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Barium Bioaccumulation in Clams Collected from Different Salinity Regimes Along the Saudi Coast of the Arabian Gulf

M. Sadiq,* T. H. Zaidi, and H. Al-Mohana

Water Resources and Environment Division, Research Institute, King Fahd University of Petroleum and Minerals, Dhahran 31261, Saudi Arabia

There are several operational and undeveloped oil fields in the Saudi coastal areas of the northern Arabian Gulf. One potential source of pollution from the development of oil fields is the mud used during drilling of oil wells. There are many types of mud with different constituents (Tagatz et al. 1978). Bayrite (barium hydroxide) is a common drilling mud component. Because of several oil fields and a large number of oil wells, Saudi coastal areas of the Arabian Gulf might have been contaminated with barium.

Many investigators have reported toxicity of drilling muds (Dames and Moore 1978; Rice et al. 1981; Carls and Rice, 1984). However, reports on bioaccumulation of barium are scarce (Merefield, 1987). The objective of this study was to investigate barium bioaccumulation by clams as function of sediment concentrations and seawater salinity.

MATERIALS AND METHODS

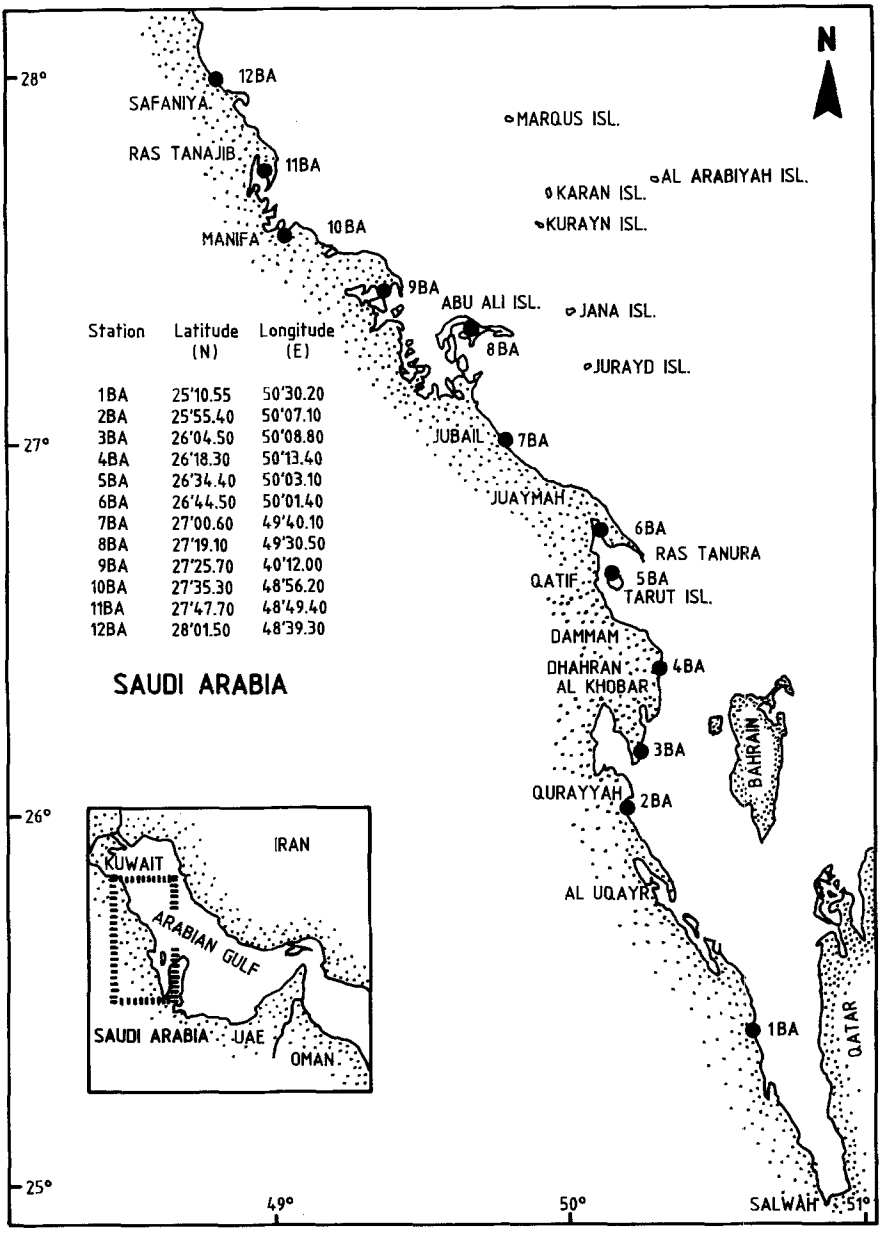
Clams, *Maritrix maritrix*, were collected from 12 locations on the Saudi coast of the Arabian Gulf. A brief description of the sampling sites is given in Table 1 and their geographical locations are shown on Figure 1.

Fifteen to twenty clams were collected quarterly from each station between March 1985 and April 1986. However, stations 1BA, 6BA, and 10BA were sampled bimonthly for one year to investigate spatial variations in Ba concentrations in clams. After collecting from the field, clams were immediately stored on ice in plastic containers and transported to

* Send reprint requests to the above address.

Table 1 Description of sampling stations

Station	Description
1BA	Minimal human activity within about 5 kilometers; mean seawater salinity 60 mg/kg.
2BA	In the vicinity of an old harbor, next to a community beach; clams found on rocky seabed; mean seawater salinity 57 mg/kg.
3BA	Actively used community beach area; mean seawater salinity 50 mg/kg.
4BA	AlKhobar city beach area; lots of broken metal and garbage; recent dredging activities in its vicinity; mean seawater salinity 47 mg/kg.
5BA	Tarut Bay area which receives agricultural drainage from Al-Qateef Oasis and municipal sewage; mean seawater salinity 47 mg/kg.
6BA	Tarut Bay area near Rahima city sewage outfall; clams were on a rocky bed with few cm of sediments; mean seawater salinity 51 mg/kg.
7BA	Clam site next to Jubail commercial port but not directly affected by port activities; station is landfilled now; mean seawater salinity 42 mg/kg.
8BA	Abu Ali Island area next to a barge and road side; probably contaminated by drilling muds from Beri Oil Field; mean seawater salinity 44 mg/kg.
9BA	A semi-closed lagoon in a remote area with mean seawater salinity of 46 mg/kg; no obvious contamination point source.
10BA	In Manifa Bay area, might have been affected by drilling activities in the past, mean seawater salinity 45 mg/kg.
11BA	A hypersaline lagoon; might have been affected by drilling activities in the past; mean seawater salinity 48 mg/kg.
12BA	An adequately flushed bay; might have been affected by drilling activities in the past; mean seawater salinity 46 mg/kg.



Station	Latitude (N)	Longitude (E)
1BA	25°10.55	50°30.20
2BA	25°55.40	50°07.10
3BA	26°04.50	50°08.80
4BA	26°18.30	50°13.40
5BA	26°34.40	50°03.10
6BA	26°44.50	50°01.40
7BA	27°00.60	49°40.10
8BA	27°19.10	49°30.50
9BA	27°25.70	40°12.00
10BA	27°35.30	48°56.20
11BA	27°47.70	48°49.40
12BA	28°01.50	48°39.30

Figure 1 : Sampling Stations

the laboratory. Seawater salinity was measured during each sampling. Triplicate samples of sediments from each station were collected during quarterly sampling.

Biometric observations (total weight, shell length, and width) of each clam were recorded. After thawing, the clams were placed on their side to drain free water. Each clam was opened and the soft tissue was carefully removed, weighed and transferred to a 75 ml digestion tube. Ten ml of concentrated HNO_3 and 2 ml of $HClO_4$ were added to each tube. The tubes were left overnight and than digested in a block digester for 3 hours at 120^{o} C. On cooling, the contents of the tubes were filtered and volume was made to 25 ml using distilled water. All the chemicals used in this study were of high purity.

The surface sediment samples collected during each quarterly sampling from each station were air dried and passed through a 2 mm sieve. Two g of each sediment sample was placed in a digestion tube of 75 ml and 10 ml concentrated HNO_3 was added. The content of each tube was digested in a block digester for 3 hours at 120^{o} C. The digestates were filtered and volume was made to 50 ml with distilled water.

Concentrations of Ba in aliquots of clams and sediments were determined using a simultaneous inductively coupled argon plasma analyzer (ICAP). Internal standards, spiked samples and analyses of standard reference material of oyster tissues from the United States Bureau of Standards were regularly analyzed as a quality control measure. The analytical data were statistically evaluated using SAS (Statistical Analysis System) package.

RESULTS AND DISCUSSION

Concentrations of Ba in clam and sediment samples collected from the Saudi coastal areas of the Arabian gulf are summarized in Table 2. The maximum concentrations of Ba were found in the sediments from Station 8, followed by Station 12. Both of these stations were probably affected by the drilling muds during the development of Beri and Manifa oil fields, respectively. Similarly, drilling muds might have contributed to the relatively higher Ba concentrations in the sediments from Station 10. Reasons for elevated concentrations of Ba in the sediments from Stations 2 and 6 cannot be speculated. The spatial variation in Ba concentrations were found to be significant ($P < 0.01$).

Table 2 Summary of Ba concentrations (mg/kg) in clams and sediments

Station	Sample #	Ba (wet wt) Mean	Std	Range	Sediment* (dry wt)
1BA	131	1.19d	0.73	0.19 - 4.29	5.4
2BA	26	0.79c	0.55	0.15 - 2.12	14.4
3BA	45	0.46b	0.19	0.04 - 0.82	---
4BA	29	0.16a	0.09	0.03 - 0.36	8.0
5BA	40	0.62c	0.31	0.15 - 1.64	14.2
6BA	152	0.41b	0.24	0.02 - 1.52	10.4
7BA	36	0.37b	0.20	0.14 - 1.03	10.7
8BA	34	0.69c	0.69	0.11 - 2.94	22.5
9BA	42	0.35b	0.39	0.07 - 2.23	6.5
10BA	107	0.28ab	0.22	0.04 - 1.55	12.9
11BA	74	0.40b	0.25	0.05 - 1.37	7.2
12BA	37	3.98e	2.55	0.68 - 9.39	17.8

---- no data collected * One-time sampling only
Std Standard deviation
a,b,c,d,e Statistically different at $P < 0.01$

The maximum and significantly ($P < 0.001$) higher concentrations of Ba were found in clams from Station 12. Statistical analysis showed significant differences in Ba concentrations in clams from the same station and even for the same sampling period. One possible explanation for intra-station significant variations could be the dependency of Ba concentrations on clam size. This was checked by developing a correlation matrix between clam body size and Ba concentrations.

Correlation analysis between Ba concentrations in the clams and their body weight (fresh weight) revealed no significant ($P < 0.01$) associations when all the data were considered. Significant correlations between the clam body size and Ba concentrations were found at Station 2 ($r^2 = 0.53$, $P < 0.0046$), Station 10 ($r^2 = 0.31$, $P < 0.0006$) and adverse correlation at Station 6 ($r^2 = -0.29$, $P < 0.0003$). The weight of clams was not related to Ba concentrations at other stations.

The influence of sediment concentrations on Ba in the clams was investigated taking the mean Ba concentration data in clams for each station. No significant correlation between Ba concentrations in the sediments and mean clam concentrations was found when all the data were considered in statistical analysis. Removing Ba data for Station 1 and 12 resulted in a significant linear correlation ($P < 0.01$).

Temporal variations in Ba concentrations in clams were investigated by analyzing data for Stations 1, 6 and 9

collected at monthly intervals. No general temporal trend could be seen in the data. Variation in Ba concentrations in clams from the same sampling station and period were more pronounced than temporal effects. This fact of Ba concentrations makes it difficult to generalize trends observed in Ba distribution in clams.

Salinity measurements were made at each quarterly sampling, a mean salinity value for each sampling station was computed and these values are given in Table 1. The mean Ba concentrations in clams from each station were compared the mean seawater salinity using the t-test technique. It was found that salinity has no affect on Ba bioaccumulation by clams. However, a relatively high concentration of Ba was found in clams from stations with the highest salinity. This could be explained on the basis of Ba seawater chemistry. Sadiq (1988) reported an adverse effect on Ba concentrations with an increase in seawater alkalinity and sulfate concentrations. At Station 1, the most of sulfate and carbonate could have precipitated as calcium leaving behind chloride when excess evaporation resulted in the enhancement of seawater salinity. The high chloride ions complexed more of Ba and kept it soluble (Sadiq, 1988), and probably improved its availability to clams.

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