FLUORIDE AND CHLORIDE LEVELS IN BALLAST WATER IN COMMERCIAL SHIPS ENTERING BUSHEHR PORT ON THE PERSIAN GULF

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ABSTRACT: The objective of the present study was to measure the concentration levels of the ions of fluoride (F) and chloride (Cl) and the F to Cl ratio in the ballast water of commercial ships entering Bushehr port on the Persian Gulf. Ballast water samples were collected from commercial ships entering Bushehr port, from 34 ports around the world, between 15 February and 25 August 2016. The ranges for the concentration levels for F and Cl were 1.19–2.82 mg/L and 18.99–33.1 g/L, respectively. The highest F concentration level, of 2.82 mg/L, was in a sample from Duqm port, Oman, and the lowest F concentration level, of 1.19 mg/L, in a sample from Jebel Ali port, United Arab Emirates. The range for the F to Cl ratio in the ballast water was 3.76×10^{-5}–11.06×10^{-5}.

Keywords: Ballast water; Bushehr port; Fluoride to chlorinity ratio; F:Cl ratio; Persian Gulf.

INTRODUCTION

Anthropogenic activities, industrial and urban wastewater, dredging and reclamation, power plants, sea traffic, and the port services related to the disposal of bilge and ballast water are the main sources of chemical contamination to the coastal and marine environments.[1] Ballast water is taken onboard ship to maintain ship stability while in transit. The transport of ballast water transport from port to port has been linked to the movement of microbial and chemical pollutants to new environments.[2-3] The fluoride ion (F) is broadly distributed in the environment and is therefore of particular importance everywhere. Many studies have been performed on (i) the F content in drinking water, fish, seawater, and air; (ii) the effects of F on health; and (iii) the removal of F from water in areas where the level is high.[4-25] However, to the best of our knowledge, there have been no reports on the F concentration levels in ballast water around the world. The objective of the present study was to measure the concentration levels of the ions of fluoride (F) and chloride (Cl) and the F to Cl ratio in the ballast water of commercial ships entering Bushehr port on the Persian Gulf.

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MATERIALS AND METHODS

The ballast water samples were collected from commercial ships entering Bushehr port on the Persian Gulf from 34 ports around the world between 15 February and 25 August 2016 (Figure).

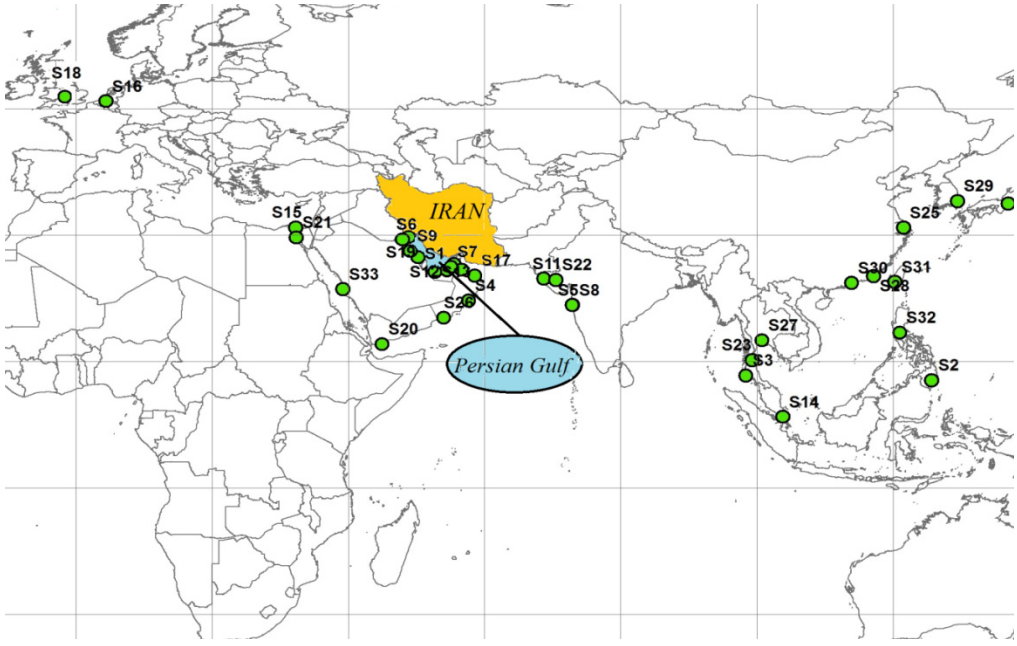

Figure. The geographical location of the ports of origin, where the ballast water was harvested of the ships that entered Bushehr port.

The Cl content was determined by standard methods[26] and the pH was determined by using a pH meter. While the chlorinity is not equivalent to the Cl concentration levels, the factor for converting a chloride concentration level in seawater to include bromide, for instance, is only 1.0045. Therefore, for practical purposes, as well as here, the Cl content (in g/kg of solution) is considered almost equivalent to the chlorinity in both seawater and ballast water samples.

RESULTS AND DISCUSSION

The results for the ballast water samples of the water temperatures, pH, the F and Cl concentration levels, and the F:Cl ratios, in the commercial ships entering the Bushehr port are shown in the Table 1.

The content level of F in the ballast water in commercial ships ranged from 1.19 to 2.82 mg/L, and the Cl content ranged from 18.99 to 33.1 g/L. The F to Cl ratio in different ballast waters ranged from 3.76×10^{-5} to 11.06×10^{-5} (Table 1). No correlation was present between the F and Cl concentrations in the samples.

Table 1. The values for the 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 ballast water of commercial ships entering Bushehr port from 34 ports around the world

Sample code	The ports of origin where the ballast water was harvested	Temp (°C)	pH	F (mg/L)	Cl (g/L)	F:Cl (value $\times 10^{-5}$)
S_1	Dammam, Saudi Arabia	24.8	8.44	2.16	21.49	10.05
S_2	Davao, Philippines	24.3	7.99	1.65	21.99	7.5
S_3	Phuket, Thailand	25.8	7.67	1.93	23.49	8.21
S_4	Duqm, Oman	25.2	7.49	2.82	25.5	11.06
S_5	Jawaharlal Nehru port, India	26/8	7.67	1.94	18.99	10.22
S_6	Kuwait, Kuwait	27.3	7.8	1.83	26.99	6.78
S_7	Jebel Ali, United Arab Emirates	25.2	7.52	1.19	26.99	4.41
S_8	Mumbai, India	26.2	7.38	1.8	29.99	6
S_9	Shuhaikh– Kuwait	27.4	7.74	1.22	32.48	3.76
S_{10}	Hamriyah, United Arab Emirates	25.9	7.87	1.95	22.49	8.67
S_{11}	Kandla port – India	26.3	7.65	1.4	22.99	6.08
S_{12}	Ajman port, United Arab Emirates	25.1	7.68	1.82	27.99	6.5
S_{13}	Mina Rashid, United Arab Emirates	25.9	7.89	1.86	25.48	7.3
S_{14}	Singapore, Singapore	26.8	7.95	2.23	22.98	9.7
S_{15}	Port Said, Egypt	27.2	7.6	2.15	27.56	7.8
S_{16}	Antwerp, Belgium	25.3	7.92	1.59	33.1	4.8
S_{17}	Muscat, Oman	27.2	7.55	2.05	24.6	8.33
S_{18}	Portsmouth, UK	26.9	7.72	1.95	24.9	7.83
S_{19}	Basra, Iraq	28.1	7.85	1.95	23.99	8.13
S_{20}	Aden, Yemen	25.9	7.43	1.8	24.7	7.29
S_{21}	Suez, Egypt	26.7	7.61	1.6	31.4	5.09
S_{22}	Navlakhi, India	27.2	7.92	1.92	27.1	7.08
S_{23}	Bangkonk, Thailand	28.2	8.1	1.65	21.99	7.5
S_{24}	Sohar, Oman	26.9	7.65	1.27	26.49	4.79
S_{25}	Shanghai, PR of China	26.7	7.8	1.6	21.99	7.27
S_{26}	Salalah, Oman	25.1	8.1	1.94	24.99	7.76
S_{27}	Laemchabang, Thailand	26.2	7.65	1.34	20.45	6.55
S_{28}	Hong Kong, PR of China	26.9	7.84	2.05	21.42	9.57
S_{29}	Busan, Korea	27.1	7.6	1.75	22.99	7.61
S_{30}	Shenzhen, PR of China	26.5	7.85	1.8	20.49	8.78
S_{31}	Kaohsiung, Taiwan	26.9	7.6	1.94	22.3	8.7
S_{32}	Manila, Philippines	27.3	7.85	1.8	21.1	8.5
S_{33}	Jeddah, Saudi Arabia	26.8	7.3	1.67	24.3	6.87
S_{34}	Nagoya, Japan	25.1	7.67	1.74	20.9	8.32

Table 2 summarizes some previous reports on the F concentration and the F:Cl ratio in different seas around the world.[8, 27-32]

Table 2. The values reported from previous studies 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 different seas around the world. (Ref = reference)

Sample site	F (mg/L or mg/kg)	F:Cl (value$\times 10^{-5}$)	Ref
Bushehr coastal area	2.64 mg/L	9.73	8
West coast of India	1.33 mg/L	6.83	28
Atlantic Ocean	1.45 mg/L	-	29
Tokyo Bay	0.63–1.27 mg/kg	6.71–8.76	30
Narragansett Bay	-	6.7–8.3	31
Juneau glacier area, Alaska	0.81–1.493 mg/L	0.99–8.66	32
Mediterranean sea (Barcelona)	1.45 mg/L	-	33
Mediterranean sea (Oliva)	2.50 mg/L	-	33

The findings of high sea water F levels in Persian Gulf seawater (in the Bushehr coastal area, 2.64 mg/L)[8] and in Mediterranean seawater (Oliva on the east coast of Spain, 2.50 mg/L)[32] are consistent with our finding of the upper limit for F in the ballast water in commercial ships of 2.82 mg/L (Table 2).

A mean F concentration level of 1.33 mg/L was found in sea water on the west coast of India[27] with a F to chlorinity ratio of 6.83×10^{-5}. The range of the sea water F concentration levels in the Juneau glacier area, Alaska,[28] was 0.81–1.493 mg/L with a F to chlorinity ratio range of $0.99–8.66\times10^{-5}$. In a study on sea water in Tokyo Bay, the range of the F concentration levels was 0.63–1.27 mg/kg and the range for the F to chlorinity ratio was $6.71–8.76\times10^{-5}$.[29] The effects of industrial activities on the F to chlorinity ratio in the Tokyo Bay sea water were considered to be insignificant due to the large exchange volume and the high exchange rate in these waters.[29]

In a recent study,[8] we reported on the Bushehr coastal seawater of the Persian Gulf and found a mean F concentration level of 2.64 mg/L, range 2.28–2.92 mg/L, and a mean F:Cl ratio of 9.73×10^{-5}, range $7.22–12.77\times10^{-5}$. We also examined two commercially important species of fish, Indo-Pacific king mackerel (*Scomberomorus guttatus*) and tiger tooth croaker fish (*Otolithes ruber*), that are harvested commercially off the Bushehr shores along the Persian Gulf, where the mean sea water F concentration was 1.97 mg/L, and reported that the ranges for the F levels of the muscle and skin tissues of these two species were 5.56–6.09 and 5.78–6.14 mg/kg wet weight, respectively.[14]

CONCLUSION

Due to the high content of F in the examined ballast waters from different ports around the world (1.19–2.82 mg/L) and the relatively high consumption of sea food in seaports worldwide, like Bushehr port, more studies on the F level of sea foods harvested from different parts of the seas around the world are highly suggested.

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