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Metal Concentrations in Pearl Oyster, *Pinctada radiata*, Collected from Saudi Arabian Coast of the Arabian Gulf

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The Arabian Gulf is a shallow semi-closed water body. Several industrial complexes have been established along its coast line during the past decade. The effluent from these facilities is being discharged into the Gulf. These discharges pose potential hazards to the marine environment of the Arabian Gulf. The Saudi Arabian government is striving to protect the marine environment of the Gulf and has commissioned several studies to assess the damage from the industrial and municipal discharges (KFUPM-RI 1987; 1983; 1982a; 1982b; Sadiq and Zaidi 1985; Sadiq et al. 1982). In these studies, marine organisms, for example, fish, clams, sea urchins, oysters, and plankton, along with sediments and seawater, have been analyzed for various pollutants. This study reports metal concentrations in pearl oysters collected from the Saudi Arabian coastal areas of the Arabian Gulf.

MATERIALS AND METHODS

Pearl oyster and sediment samples were collected from four locations along the Saudi Arabian coast of the Arabian Gulf. The locations are shown in Figure 1. Location 1 (Station 4) was remote with no appreciable human activities. Location 2 (Station 3) was a public beach serving Al-Khobar city. Location 3 (Station 1) was in Tarut Bay which receives municipal and industrial effluent. Location 4 (Station 1) was in Manifa Bay of the Manifa oil fields and have been exposed to drilling activities in the past.

Pearl oysters, Pinctada radiata, were collected from each location in October 1985. The collected oysters were placed on ice and transported to the laboratory.

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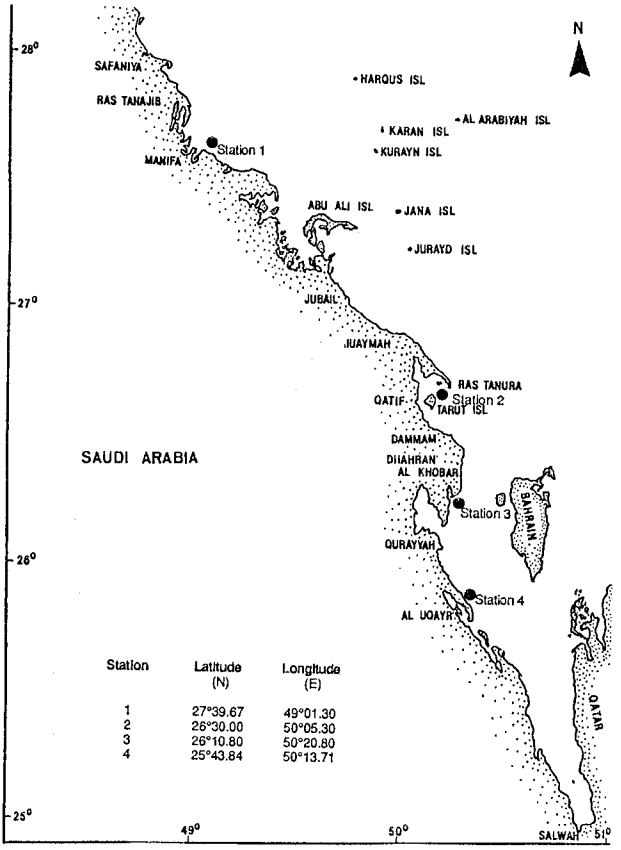

Figure 1. Sampling locations

In the laboratory, the oysters were shucked and placed on their edges to drain extra fluid. All the soft tissue from each oyster was carefully removed and weighed into 100 milliliter (mL) digestion tubes. Ten mL of concentrated ultrex nitric and 1.5 mL of ultrex perchloric acids (J.T. Baker, USA) were added to each tube and were left overnight. The tubes were heated in a block digester at 100 ^{o}C for 3 h or until the solution cleared. The aliquot was filtered and the volume was increased to 50 mL with double distilled water. The concentrations of Al, Ba, Ca, Cd, Cu, Fe, K, Mg, Mn, Ni, P, Sr, Ti, V, and Zn were determined in the aliquots using an inductively coupled argon plasma analyzer (ICAP).

Surface sediment samples (upper 2 cm layer) were scooped into plastic bottles from each location by pushing them horizontally. Depth of the water column at

all locations was < 1 m. The sediments were air dried and sieved through 20 mesh sieve. Two grams (g) of each sediment sample were taken in triplicate in 100 mL digestion tubes containing 10 mL of concentrated ultrex nitric acid. The sediment-acid mixture was heated at 120 ^{o}C for 2 h. The aliquots were filtered and the volume was increased to 50 mL with double distilled water. The concentrations of Ba, Cd, Cu, Fe, Mn, Ni, P, V, and Zn were determined in the aliquots using an ICAP (Sadiq and Zaidi 1985).

As a quality control measure, standard reference materials (SRM) of estuarine sediment (SRM 1646), river sediment (SRM 1645) and oyster tissue (SRM 1566) from the United States National Bureau of Standards were included in this study. About 10% of the samples were spiked to evaluate recoveries. As a check to outlier values, all the samples were prepared in triplicate and each aliquot was analyzed 4 times.

RESULTS AND DISCUSSION

Metal concentrations in the sediment samples are listed in Table 1. The authors were surprised that the maximum concentrations of Ba, Cr, Fe, Ni, and Ti were found in the sediments from Station 1 which was considered relatively clean. The sediment samples from Station 4 contained the highest concentrations of Mn and V. The concentrations of Cu, P, Pb, and Zn were higher in the sediments from Station 3. It was thought that effluent discharges might be responsible for the elevated levels of Cu, P, Pb and Zn in the sediments from Station 3.

Oyster soft tissue weight varied between 0.32 and 14.61 g with 4.05 g as mean weight per individual. Aluminum concentrations in the oyster tissue ranged between 5.92 and 101.68 ug/g tissue. Barium in all the tissue samples was less then 0.7 ug/g tissue. The mean Ba concentration for oyster tissue from Station 2 was twice as high as that of oysters from Station 1 even though the sediments from Station 1 contained the highest Ba concentrations. The reason for this was not known. From the data of this study, it might be concluded that Ba in the sediments did not affect its uptake by pearl oysters. The calculated mean bioaccumulation factor for Ba was less than 0.1.

Cadmium concentrations in the soft oyster tissue varied between 0.03 and 6.19 ug/g tissue. The concentrations of Cd in the sediments from all locations were below 0.1 ug/g sediment. The bioaccumulation factor for Cd varied between 2 and 186 suggesting that Cd was concentrating in the oyster tissue. Pearl oysters

accumulated Cd more efficiently than clams from the same stations (KFUPM-RI 1987).

Table 1. Metal concentrations in the sediment samples

Metal Type	Mean Concentration (ug/g wet weight)* Station 1	Station 2	Station 3	Station 4
Tissue weight	2.20	0.93	4.93	6.45
Barium	11.32	7.03	3.07	4.33
Cadmium	0.08	0.03	0.03	0.03
Chromium	6.15	3.82	2.64	5.06
Copper	1.19	0.89	2.58	0.32
Iron	2344.	1297.	1061.	2040.
Manganese	24.58	44.95	19.02	46.68
Nickel	12.79	6.40	5.30	11.51
Phosphorus	102.6	56.3	106.5	79.5
Lead	0.41	0.38	1.28	0.82
Titanium	129.5	30.1	22.5	40.9
Vanadium	5.29	7.00	4.96	8.50
Zinc	2.21	3.26	4.89	2.54

* Mean of six determinations

The mean Cu concentration in the oyster tissue was 1.0 ug/g tissue. Maximum concentrations of Cu were found in the oysters from Station 3. The sediments from this location also contained the highest Cu content. The mean bioaccumulation factor of Cu in the oysters from Station 3 was less than 0.5 as compared with greater than 2 for Station 2 and Station 4. Variations in Cu concentrations in the sediment are probably exhibited in its bioaccumulation in the oyster tissue.

Concentrations of Ca in the oyster tissue ranged between 537 and 3730 ug/g tissue. The highest concentrations of Fe were found in oysters from Station 4 followed (in descending order) by oysters from Station 2, Station 3, and Station 1, respectively. The concentrations of K in the oyster tissue varied between 752 and 3301 ug/g tissue. The inter- and intra-station variations in the concentrations of Ca, Fe, K, and Mg in the oyster tissue were significant ($P < 0.01$).

Manganese concentrations in the oyster soft tissue were between 0.47 and 4.92 ug/g tissue. The sediments from Station 2 and Station 4 contained similar Mn concentrations and were two times higher than those found in the sediments from Station 1 and Station 3. The mean Mn bioaccumulation factor was below 0.1, and it seems that sediment Mn levels have no effect on its bioaccumulation. Nickel concentrations in the oyster soft tissue varied between 0.03 and 0.88 ug/g tissue.

Table 2. Metal concentrations in oyster samples

Station	Sample	Weight (g)*	Metal Concentration(ug/g wet weight) Al	Ba	Cd	Cu	Ca	Fe	K
1	1	3.54	8.3	0.11	1.41	0.90	805	21.2	1893
1	2	2.00	12.3	0.16	1.38	0.89	890	23.8	1880
1	3	2.74	11.9	0.18	2.53	0.89	912	29.7	1423
1	4	2.52	15.5	0.12	1.29	0.97	785	27.6	2087
1	5	2.28	7.6	0.09	1.43	0.80	769	21.5	1912
1	6	2.97	12.5	0.13	1.66	0.77	699	26.1	1385
1	7	2.07	28.2	0.20	1.96	0.80	1554	39.4	1699
1	8	2.25	10.8	0.17	0.98	0.92	965	21.8	1985
1	9	2.03	11.7	0.14	1.08	0.70	1615	22.4	1568
1	10	1.95	12.8	0.15	1.34	0.81	870	23.9	1803
1	11	2.62	13.3	0.12	0.94	0.72	732	23.0	1299
1	12	3.04	5.9	0.09	1.09	0.71	715	18.3	1875
1	13	2.89	10.5	0.13	1.03	0.74	960	23.9	1574
1	14	1.24	22.8	0.19	0.71	0.74	1359	31.7	1841
1	15	1.69	12.4	0.13	0.79	0.77	662	20.8	1422
1	16	0.61	22.4	0.28	0.76	0.91	1460	29.4	1697
1	17	0.92	18.4	0.25	0.85	1.04	861	27.7	2268
2	18	2.77	38.4	0.36	0.38	1.48	1318	41.9	2076
2	19	0.63	41.0	0.40	0.38	1.51	1275	47.6	1952
2	20	0.97	38.9	0.41	0.41	1.65	1186	46.9	2706
2	21	0.32	52.3	0.55	0.27	1.91	1680	57.4	1836
2	22	0.46	46.2	0.46	0.09	2.11	1757	59.2	2297
2	23	0.45	24.7	0.28	0.65	1.88	927	33.7	1742
3	24	4.14	20.2	0.28	0.61	1.23	1437	38.2	2452
3	25	5.55	11.4	0.27	0.45	8.83	1135	28.7	2171
3	26	4.07	14.7	0.26	0.53	0.63	1204	33.3	2162
3	27	2.73	38.3	0.70	0.81	1.68	2857	65.4	3004
3	28	6.69	10.8	0.16	0.57	0.70	1016	21.7	1824
3	29	5.58	21.4	0.29	0.44	0.71	1586	28.4	1900
3	30	5.55	21.6	0.32	1.11	0.45	3730	35.0	829
3	31	8.07	37.8	0.38	0.53	0.65	2429	39.0	1221
3	32	2.97	14.3	0.25	0.52	0.72	1212	25.9	943
3	33	7.31	16.3	0.31	0.48	0.56	1566	30.3	752
3	34	5.39	19.2	0.30	0.52	0.83	1614	31.3	1048
3	35	4.96	14.0	0.27	0.36	0.88	1210	25.2	1008
3	36	3.80	8.3	0.21	0.46	0.96	987	19.3	1092
3	37	2.82	16.0	0.35	0.32	1.54	851	21.1	1720
3	38	4.38	8.3	0.23	0.32	1.39	537	13.8	1872
3	39	4.81	8.2	0.14	0.44	0.34	842	23.4	1809
3	40	4.01	26.6	0.30	0.47	0.42	1895	32.7	1970
3	41	4.19	16.8	0.29	0.45	0.43	1277	30.4	1957
3	42	4.68	31.0	0.41	0.48	0.57	2158	33.9	1976
3	43	3.59	16.3	0.18	0.53	0.38	1226	32.2	3301
3	44	4.58	21.4	0.34	0.39	0.70	1463	31.0	2230
3	45	7.91	9.4	0.13	0.69	0.86	948	20.2	1188
3	46	3.91	15.6	0.18	0.35	3.21	959	26.1	1854

Table 2. contd.

Station	Sample	Weight (g)	Al	Ba	Cd	Cu	Ca	Fe	K
3	47	5.09	17.7	0.21	0.24	2.32	1149	21.3	1473
3	48	6.59	13.4	0.27	0.49	2.55	857	20.2	1267
4	49	12.56	26.0	0.18	3.26	0.97	717	39.4	1413
4	50	7.41	70.2	0.40	3.08	0.56	1370	59.9	1680
4	51	14.61	25.9	0.16	5.03	0.41	808	34.2	1280
4	52	11.68	25.1	0.15	5.57	0.39	741	33.4	1211
4	53	3.57	99.8	0.45	2.38	1.33	1779	86.8	1485
4	54	3.72	84.8	0.44	1.10	0.87	1478	67.2	1801
4	55	2.55	41.6	0.31	1.10	0.92	1059	45.9	1510
4	56	2.42	96.5	0.64	1.18	1.01	1696	83.5	1529
4	57	5.95	94.8	0.48	1.63	0.86	1765	83.2	1891
4	58	4.75	94.7	0.51	1.47	0.95	1705	75.0	1895
4	59	1.74	82.8	0.57	1.06	0.93	1624	71.4	1509

		Mg	Mn	Ni	P	Sr	Ti	V	Zn
1	1	1497	1.88	0.14	1257	10.2	0.31	0.07	367
1	2	1604	2.21	0.13	1241	10.9	0.78	0.19	288
1	3	1843	1.51	0.09	1050	13.3	0.36	0.16	310
1	4	1292	3.42	0.20	1571	10.1	0.39	0.15	447
1	5	1374	1.27	0.15	1396	9.8	0.30	0.14	352
1	6	1338	2.19	0.29	1187	9.4	0.36	0.24	446
1	7	1398	2.17	0.27	1361	20.7	0.76	0.23	542
1	8	1486	2.36	0.19	1220	10.4	0.30	0.17	277
1	9	1434	0.97	0.21	1231	14.8	0.38	0.19	303
1	10	1496	1.27	0.27	1445	11.8	0.40	0.18	307
1	11	1318	1.64	0.18	1287	10.1	0.41	0.20	331
1	12	1439	1.69	0.13	1242	9.5	0.14	0.15	337
1	13	1514	2.31	0.13	1125	12.0	0.31	0.15	285
1	14	1383	1.88	0.15	1455	13.4	0.53	0.23	145
1	15	1272	2.14	0.16	1228	8.9	0.38	0.18	156
1	16	1493	2.54	0.20	1591	15.0	0.74	0.26	114
1	17	1311	2.19	0.25	1844	10.3	0.56	0.22	137
2	18	1643	0.27	0.27	1841	16.2	0.87	0.31	90
2	19	1434	3.82	0.16	1594	15.5	1.08	0.26	134
2	20	1289	2.99	0.23	2139	13.6	1.06	0.34	119
2	21	2031	4.92	0.23	2070	19.9	1.43	0.23	206
2	22	1514	2.14	0.19	2162	19.0	1.27	0.16	486
2	23	1292	1.54	0.03	1629	12.3	0.56	0.00	252
3	24	1111	2.17	0.27	1365	26.9	3.02	0.24	459
3	25	1144	0.99	0.20	1351	19.0	0.32	0.14	472
3	26	983	1.07	0.28	1646	20.6	0.17	0.26	442
3	27	1073	2.38	0.37	1813	53.3	0.70	0.48	648
3	28	1256	1.08	0.19	1084	18.5	0.48	0.16	508
3	29	1281	1.59	0.27	1147	29.6	0.47	0.17	358
3	30	1640	0.67	0.29	694	61.0	0.51	0.25	1189

Table 2. contd.

Station	Sample	Mg	Mn	Ni	P	Sr	Ti	V	Zn
3	31	1462	0.99	0.27	1171	44.1	0.46	0.31	564
3	32	1582	2.26	0.25	1027	22.6	0.44	0.25	473
3	33	1375	1.05	0.26	855	23.0	0.24	0.16	663
3	34	1020	0.82	0.21	1271	26.9	0.42	0.19	612
3	35	948	0.95	0.19	1099	19.5	0.22	0.16	343
3	36	895	1.37	0.18	1013	12.8	0.12	0.22	395
3	37	691	1.08	0.22	1064	14.9	0.17	0.25	408
3	38	696	0.53	0.19	833	8.6	0.09	0.14	228
3	39	1331	1.09	0.10	1393	15.0	0.20	0.09	405
3	40	1471	1.96	0.31	1409	36.5	0.66	0.20	574
3	41	1337	1.00	0.16	1360	24.0	0.45	0.26	418
3	42	1432	2.18	0.27	1111	43.9	0.53	0.24	545
3	43	1588	1.49	0.24	1114	25.3	0.38	0.24	571
3	44	1365	2.14	0.17	993	29.6	0.51	0.23	480
3	45	1049	0.47	0.27	708	15.7	0.17	0.09	891
3	46	876	1.83	0.23	937	16.8	0.31	0.15	384
3	47	766	0.82	0.24	855	19.2	0.22	0.10	255
3	48	744	1.81	0.24	986	10.2	0.10	0.13	516
4	49	1075	0.98	0.25	900	12.6	0.64	0.40	393
4	50	1296	1.55	0.38	965	25.6	1.34	0.52	155
4	51	1085	0.84	0.24	760	14.4	0.54	0.37	205
4	52	1263	0.66	0.26	642	13.5	0.58	0.37	338
4	53	1583	1.83	0.00	1143	30.8	1 74	0.22	101
4	54	1223	2.11	0.40	1142	26.2	1.63	0.74	56
4	55	1588	1.55	0.31	1476	17.6	1.00	0.78	67
4	56	1715	2.13	0.56	1157	29.6	1.92	1.20	77
4	57	1361	3.22	0.52	1176	32.1	2.08	0.84	118
4	58	1316	2.71	0.41	1137	30.3	1.77	0.77	85
4	59	1552	2.26	0.39	1092	28.9	1.47	0.73	61

* oyster soft tissue weight (wet)

Phosphorus concentrations varied between 642 and 2162 ug/g tissue as compared with 56.3 to 106.5 ug/g in the sediment samples. The oysters from Station 2 contained maximum P content even though the sediments from that location had the lowest concentrations of P. Bioaccumulation factor calculations indicated that, in the oyster soft tissue, P was concentrating between 6 and 39 times more than its concentrations in the sediments. Statistically similar ($P < 0.1$) mean concentrations of Sr were found in the oyster from Station 2, Station 3, and Station 4 and decreased to less than half in oyster tissue from Station 1. Titanium concentrations ranged between 0.09 and 3.0 ug/g tissue. The maximum V concentrations were found in the soft tissue of oysters from Station 4 and seems to be influenced by V content of the sediments.

Zinc concentrations in oysters ranged between 55 and 1189 ug/g tissue. Zinc concentrated many times more in the pearl oyster tissue (21 to 245 times) when compared with the sediment concentrations. The concentrations of Cr and Pb in the soft tissue of pearl oysters were below the detection limits of ICAP. It may be concluded from the results of this study that pearl oysters were selectively accumulating Cd, P, and Zn in their soft tissue.

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