	2	24.8	7.57	0.35	25.99	1.34
S ₁₃	Lavare Saheli	3	25.1	7.23	0.51	24.99	2.03
S ₁₄	Lavare Saheli	4	24.3	7.13	0.49	21.99	2.24
S ₁₅	Lavare Saheli	5	24.7	7.62	1.42	20.99	6.75
S ₁₆	Nakhle Taghi	1	29.5	7.93	2.76	23.99	11.50
S ₁₇	Nakhle Taghi	2	29.4	8.10	1.68	22.49	7.48
S ₁₈	Nakhle Taghi	3	29.2	8.10	1.48	19.99	7.39
S ₁₉	Nakhle Taghi	4	29.3	8.10	1.29	23.49	5.48
S ₂₀	Nakhle Taghi	5	29.5	7.60	1.69	22.99	7.34
S ₂₁	Kangan	1	29.7	8.37	1.48	23.99	6.16
S ₂₂	Kangan	2	29.8	7.70	1.27	20.49	6.18
S ₂₃	Kangan	3	29.9	7.80	1.38	22.49	6.16

Table 1B. The values for samples 24–45 for the water temperature (Temp, °C), the pH, the fluoride ion (F, mg/L) and chloride ion (Cl, g/L) concentrations, and the F:Cl ratio (value $\times 10^{-5}$) in the seawater at various sampling points in the Nakhle Taghi, Kangan, and Lavare Saheli areas of the industrial region of Bushehr together with the means for each of the three locations for samples 1–45

Sample code	Location	Station	Temp (°C)	pH	F (mg/L)	Cl (g/L)	F:Cl (value $\times 10^{-5}$)
S ₂₄	Kangan	4	29.8	7.70	2.63	24.99	10.53
S ₂₅	Kangan	5	29.7	8.20	1.37	25.49	5.39
S ₂₆	Lavare Saheli	1	30.1	7.09	1.27	22.99	5.51
S ₂₇	Lavare Saheli	2	29.9	7.60	1.43	21.49	6.63
S ₂₈	Lavare Saheli	3	29.8	8.10	1.47	23.49	6.24
S ₂₉	Lavare Saheli	4	29.9	8.20	2.02	22.49	8.96
S ₃₀	Lavare Saheli	5	30.1	8.40	1.37	26.49	5.19
S ₃₁	Nakhle Taghi	1	33.8	8.23	1.97	23.99	8.23
S ₃₂	Nakhle Taghi	2	33.2	8.92	2.24	23.49	9.54
S ₃₃	Nakhle Taghi	3	33.7	8.97	2.70	24.49	11.03
S ₃₄	Nakhle Taghi	4	33.7	8.77	1.91	25.99	7.36
S ₃₅	Nakhle Taghi	5	33.7	8.69	2.79	25.49	10.94
S ₃₆	Kangan	1	33.0	8.73	2.07	24.99	8.27
S ₃₇	Kangan	2	33.4	8.31	2.35	20.99	11.21
S ₃₈	Kangan	3	33.9	8.22	1.83	19.99	9.16
S ₃₉	Kangan	4	33.4	8.88	2.50	24.99	9.99
S ₄₀	Kangan	5	33.6	8.01	1.67	22.49	7.41
S ₄₁	Lavare Saheli	1	33.4	8.72	2.37	25.99	9.13
S ₄₂	Lavare Saheli	2	33.5	8.74	2.28	25.99	8.78
S ₄₃	Lavare Saheli	3	33.7	8.82	1.31	20.99	6.23
S ₄₄	Lavare Saheli	4	33.5	8.02	1.84	21.49	8.54
S ₄₅	Lavare Saheli	5	33.7	8.26	2.08	24.99	8.31
Mean \pm SD	Nakhle Taghi		29.45 \pm 3.49	8.09 \pm 0.54	1.82 \pm 0.55	24.72 \pm 3.35	7.48 \pm 2.36
	Kangan		29.38 \pm 3.63	7.96 \pm 0.50	1.70 \pm 0.46	22.72 \pm 1.94	7.50 \pm 1.87
	Lavare Saheli		29.39 \pm 3.79	7.94 \pm 0.58	1.44 \pm 0.63	23.56 \pm 2.01	6.12 \pm 2.56

The ranges for the concentration levels of F and Cl were 0.35–2.79 mg/L and 19.99–35.49 g/L, respectively. The range for the F:Cl ratio was $1.34\text{--}11.50 \times 10^{-5}$.

Some previous reports on the F concentration and the F:Cl ratio in ballast water and in different seas around the world are summarized in Table 2.^{5, 22, 24-29}

Table 2. The values reported from previous studies and the present study for the fluoride ion (F, mg/L or mg/kg) concentration and the fluoride ion:chloride ion ratio (F:Cl, value $\times 10^{-5}$) in ballast water and in different seas around the world. (Ref = reference)

Sample source	F (mg/L or mg/kg)	F:Cl (value $\times 10^{-5}$)	Ref
Bushehr coastal area	2.64 mg/L	9.73	5
Ballast water in commercial ships entering Bushehr port	1.19– 2.82 mg/L	3.76–11.06	23
Tokyo Bay	0.63–1.27 mg/kg	6.71–8.76	25
West coast of India	1.33 mg/L	6.83	26
Juneau glacier area, Alaska	0.81–1.493 mg/L	0.99–8.66	27
Narragansett Bay	-	6.7–8.3	28
Mediterranean sea (Barcelona)	1.45 mg/L	-	29
Mediterranean sea (Oliva)	2.50 mg/L	-	30
The present study	0.35–2.79 mg/L	1.34–11.50	

Our finding of a high upper limit for F in the seawater adjacent to the industrial region of the Pars Special Energy Economic Zone along the northern part of the Persian Gulf in Bushehr province, Iran, of 2.79 mg/L is consistent with the values of 2.50 mg/L found in Mediterranean seawater at Oliva on the east coast of Spain²⁹ and of 2.82 mg/L found in the ballast water of ships from different parts of the world that entered Bushehr port.²²

In a study on sea water in Tokyo Bay, Japan, the range of the F concentration levels was 0.63–1.27 mg/kg and the range for the F to chlorinity ratio was $6.71\text{--}8.76 \times 10^{-5}$.²⁴ A study of sea water on the west coast of India found a mean F concentration level of 1.33 mg/L with a F to chlorinity ratio of 6.83×10^{-5} .²⁵ The sea water in the Juneau glacier area, Alaska, was found to have a F concentration range of 0.81–1.493 mg/L with a F to chlorinity ratio range of $0.99\text{--}8.66 \times 10^{-5}$.²⁶

The high concentration levels of total dissolved solids (TDS), F, and Cl in the region of the Persian Gulf compared to other seas and oceans is due to the low precipitation and high evaporation in the area.

CONCLUSION

Because there are high levels of F in the seawater in some locations of Bushehr province, we recommend that more studies be done on the F content of the marine products harvested from the various parts of the Persian Gulf to establish baseline data.

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- 134 Research report The fluoride and chloride ion levels in the seawater along the northern part
Fluoride 50(1 Pt 2):127-134 of the Persian Gulf in Bushehr province, Iran 134
January-March 2017 Izadi, Dobaradaran, Nabipour, Mahvi, Abedi, Keshtkar
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