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Distribution of Heavy Metals in the Bottom Sediments of the Arabian Gulf, United Arab Emirates

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Thirty two bottom sediment samples were collected from four different areas from Arabian Gulf, United Arab Emirates. These areas include: (a) Dubai, (b) Sharjah, (c) Ajman, and (d) Ras Al-Khaimah. The present study focuses on the levels of copper, lead, iron, manganese nickel, cadmium, zinc and vanadium in order to assess the extent of environmental pollution and to discuss the origin of these contaminants in sediments. Positive correlations are found between increase of heavy metals concentration and decrease of grain size. It is well established that heavy metals tend to be concentrated in the finer grain sizes of bottom sediments of the studied areas. Some large size grain sediments show high heavy metals concentrations due to formation of large agglomerates from the smaller particles enriched by contaminations. The concentrations of copper, zinc, lead, iron, manganese, nickel, cadmium, and vanadium are varied between 5.05, 10.15, 2.82, 3230, 119.0, 16.92, 0.105, and 11.04 μg/g, respectively, which are within the permission levels. This means that the samples containing these metals were derived from non-pollutant sources.

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1. Introduction

The United Arab Emirates is situated at the southern part of the Arabian Gulf (Fig. 1). It extends from the Qatar peninsula to Oman over a distance of 725 km along the Arabian Gulf coast, additionally 76 km of the Eastern Coast borders, immediately south the Musandam Peninsula, in the Sultanate of Oman [1]. The Arabian Gulf Coastal sector is a low-lying area of extensive tidal flats, lagoons and sand dunes, while the Eastern coastal area bordering is mountainous. In the north, the Eastern coast of UAE consists of sandy beaches with rocky headlands with relief diminishing towards the south as the coastal strip passes into low-lying lagoonal environments [2].

Fig. 1. Location map of the study area and the sampling location.

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The Eastern coast of UAE is affected by three coastal actions. These are (a) along shore current moving eastwards in the Arabian Gulf, (b) wave action, and (e) tide action. The energy of each process depends on several variables, vis. wide velocity, configuration of the coastline, lithology and structure of the coastal geology, relief of the coastal area, and nature of the marine sediments [3]. Accordingly, several coastal and marine subsystems have evolved. On the whole, the coastal region of the United Arab Emirates can be divided into the Arabian Gulf Coastal region (study area) and the eastern coast of UAE region (Oman Gulf).

2. Natural of the study area

The UAE coast of the Arabian Gulf, between the base of Qatar Peninsula and the southern end of Musandam Peninsula, is composed primarily of relatively pure carbonate sediments [4]. Concurrently, the offshore area is occupied mainly by coarse-grained sediments (sand and muddy sand) [5]. Although the coastline here is essentially linear, in detail its morphology is exceedingly complex. These complexities are the product of both pre-Holocene erosion and sedimentation. Holocene sedimentation causes rapid lateral variations in the environments and sedimentary patterns. These contrasts markedly with the relatively simple distribution of sediments in the offshore areas [4]. The coastal area is protected by a group of islands and patch coral reefs. According to [4], sediment composition, surface patterns and vertical sequences vary laterally along the Gulf coast depending on three major factors: (a) orientation of the shoreline with respect to the onshore north winds, (b) proximity to Qatar Peninsula, an up-wind barrier, and (c) the presence of the Great Pearl Bank coastal barrier [6].

3. Experimental study

3.1. Hydrographic survey

Some physicochemical parameters e.g. pH, dissolved oxygen, salinity, temperature and depth were measured *in situ* using the water quality logger, where locations were determined by a GPS.

3.2. Sampling

In most aquatic systems, the concentrations of the heavy metals in the bottom sediments are much greater than their concentrations in the water column. Bottom sediments are known to act as a reservoir or sink for many trace metals and some other pollution. The studied areas are located at Arabian Gulf between 25°43′ and 25°02′ North and 56°48′ and 56°03′ East. Thirty two sediment samples (one kg) were collected from the bottom of the Arabian Gulf from 6 to 10 m depth in order to trace the pollution level of these sediments by using the mineralogical and geochemical analyses. Samples were collected by using Grab Sampler from each station using GPS to determine the coordinates of each one and immediately transferred to sampling containers. The sampling containers were immediately sealed, labeled, refrigerated, and kept frozen prior to chemical and physical analyses. These samples were collected from: Ras Al-Khaimah — Umm Al-Quwain (15 samples), Sharjah (6 samples), Ajman (3 samples), and Dubai (8 samples), all of which lie along the eastern coast of the UAE. In the laboratory the collected samples were dried and sieved for grain size analysis and measuring heavy metals concentrations.

3.3. Laboratory analyses

Laboratory analyses were carried out for the bottom sediments for Arabian Gulf. These analyses include: grain size analyses and heavy metals concentration.

4. Results

The grain size statistical parameters according to [7], i.e. mean size of samples which are taken from Dubai and Sharjah, indicate that these areas (from the Arabian Gulf sector) are covered by medium sand (muddy sand to gravels) (Fig. 2). On the other hand, Ajman and Ras Al-Khaimah sampling areas are apparently covered by sandy to gravelly sand.

4.1. Grain size–heavy metals relationship

Grain size of the studied areas are thought to play an important role in controlling the concentrations of trace metals on/in suspended and bottom sediments [8]. In general, positive correlation has been reported between increase of heavy metal concentrations and decrease of grain size. Table I gives a summary of the average heavy metal concentration levels in the different grain size textural in Arabian Gulf, which are calculated from the measurements of the bottom sediments. Positive correlations are found between increase of heavy metals concentration and decrease of grain size (Fig. 3), verifying that adsorption onto muds is the primary mechanism of trace metal concentration in marine bottom sediments. It is well established that heavy metals tend to be concentrated in the finer grain sizes of bottom sediments. Therefore, heavy metal concentrations in the fine grained muddy sediments (sandy mud or muddy sand) of Gulf of Oman. Some large size grain sediments show high heavy metals concentration due to formation of large agglomerates from the smaller particles enriched by contaminations.

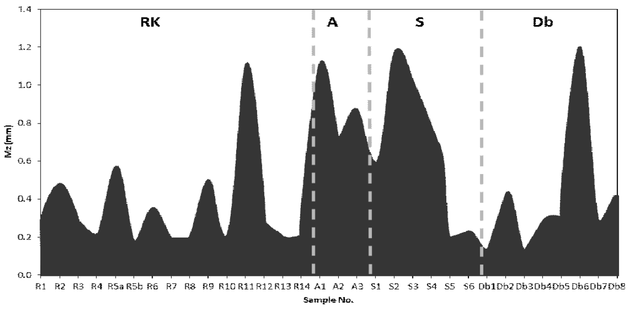

Fig. 2. The mean size of samples from Ras Al Khaimah (Rk), Ajman (A), Sharjah (S) and Dubai (Db).

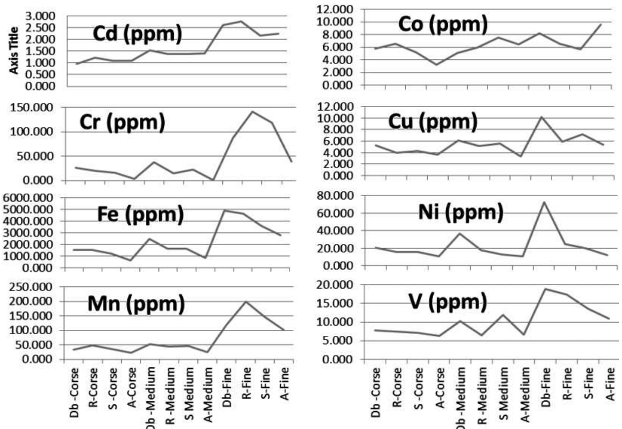

Fig. 3. The positive relationship between the heavy metals and the grain size in the studied areas.

4.2. Heavy metals concentration

Thirty two samples were extracted from bottom powdered sediments of Arabian Gulf (Ras Al-Khaimah — Umm Al-Quwain (15 samples), Sharjah (6 samples), Ajman (3 samples) and Dubai (8 samples)).

Concentrations of heavy metals (Cd, Co, Cr, Cu, Fe, Mn, Ni, Pb, V, and Zn) (Table II) were determined in an aliquot using inductively coupled plasma-mass spectrometry (ICP-MS) at Acme Labs, Canada. Along with the samples, system and method blanks were run with standard material for background correction and quality control.

TABLE I

Concentration of some heavy metals (ppm) with different grain size in the studied area Ras Al Khaimah (R), Ajman (A), Sharjah (S) and Dubai (Db).

Sample ID	Cd	Co	Cr	Cu	Fe	Mn	Ni	Pb	V	Zn
Db-coarse	0.947	5.765	26.292	5.253	1523.545	32.899	20.811	27.964	7.782	5.015
R-coarse	1.219	6.547	20.386	3.991	1498.490	48.441	15.822	19.230	7.387	2.895
S-coarse	1.085	5.170	16.544	4.308	1206.892	34.384	15.709	22.279	7.169	5.617
A-coarse	1.090	3.199	2.954	3.678	598.640	21.814	10.493	19.644	6.338	8.941
Db-medium	1.530	5.040	37.636	6.076	2457.293	52.500	36.687	23.721	10.281	7.352
R-medium	1.387	5.935	14.411	5.177	1606.852	43.880	17.336	15.398	6.441	21.745
S-medium	1.385	7.501	22.832	5.574	1613.947	46.634	12.624	11.048	11.917	4.375
A-medium	1.410	6.494	1.417	3.322	842.117	24.383	10.772	8.814	6.549	10.006
Db-fine	2.606	8.232	86.883	10.209	4924.215	117.451	72.063	12.062	18.890	11.414
R-fine	2.762	6.531	140.812	5.930	4638.705	200.009	24.956	13.477	17.328	8.660
S-fine	2.155	5.696	118.419	7.230	3560.753	146.509	19.992	13.502	13.552	20.854
A-fine	2.251	9.529	39.347	5.323	2758.420	100.398	11.753	11.482	10.868	7.803

TABLE II

Average of heavy metals concentrations in the bottom sediments of the Arabian Gulf.

	Mo ppm	Cu ppm	Pb ppm	Zn ppm	Ag ppm	Ni ppm	Co ppm	Mn ppm	Fe [%]	As ppm	Cd ppm	V ppm	Cr ppm
Ras Al Khaimah	0.38	3.58	4.03	10.23	76.13	24.93	2.59	175.93	0.47	3.45	0.17	15.40	53.00
Sharjiah	0.32	12.33	3.41	16.57	52.14	11.24	1.84	147.86	0.36	3.42	0.11	12.43	66.00
Ajman	0.27	1.56	1.99	7.23	24.67	4.60	0.73	33.67	0.09	2.07	0.06	3.33	8.67
Dubai	0.27	2.74	1.85	9.87	39.48	26.93	2.58	118.74	0.37	2.65	0.08	13.02	46.51
Average	0.31	5.053	2.820	10.975	48.105	16.925	1.935	119.050	0.323	2.898	0.105	11.045	43.545

4.3. Natural background levels of heavy metals

Heavy metals are natural constituents of all environments found in the seawater, marine organisms and sediments [9]. Therefore, knowing their natural background levels, or at least their permanent concentrations in a marine environment, is essential for detecting and assessing trace metal pollution [10].

Heavy metals are one of the most important factors among many others in biosphere pollution. Great interest for heavy metals results mainly from the serious dangers which are created by the present increase of their quantities. After exceeding a definite barrier of their concentration they start to act inhibitedly or quite toxically on growth and metabolic processes of animal and plant organisms.

Table II shows the analysis of the bottom sediment samples of the studied areas. The concentrations of copper, zinc, lead, iron, manganese, nickel, cadmium, and vanadium are varied between (5.05, 1.15, 2.82, 3230, 119.0, 16.92, 0.105, and 11.04 μg/g), respectively, which are within the permission levels. Figure 4 represents the concentration % of different heavy metals in the different studied areas. It is clear that Ras Al Khaimah bottom sediments have a high concentration of most of heavy metals and Sharjah come in the second role. On the other hand, Ajman bottom sediments have the lowest concentration percentage of heavy metals due to low population and limited industry activities rather than in the other studied areas.

TABLE III

The comparison between average of the trace elements in the Arabian Gulf and studied areas.

Trace elements	Average (Arabian Gulf)	Average studied areas
zinc (Zn)	30–60 μg/g	10.15 μg/g
lead (Pb)	15–30 μg/g	2.82 μg/g
cadmium (Cd)	1.2–2.0 μg/g	0.105 μg/g
nickel (Ni)	70–80 μg/g	16.92 μg/g
manganese(Mn)	300–600 μg/g	119.0 μg/g
iron (Fe)	10000–20000 μg/g	3230 μg/g
vanadium (V)	20–30 μg/g	11.04 μg/g
copper (Cu)	15–30 μg/g	5.05 μg/g

Table III gives a summary of the concentrations recorder in unpolluted sediments as guidelines for the natural background levels (upper limits) in the dry, silt-clay fraction of unpolluted bottom sediments in the Arabian region (north-eastern Kuwait, Saudi Arabian, Iran, Bahrain, Qatar and UAE) in the comparison to the

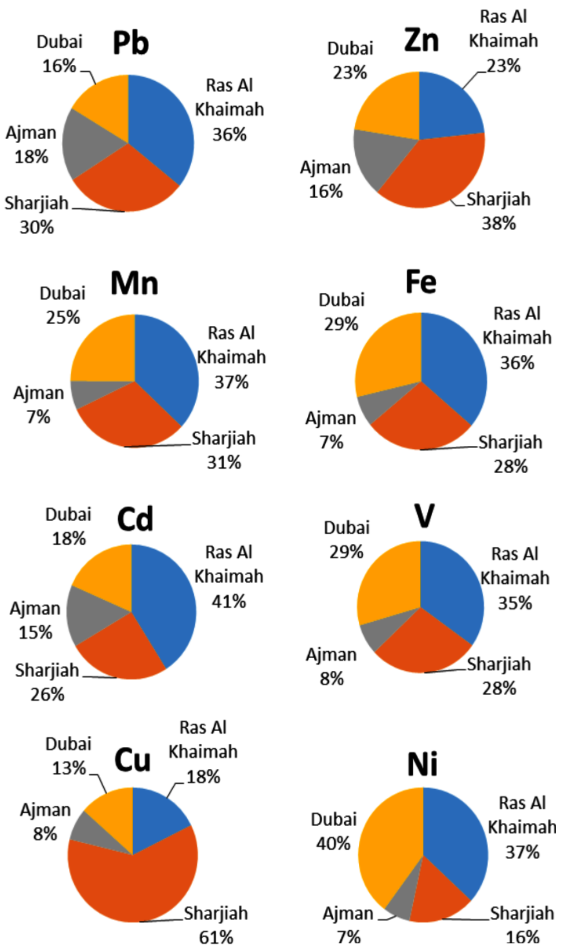

Fig. 4. Concentration [%] of the heavy metals in the bottom sediments of studied areas.

studied area. The average values of the trace elements in the Arabian Gulf were calculated [11] and compared with the results obtained from the present study of bottom sediments in the offshore areas of the UAE.

5. Conclusion

The most studied bottom sediment samples range in size from sandy mud to muddy sand. The sand and the gravels are restricted to the tidal and near shore line. The moderately to well sorted sandy mud occupies most the offshore bottom sediments. A well define relationship between the grain size of the bottom sediment and the heavy metals concentration was achieved. In general, a positive correlation has been reported between increase of trace metal concentrations and decrease of grain size. Some large size grains sediments show high heavy metals concentrations due to formation of large agglomerates from the smaller particles enriched by contaminations. The concentrations of copper, zinc, lead, iron, manganese, nickel, cadmium, and vanadium are varied between 5.05, 10.15, 2.82, 3230, 119.0, 16.92, 0.105, and 11.04 μg/g, respectively, which are within the permission levels. This means that the samples containing these metals were derived from non-pollutant sources.

Acknowledgments

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