Baseline investigation of Saudi seashore water concentrations along the Gulf of Aqaba

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Abstract

This investigation aims to measure the elemental concentrations of sea water samples from the Gulf of Aqaba along the Saudi seashore. Seventy elements were investigated using the Inductively Coupled Plasma Mass Spectrometry (ICP-MS) technique. Sixty samples were collected starting from Ad Dorah city at the national border between Saudi Arabia and Jordan to Ra's Al-Sheikh Humayed at the south of Aqaba Gulf. Elemental concentrations of major, trace, toxic, and radioactive sources in this area are measured. The results represent a database for many vital areas of interest.
Keywords: ICP-MS, elemental analysis, sea water, Gulf of Aqaba, trace elements, concentrations.

1 Introduction

Although the Gulf of Aqaba region has remained relatively free of pollution [1], the environment is currently under increasing threat from a wide range of human activities. Also, marine-based activities such as shipping and oil exploitation are becoming a significant source of marine pollution in this Gulf. Except for this region, many national and international investigations have been carried out to the Red Sea water [1–8].

This work is part of a research project funded by Tabuk University to investigate this region. This work is dedicated to map the concentrations of Red Sea water along the Gulf of Aqaba of the Saudi Arabia seashore.

Inductively Coupled Plasma Mass Spectrometry (ICP-MS) will be used to measure the elemental concentration in this study. The technique was

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commercially introduced in 1983 and has gained general acceptance because of its superior detection capabilities [9].

2 History and development of ICP-MS

The major components of a modern Inductively Coupled Plasma Mass Spectrometry (ICP-MS) can be traced directly back to the work done during the 1960s and 1970s [10–13]. Dr Alan Gray of Applied Research Laboratories in Luton, UK, conducted much of the early research work that led to the commercial development of ICP-MS instrumentation [9]. Another important publication by Houk *et al.* in 1980 demonstrated the possibilities offered by the ICP-MS technique [14].

Although the early ICP-MS systems were expensive, large, complex, had limited automation and tended to suffer from significant signal drift, the obvious benefits of such multi-elements technique with low limits of detection and a simple mass spectrometric data output (including isotope ratio information) led to acceptance of the fledgling technique, particularly among those involved in research and geological applications. Due to many improvements, ICP-MS has become a widely used tool [15–19]. It is a flexible technique that offers many advantages over more traditional techniques for elemental analysis.

3 Red Sea and Gulf of Aqaba

The Gulf of Aqaba is located to the east of the Sinai Peninsula and west of the Arabian mainland [20]. This and the Gulf of Suez are the two gulfs extending from the northern portion of the Red Sea. It reaches a maximum depth of 1,850 m in its central basin. The Gulf measures 24 kilometers at its widest point and stretches some 160 kilometers long. Unfortunately, water renewal in the Red Sea is slow, and exchange with the ocean takes approximately 200 years for the entire sea.

Although the Red Sea is known for its natural beauty, there are major industries in the Red Sea region include oil industries, manufacturing industries, tourism, fisheries and oil transport. Besides, treated or untreated sewage effluents from plants, cargo vessels, tour boats and ferries have damaged marine life in certain areas inside the Gulf of Aqaba.

4 Work aim, objectives, and targets

The aim of this study is to investigate the state of pollution of the Gulf of Aqaba along the Saudi seashore. The objectives of this work are to:

1. Measure the levels of potential heavy metals, major components, radiation sources, and some trace elements in the sea water of the samples.
2. Shed some light on the most prominent contaminants of the marine resources in the region, as well as its possible implications for human health if any.

3. Collect, review, and arrange the results that obtained during the study to serve as baseline data for further follow-up studies in this region.

This investigation covers seventy elements of periodic table. Table 1 illustrates these elements by their common used symbols.

Table 1: The following list illustrates seventy elements under investigation in Red sea water samples.

Ag	Al	As	Au	B	Ba	Be	Bi	Br	Ca	Cd	Ce	Cl	Co
Cr	Cs	Cu	Dy	Er	Eu	Fe	Ga	Gd	Ge	Hf	Hg	Ho	In
K	La	Li	Lu	Mg	Mn	Mo	Na	Nb	Nd	Ni	P	Pb	Pd
Pr	Pt	Rb	Re	Rh	Ru	S	Sb	Sc	Se	Si	Sm	Sn	Sr
Ta	Tb	Th	Ti	Tl	Tm	U	V	W	Ta	Y	Yb	Zn	Zr

5 Sampling and calibration

Sixty water samples were collected during February 2011. The samples were taken from the seashore water. The region of interest is illustrated throughout the black dashed line shown in figure 1. Samples were collected in 200 ml plastic bottles manufactured for chemical laboratories. Samples were numbered from 1 up to 60 according to site location number. The numbering started from the north at Ad Dorah city until the city of Ra’s Al-Sheikh Humid. The geographical locations of the samples are listed in table 2 with the errors of GPS readings and the regions where the samples were taken from.

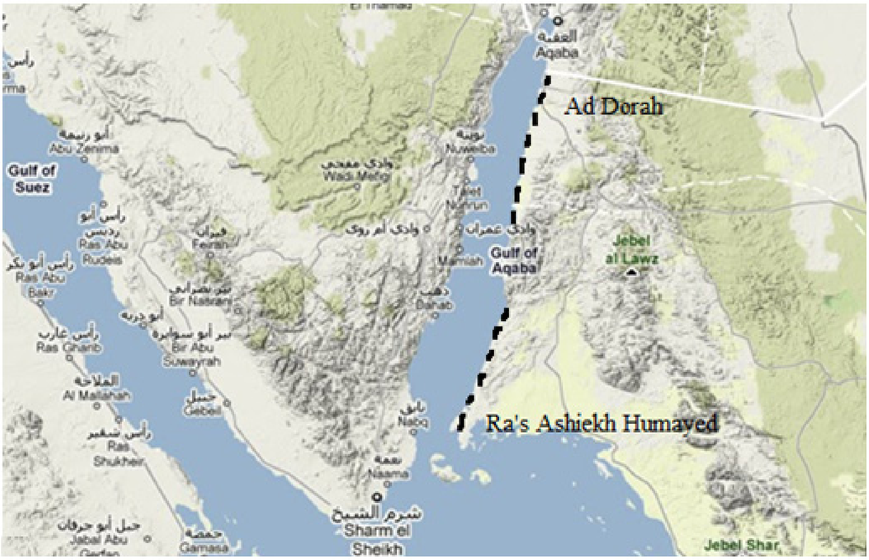

Figure 1: The Gulf of Aqaba region is shown. The black dashed line illustrates the path along which the sixty samples were collected.

Table 2: Geographical locations and identification codes of the water samples.

Sample ID	Geographical location		error (±m)	Reference site
	North	East		
1	29.3380	34.95000	4	Ad Dorah
2	29.3311	34.94893	6	
3	29.3230	34.94503	5	
4	29.31512	34.94786	4	
5	29.30630	34.95104	5	
6	29.29901	34.94946	6	Haql
7	29.30039	34.93801	5	
8	29.28727	34.92873	4	
9	29.27790	34..93108	4	
10	29.26712	34.93493	4	
11	29.25267	34.93960	2	
12	29.24146	34.94175	3	
13	29.23410	34.93177	3	Al Humaydah
14	29.22940	34.91946	3	
15	29.21668	34.91261	3	
16	29.19475	34.90820	3	
17	29.18811	34.89871	3	
18	29.18366	34.89539	3	
19	29.16452	34.89496	4	
20	29.14950	34.89251	3	
21	29.13983	34.88197	3	
22	29.12753	34.87969	3	
23	29.12304	34.88006	3	
24	29.10978	34.87532	4	
25	29.09291	34.87386	3	
26	29.07555	34.87169	3	
27	29.07318	34.87271	3	
28	29.07020	34.87265	2	Ra’s Dabr
29	29.06911	34.87179	4	
30	29.06551	34.86944	3	
31	28.44526	34.75785	3	Maqna
32	28.43604	34.75777	3	
33	28.43244	34.75546	3	
34	28.42028	34.75175	4	
35	28.41032	34.74424	3	
36	28.40022	34.74049	2	
41	28.34919	34.72308	2	
42	28.33982	34.71671	3	
43	28.33192	34.71280	3	

Table 2: Continued.

44	28.32101	34.70717	2	Sharm Al Ishsh
45	28.30841	34.70168	3	
46	28.29068	34.69466	2	
47	28.25229	34.67577	3	
48	28.24627	34.67844	2	
49	28.22206	34.66702	3	
50	28.20022	34.66212	5	Sharm al Majwah
51	28.16421	34.65891	2	
52	28.15162	34.61545	3	
53	28.14547	34.61133	4	
54	28.13941	34.60188	3	
55	28.12841	34.59019	3	Ra's ash Shaykh Humayd
56	28.11979	34.58235	3	
57	28.10244	34.57655	4	
58	28.09352	34.57421	4	
59	28.08616	34.58070	4	
60	28.09058	34.58930	4	

Samples were analyzed using Perkin Elmer Elan 900 ICP-MS. Data processing is through ACME proprietary software.

6 Results and discussion

The results of this investigation can be pointed out in the followings:

1. Au, Be, Fe, Ni, and Zn have concentration values above the detection limits in only a few sea water samples. Except Zn, the concentrations of these elements are very close to the detection limits. The locations and concentration values of these elements are presented in table 3.

2. As, Mo, Rb, and Sr, are found in trace amounts in all samples. The locations and concentration values of these elements are presented in table 4.

3. The major sea water constituents found in this investigation are B, Ba, Br, Ca, Cl, K, Li, Mg, Na, and S. The elements are detected in all samples with concentration values above the detection limits. The major sea water constituents in this investigation are those that represent greater than one percent of the total molar weight of the constituents of slandered sea water. Those elements are shown in table 4.

4. Fifty one elements were not found in all samples. The measured concentrations of these elements were below the detection limits. Table 5 lists these elements with their detection limits in each sample with their detection limits.

Table 3: Elements that were found in some samples.

	Au	Be	Fe	Ni	Zn
	Ppb	Ppb	ppm	Ppb	Ppb
Detection Limit	5	5	1	20	50
Sample I.D. No.					
5	<5	7	<1	<20	<50
10	<5	<5	<1	<20	168
21	<5	<5	<1	<20	65
23	<5	<5	<1	<20	108
24	<5	<5	<1	<20	52
32	<5	<5	<1	<20	164
33	<5	<5	<1	<20	63
34	<5	<5	<1	<20	95
35	11	<5	<1	<20	<50
36	6	<5	<1	<20	<50
37	<5	<5	1.256	<20	<50
39	<5	<5	1.245	<20	<50
46	<5	7	<1	<20	<50
47	<5	7	<1	<20	<50
53	<5	7	<1	<20	<50
59	<5	<5	<1	23	<50
60	<5	6	<1	21	<50

Table 4: A list of elements that were found in all sea water samples.

	As	B	Ba	Br	Ca	Cl	K
	ppb	ppm	ppb	Ppm	ppm	ppm	ppm
Detection Limit	50	0.5	5	0.5	5	100	5
Sample I.D.							
1	86	5.95	8	83.3	511	21349	474
2	95	5.33	14	82.5	512	21425	504
3	82	5.41	6	86.0	510	22786	483
4	85	5.34	<5	85.4	498	23064	483
5	84	5.43	8	88.8	488	24334	470
6	90	5.46	7	86.8	514	24117	482
7	88	5.23	6	90.4	495	24399	480
8	91	5.26	9	89.9	509	24730	467
9	97	4.84	11	90.1	541	24653	470
10	92	5.19	7	88.5	485	23932	480
11	101	4.77	12	86.9	541	22979	490
12	99	4.51	12	84.5	538	22632	464
13	90	4.88	6	83.5	493	23380	483
14	107	4.94	11	86.9	513	23209	494

Table 4: Continued.

	As	B	Ba	Br	Ca	Cl	K
	ppb	ppm	ppb	Ppm	ppm	ppm	ppm
Detection Limit	50	0.5	5	0.5	5	100	5
Sample I.D.							
15	101	4.63	7	85.1	482	22789	464
16	102	4.67	7	83.6	492	23616	483
17	117	5.41	8	87.0	533	22926	522
18	108	5.17	7	84.9	522	23883	518
19	107	5.20	8	86.5	542	23832	532
20	119	5.08	8	90.3	529	24890	544
21	114	5.16	8	87.9	526	24180	525
22	107	5.24	6	85.8	525	23732	523
23	110	4.65	6	86.2	496	23928	481
24	108	4.79	8	86.1	479	24018	485
25	105	4.68	8	86.6	477	24285	483
26	122	4.934	11	88.1	523	24180	509
27	117	4.688	10	86.5	506	23628	496
28	114	5.016	8	87.8	514	24246	514
29	110	4.75	8	85.2	515	24629	520
30	123	5.78	8	83.2	562	23207	548
31	113	4.54	12	85.2	487	23967	499
32	104	4.59	9	83.2	483	23346	482
33	108	4.50	8	84.4	478	23745	490
34	112	4.94	12	87.0	494	23949	495
35	109	5.81	12	93.4	544	23905	515
36	120	5.31	9	93.5	539	24436	510
37	127	5.45	12	89.1	525	24340	506
38	136	5.37	13	95.2	555	26025	540
39	134	5.11	8	92.2	545	25525	532
40	129	4.77	6	88.4	525	25183	509
41	134	4.81	12	91.3	542	25883	526
42	135	4.63	8	90.9	534	25722	520
43	134	5.26	11	92.5	540	25951	524
44	140	4.35	9	90.4	534	25573	522
45	132	4.85	6	88.7	527	24441	519
46	133	4.67	10	90.3	542	25846	530
47	121	4.44	7	89.0	528	24633	530
48	126	5.77	10	88.3	530	24983	531
49	135	4.61	7	92.1	541	25045	526
50	138	4.38	8	86.1	513	24105	504
51	148	4.69	9	88.3	533	25186	522
52	137	4.75	8	89.5	543	26013	547

Table 4: Continued.

	As	B	Ba	Br	Ca	Cl	K
	ppb	ppm	ppb	Ppm	ppm	ppm	ppm
Detection Limit	50	0.5	5	0.5	5	100	5
Sample I.D.							
53	151	4.78	9	95.4	557	26321	543
54	151	4.65	6	91.9	556	25953	543
55	151	4.31	10	89.5	551	25663	538
56	143	4.73	10	89.8	536	25710	544
57	156	4.31	5	88.7	538	25252	524
58	143	4.33	7	89.2	540	25004	557
59	143	4.40	9	83.0	513	24044	506
60	158	4.33	8	87.6	541	24803	529

Table 5: The rest of the elements with their concentrations that were found in all sea water samples.

	Li	Mg	Mo	Na	Rb	S	Sr
	ppb	ppm	ppb	ppm	ppb	ppm	ppb
Detection Limit	10	5	10	5	1	100	0.01
Sample I.D.							
1	213	1746	12	13604	138	1126	9.10
2	276	1736	14	13715	163	1102	9.33
3	222	1735	11	13600	133	1101	9.16
4	201	1728	12	13678	134	1091	9.36
5	206	1697	12	13713	131	1090	10.1
6	219	1717	12	13594	135	1101	9.53
7	207	1723	12	13315	130	1104	9.66
8	216	1731	<10	13720	134	1133	10.1
9	259	1688	12	13309	151	1088	11.0
10	171	1740	12	13575	131	1094	9.84
11	232	1728	12	13638	146	1090	10.9
12	203	1653	<10	13127	132	1045	11.2
13	162	1705	11	13764	131	1104	10.6
14	199	1731	12	13817	136	1120	10.2
15	182	1698	11	13689	133	1090	10.4
16	178	1687	11	13471	129	1077	10.2
17	184	1862	12	14849	145	1183	10.5
18	180	1804	12	14443	138	1157	10.1
19	166	1842	13	14613	143	1181	10.4
20	182	1914	13	15455	144	1226	10.5
21	216	1811	12	14191	142	1174	10.5
22	183	1819	13	14459	140	1159	10.6

Table 5: Continued.

	Li	Mg	Mo	Na	Rb	S	Sr
	ppb	ppm	ppb	ppm	ppb	ppm	ppb
Detection Limit	10	5	10	5	1	100	0.01
Sample I.D.							
23	179	1719	12	13838	133	1094	10.4
24	164	1701	10	13711	129	1079	10.3
25	168	1696	11	13637	127	1082	10.3
26	181	1718	11	13574	140	1106	10.2
27	181	1739	12	13615	133	1101	10.2
28	184	1804	11	13913	136	1166	10.5
29	195	1801	11	14623	137	1170	10.5
30	203	1895	13	14964	158	1210	10.1
31	186	1748	10	13708	133	1113	10.0
32	178	1675	11	13479	128	1078	10.1
33	171	1703	11	13500	127	1073	9.92
34	185	1730	12	13748	133	1111	10.1
35	240	1750	10	13887	143	1073	9.69
36	204	1734	14	13783	147	1071	10.0
37	214	1770	12	14027	139	1092	9.46
38	203	1769	12	13919	152	1093	9.93
39	198	1764	13	13926	149	1092	9.89
40	194	1746	11	13805	143	1068	9.64
41	183	1747	12	13757	148	1082	9.80
42	189	1756	13	13842	148	1080	9.82
43	187	1774	12	14048	151	1102	10.1
44	181	1730	14	13498	141	1069	9.68
45	188	1746	12	13651	145	1084	9.57
46	188	1720	12	13672	146	1071	9.86
47	178	1719	11	13715	144	1064	9.62
48	247	1733	12	13702	143	1057	9.63
49	174	1747	11	13808	152	1095	10.0
50	165	1700	12	13442	140	1060	9.72
51	180	1715	11	13664	143	1055	9.58
52	173	1749	12	13779	149	1078	10.2
53	181	1791	13	14139	160	1112	10.5
54	189	1754	13	13946	152	1090	10.1
55	173	1698	13	13626	153	1045	10.1
56	172	1756	12	13878	150	1077	10.0
57	186	1713	13	13495	150	1064	10.0
58	165	1729	14	13571	151	1079	9.92
59	172	1721	13	13632	143	1082	9.62
60	173	1729	12	13584	148	1075	9.60

7 Conclusion

Sixty water samples were analyzed using ICP-MS. The results of this research can be used as a baseline data in different fields of environmental analysis and also for governmental planning and development. Concentrations of some trace elements were found in the samples. These results come from different human activities. No toxic elements were found in samples with dangerous level of concentrations. Continuous monitoring should be maintained periodically. More governmental restrictions and laws should be stated to protect this region in the future. Radioisotopes concentrations measurements in this area should start to complete the research about this region.

Table 6: A summary of all elements that are not found in the samples.

Items	Element symbol	Detection Limit (ppb)
1	Ag	5
2	Al	100
3	Bi	5
4	Cd	5
5	Ce	1
6	Co	2
7	Cr	50
8	Cs	1
9	Cu	50
10	Dy	1
11	Er	1
12	Eu	1
13	Ga	5
14	Gd	1
15	Ge	5
16	Hf	2
17	Hg	10
18	Ho	1
19	In	1
20	La	1
21	Lu	1
22	Mn	5
23	Nb	1
24	Nd	1
25	P	2
26	Pb	10
27	Pd	20
26	Pb	10
27	Pd	20
28	Pr	1
29	Pt	1
30	Re	1
31	Rh	1
32	Ru	5
33	Sb	5
34	Sc	100
35	Se	400
36	Si	4
37	Sm	2
38	Sn	5
39	Ta	2
40	Tb	1
41	Te	5
42	Th	5
43	Ti	1
44	Tl	1
45	Tm	1
46	U	2
47	V	200
48	W	2
49	Y	1
50	Yb	1
51	Zr	2

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