



Geochemistry and potential of toxic elements in sediments originating from salt domes, north of Hormuz strait (Pol, Gachin, Angouran and Hormuz)

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Received 10 November 2021; accepted 15 February 2022

Abstract

This study investigates the concentration, potential of toxicity, and source rocks of seven toxic elements (As, Cd, Cu, Cr, Pb, Zn, and Ni) in the sediments of four salt domes on the north of Hormuz Strait (Hormuz, Pol, Gachin and Angouran). In this regard, to determine the origin of toxic elements in the sediments of salt dome waterways, field studies, sediment sampling, and mass spectrometry elemental analysis were performed. Moreover, the enrichment factor and index of geo-accumulation were calculated. Agglomerative hierarchical clustering was also performed to determine the carriers and adsorbents of the elements. The results showed that sediments of the study area have the potential for toxicity of As, Cd, and Pb. In contrast, the contingency intoxication by Cu, Cr, Zn, and Ni is minimal in the sediments around the salt domes of the Hormuz strait area. Based on the concentration of elements in the sediments, determined their probable source rocks. The minerals of the sulfate salts, Fe-oxides/sulfides, and volcanic rocks of the Hormuz Series are the major sources of As and Pb, and mafic/ultramafic minerals of the volcanic rocks are sources of Cu, Zn, and Ni. Neogene carbonate rocks are also a source of cadmium.

Keywords: *Enrichment Factor, Geo-accumulation index, Hormuz strait, Salt dome sediments, Toxic elements*

1. Introduction

Today, all countries have expressed their biding concerns over the contamination of the river environment because it could expose the surrounding habitats and coastal area ecosystems to acute and chronic detriments. The disturbance caused by anthropogenic activities in the marine environment would appear in multiple forms. Many contaminants show negligible solubility in water and react with sediment particles (Liang et al. 2019). Suspended sediments and organic material would attract contaminants in short order and eliminate by them flocculation, coagulation, and deposition (Vignaroli et al. 2018).

Patently, major and, secondary elements in natural conditions as per climatic and topographic conditions on one hand, and lithology, outcrop, tectonic fracturing, diagenetic processes, and weathering on the other, separate from the source rock and are exposed to transport. The main product of chemical weathering and diagenesis is the release of metallic elements' cations, first which are introduced into sedimentary settings by colloidal clay carriers.

The process is followed by other adsorbents, specifically organic material, whose role in transporting or absorbing cations is remarkable. This role commonly becomes more remarkable in low-turbulent and deeper sedimentary environments (Gharibreza and Ashraf 2014). Rivers are known as the main source of dissolved and suspended metals in seas. As current flows into the ocean, some

changes occur that result in precipitation and mobilization of metals (Vignaroli et al. 2018). The recognition of elements concentration in fresh water and marine settings is an essential fundamental step in analyzing geochemical conditions and the quality of water/sediment resources. The contaminants which are present in sediments under specific geochemical conditions could migrate into the adjacent waters, the issue which reflects the significance of sediments as an essential source of water contaminants. The sediments of rivers, seas, gulfs, and inlets are contaminated by organic and non-organic materials in many regions. Heavy metals cannot be vanished like organic contaminants by chemo-organic bio-processes; hence, they are locally accumulated or transferred far away from the source itself (Ashraf et al. 2018). The accumulation and distribution of heavy metals hinge upon different factors like oxidation-reduction conditions and the concentration of organic material (Al-Mur et al. 2017; Romano et al. 2018; Dehghan and Yazdi 2023). The presence of heavy metals in sediments is affected by the particle size of the sediments. This trend is predominantly attributed to the sorption, co-precipitation, and complexing of metals on particle surfaces and coatings. Fine-grained sediments and organic material of fluvial environments are the sources of toxic metals' cations due to possessing adsorption capacity resulting from their negative charge, recording the trace of the events that resulted in concentration build-up of elements. Therefore, the investigation of sediment contamination would set the stage for scrutinizing controls and sources of contamination and making administrative provisions to

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lower the concentration of contaminants. Coastal regions are of great significance in respect of environmental geochemistry studies due to being the site of cross-reaction between the hydrosphere, lithosphere, stratosphere, and anthroposphere (Hoang 2020). Multiple studies have been undertaken for investigating the heavy metal concentration in aquatic environments including which those by Ashraf et al. (2017); Davoodi et al. (2017); Kwon et al. (2017); Harikrishnan et al. (2017); Little et al. (2017); Tanjung et al. (2019); Gharibreza et al. (2020) stand out. Many developed qualitative standards and indexes have been set as per the concentration of toxic elements and metals like As, Cd, Cu, Cu, Pb, Ni, Zn, Ag, Cr, and stable organic contamination. It should be noted, however, that a distinction was made between natural background values and anthropogenic inputs because the background values change from area to area (Barbieri 2016). In between, different indexes are used to identify the concentration of environmental concern, such as enrichment coefficient (EF) and geo-accumulation indexes (Feng et al 2011). The geo-accumulation index (I_{geo}) proposed by Muller (1979), was used to compare the accumulation of each metal in the chemical fractions. This index measures the concentration of the metal, within the sediment, compared with its background concentration. Salt domes are the volume of salt that flows upward elastically and perforates the slag layers asymmetrically (Jackson and Talbot 1991). Salt domes are one of the unique phenomena in the Zagros geologic zone. They belong to

the Hormuz Series (HS) of the Upper Proterozoic-Lower Cambrian age. The salt exposures in the Zagros suggest that the HS consists of colorful interlayers of salt bands allied with dark dolomite, sandstone, and siltstone or marl at the subjacent cyclic sequence (Talbot and Alavi 1996; Jehangir Khan et al. 2021).

Studies were conducted on the HS salt domes by Nasir et al. (2003); Dadolahi Sohrab and Nazarizadeh Dehkordi (2012), Yazdi et al. (2014) and Faramarzi et al. (2015) can be referred. Given the extraordinary importance of the matter notwithstanding, the salt domes and their effect on sediments have rarely been studied regarding environmental geochemistry. The main object of this study is to assess the extent, and the origin of toxic elements, in sediments of the salt domes waterways, using the enrichment factor and the geo-accumulation index. These sediments were deposited in the semi-saline to saline river environment under a seasonal surface flow regime. In this way have been used field studies, laboratory analyses, and software facilities have.

2. Geological setting

Geographically, the study area is situated in the north of Hormuz Strait and geologically at the Zagros folded belt. Its coordinates are 55° 30' to 57° E, 27° to 28° N, covering large areas of the north of Hormuz Strait in the south of Iran. The sediments sourced from the rock units of the four salt domes in Hormuz, Pol, Gachin, and Angouran were studied (Fig 1).

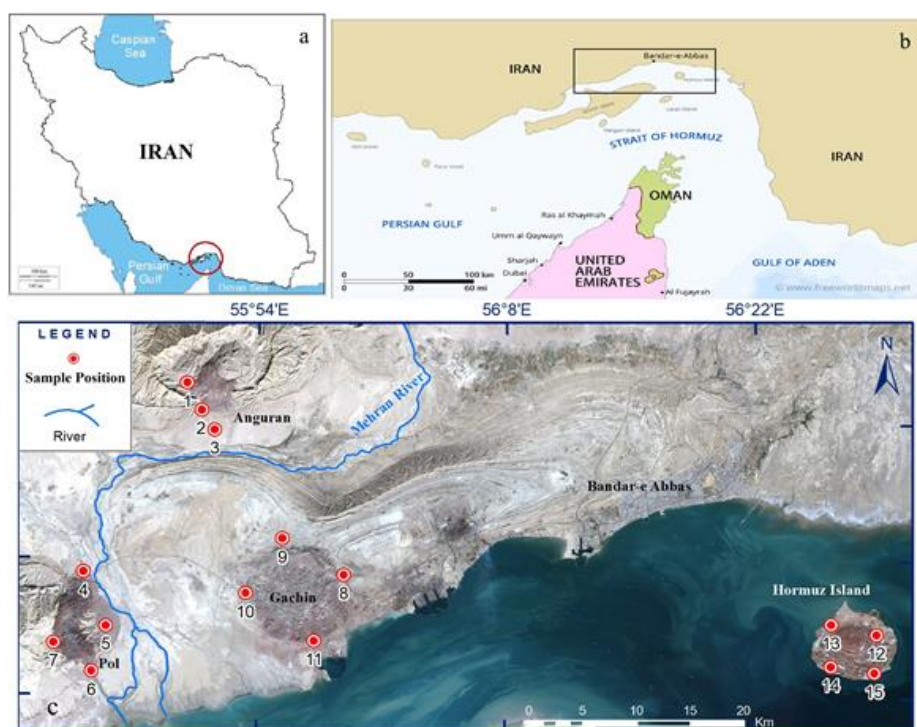


Fig 1. a: Location of the Hormuz strait. b: Location of the study area c: Location of the sampling points (Taken from LANDSAT_LC08_160041 image).

Sediments of Angouran, Pol, and Gachin salt domes (northern and western parts) are transported to Mehran River (seasonal river) through waterways and finally reach the coastal environment. Also, in the Hormuz and the eastern and southern parts of Gachin salt domes, sediments are transported directly to the coastal environment. The rock units of the HS consist of red shale, evaporative salts, thin layers of black limestone, hematite, and oligiste layers allied with a miscellany of volcanic rocks e.g., rhyolite, andesite, and basalt (Edgell 1996). Red soil is also widespread on outer and weathered surfaces of salt domes. The younger carbonate rock units Asmari and Mishan formations (Neogene) that the salt domes intrusion into is the other rock units in the Angouran and Pol areas. Salt domes affect the topography of the sedimentary basin, which causes different conditions and changes in the sediments characteristic. Under these conditions, the rock units of these highlands are affected by weathering and become the main origins of sediment.

3. Methodology

To investigate the concentration of the toxic elements in the sediments of salt domes on the north of the Hormuz Strait (e. g., Hormuz, Pol, Gachin, and Angouran), 15 samples were undertaken from the surface sediments of salt domes waterways. Sampling was done based on a pattern that was sampled from waterways entering to Mehran River and the coastal area. The samples were obtained at depths of 0-5 cm. The sampled sediments were stored and coded in plastic bags. 15 bags were frozen at 0°C and dispatched to the Zarazma Laboratory for analytical studies. The samples were subsequently dried at 80°C, and the <2 mm grains were separated based on the Unified Soil Classification System (UNIFIED). Furthermore, the clay percentage was determined by a hydrometric test of particles passing through a sieve mesh 230. Some 0.25 gr of sediments powders were prepared to determine the concentration of preferred elements (Kingston and Jassie 1998). The concentration of elements was measured based on dry weight (mg kg⁻¹). The calibration of the ICP-MS unit was conducted through the standard, and blank samples and quality control were undertaken by repeating the test for some samples (Wernimont and Spendley 1985). To validate and investigate the contaminants potential of sediments, the resulted concentrations were compared with the results of other research (Farsad et.al 2011; Nowrouzi and Pourkhabbaz 2014; Janadeleh and Jahangiri 2016; Davoodi et al 2017) and the mean concentration of elements in the earth's crust CRC (Taylor 1964; Rickwood 1983; Fortescue 1992; Rudnick and Gao 2014; Rumble 2021). To finding out toxic elements contamination in sediments, the index of geo-accumulation (I_{geo}) was determined by comparing gained concentration of elements with CRC levels (Muller 1979). Where C_n is measured concentration; B_n is background value (CRC) and 1.5 is back ground matrix

correlation factor. I_{geo} index divided into five classes as unpolluted (< 1); low polluted (1 < < 3); moderately polluted (3 < < 4); highly polluted (4 < < 5); and very highly polluted (5 <).

$$I_{geo} = \text{Log}_2(C_n/1.5 B_n)$$

The enrichment factor, which is an index of sediment quality indicating the change in the natural conditions, was measured (Loring et al. 1995; Sutherland and Tolosa 2000). Where C_i is the measured concentration for the tested element, C_{ref} is the concentration of the normalizer element in the same sample, B_n is the base concentration of the element, and B_{ref} is the base concentration of the normalizer element. The values of EF <2, 2-5, and >5 indicate minimal, moderate, and significant levels of enrichment, respectively. This factor has been widely applied to investigate the role of anthropogenic activities in the contamination of dominant sediments (Gharibreza and Ashraf 2014; Ashraf et al. 2015). The concentration of Al in the earth's crust has been used as a normalizer element.

$$EF = \frac{(C_i/C_{ref})}{(B_n/B_{ref})}$$

According to international experiences, (de Mora et al 2004; Sundaray et al 2011; Zahra et al 2014; Pavlović et al 2019; da Silva Júnior et al 2020; Gharibreza and Masoumi 2021) to identify the metal elements that have identical geochemical behavior in the sedimentary environment and to understand the most important cationic absorbents, like clay particles, the Agglomerative Hierarchical Clustering (AHC) with Pearson's correlation coefficient was implemented using XLSTAT 2020.3.1.25 software. Utilizing the geochemical behavior and elements' concentration, ultimately, the rocks' minerals present in the source of sediments were introduced. The research was achieved by Levinson (1980); du Bray (1995); Smith and Huyck (1999); Kądziałko et al. (2008); Dehbandi et al. (2019); Han et al. (2020); Nyström et al. (2021) was referred to and compared with the present study.

3. Results and discussion

The results of the study of toxic elements and Sulfur contamination, and clay percentage of surface sediments of waterways diverging from the Pol, Gachin, Angouran, and Hormuz salt domes are shown in table 1. The geochemical condition of sediments and their contamination potential were compared with the CRC level of the earth's crust elements is illustrated (Fig 2 to 8). Besides, the I_{geo} and enrichment factor level of the seven respective toxic elements are represented to uncover the effectiveness of sources at the margin of the salt domes in Fig 9. The results are suggestive of the elements' order of Cr>Zn>Cu>Pb>Ni>As>Cd in respect of the average concentration in surface sediments of salt domes which are highly similar to that of the earth's crust.

Table 1. Values of toxic elements concentration, Sulfur (mg kg⁻¹), and Clay (%).

Sample No.	As	Cd	Cr	Cu	Ni	Pb	Zn	Al	S	Clay
1	9.09	0.9	34	21	30	19	35	10282	1440	21.4
2	8.08	1.1	48	21	27	26	42	7480	1768	38.6
3	9.08	1.2	20	32	18	23	35	7891	1813	13.6
4	10.1	0.6	50	65	21	30	37	24504	2939	29.2
5	16.1	0.6	60	55	26	21	41	24377	2492	19.8
6	18.7	0.1	42	68	17	34	49	9510	2400	38.7
7	10.7	0.3	57	50	19	42	43	9129	2401	14.5
8	9.8	0.2	74	46	38	36	63	20927	1913	53.7
9	7.4	0.1	79	38	73	28	65	34699	2294	50.1
10	7.6	0.2	83	56	23	37	66	31775	1309	14.7
11	9.2	0.4	70	47	24	43	67	35324	3393	21.4
12	25.1	0.1	49	34	14	40	58	28917	1516	57.3
13	20.2	0.2	45	34	15	44	59	18641	1430	56.9
14	20.8	0.8	38	38	27	27	50	39183	1229	58.1
15	25.6	0.9	45	30	29	21	47	20825	1374	79.5

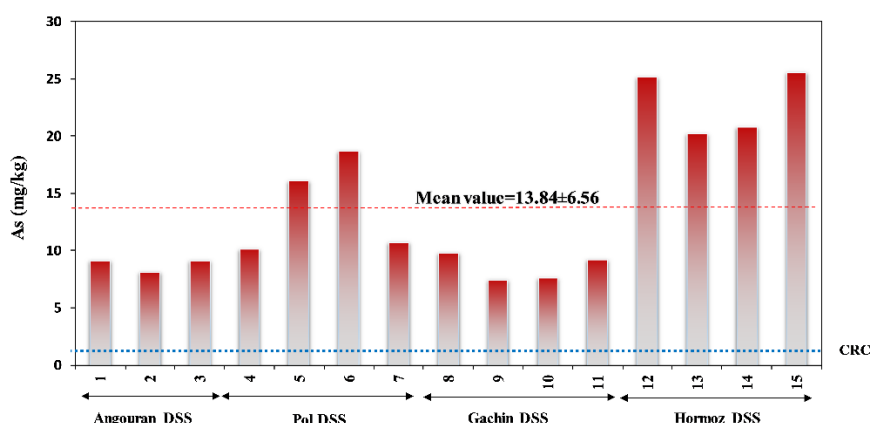


Fig 2. Comparison of As concentration in surface sediments of salt domes with an average concentration in the earth's crust.

The decreasing order of Cr>Ni>Zn>Cu>Pb>As>Cd for toxic elements in the earth's crust was reported by Rumble (2021) and Fortescue (1992). This order appears respectively as Zn>Cr>Ni>Cu>Pb>As>Cd, in Angouran DSS, Cu>Cr>Zn>Pb>Ni>As> Cd, in Pol DSS, Cr>Zn>Cu>Ni>Pb>As>Cd, in Gachin DSS and Zn>Cr>Cu>Pb>As>Ni>Cd in Hormuz DSS. It can be seen, that the concentration of sulfur in the samples is perceptibly beyond the average base concentration in the earth's crust (350 mg kg⁻¹) varying between 4-10x based on the values measured by Rumble (2021) and Fortescue (1992) due to the dominant evaporate structure in the lithology of salt domes. The sedimentary texture of samples, exclusive of samples No.3 in Angouran, No.7 in Pol, and No.10 in Gachin, are quintessentially muddy to sandy mud and clayed texture for Hormuz DSS. Also, all samples are bereft of organic material. The concentration of As in all samples is beyond CRC (1.8 mg kg⁻¹), which is construed as having a risk potential. The maximum, minimum, and average values of this element in the study area are 25.6, 7.4, and 13.84±6.56 (mg kg⁻¹), respectively with 0.47 as its variation coefficient. Furthermore, the concentration of As in samples No. 12-15 on the eastern portion of the Hormuz salt dome and No. 5-6 to the east

of the Pol salt dome is beyond the area's average (Fig 2). Considering the restricted anthropogenic activities in the study area, as compared with research by Davoodi et al (2017) at the Nayband Bay (Table 2), a high concentration of As is indicative of natural sources and the direct effect of HS lithology on the concentration of this element. Additionally, results indicated that the I_{geo} index of As is in the low polluted range and the enrichment factor is considerable in all samples (Fig 9). It indicates the adsorption of As by adsorbents in All of DSS.

The concentration of Cd as a toxic element in surface sediments varies from 1.2, 0.1, and 0.51±0.39 (mg kg⁻¹) as maximum, minimum, and average values with a variation coefficient of 0.75. This concentration in most samples is over the CRC concentration (Fig 3). The researches by Janadeleh and Jahangiri (2016), and Davoodi et al (2017) are also indicative of a similar contamination level which is evidence of the high concentration of Cd in the natural sources supplying the surface sediment to waterways in the study area. In contrast, the concentration of Cd reported by Nowrouzi and Pourkhabbaz (2014) is much higher than the concentration of Cd in this study. This is due to the

accumulation of cadmium in the Hara biosphere. The enrichment of Cd in most samples is at a considerable level. The I_{geo} index of Cd is in the unpolluted range in the Gachin and Hormuz and is low polluted in the other areas (Fig 9). It is indicating the adsorption of Cd by adsorbents in most DSS.

Results indicate the values of 68, 21, and 14.54 ± 42.33 (mg kg^{-1}) as the maximum, minimum, and average Cu concentrations with a variation coefficient of 0.33. Most samples possess a lower concentration than the CRC (60 mg kg^{-1}), and samples 4 and 6 from Pol DSS display a

concentration higher than the CRC (Fig 4). Due to limited anthropogenic activity in the study area, the high level of Cu, as compared with the research by Davoodi et al (2017) can indicate the influence of natural sources in promoting Cu concentration (Table 2).

Besides, Cu in salt dome samples is moderate in terms of enrichment and is considerable, merely, in the west of Pol DSS (Fig 9). On the other, the I_{geo} index of Cu is in the unpolluted range in the study area. It indicates the adsorption of Cu by adsorbents in the Pol DSS.

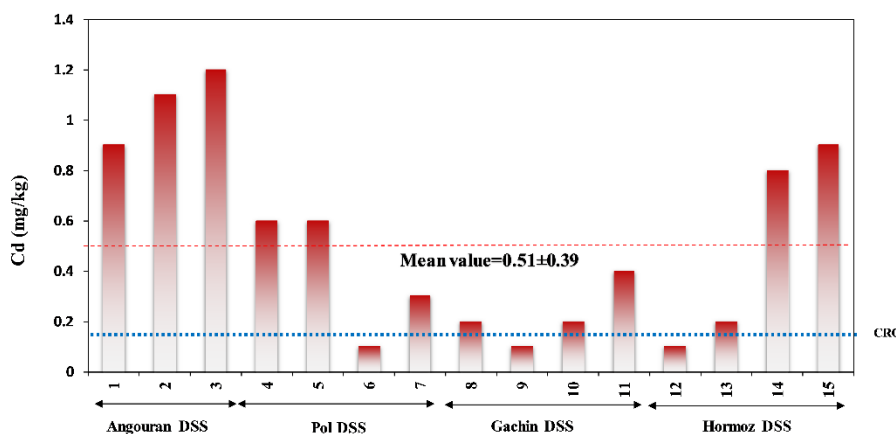


Fig 3. Comparison of Cd concentration in surface sediments of salt domes with an average concentration in the earth's crust.

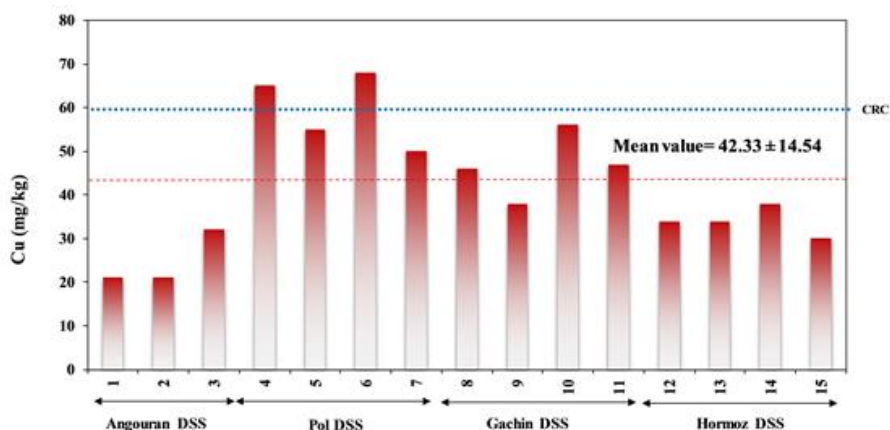


Fig 4. Comparison of Cu concentration in surface sediments of salt domes with an average concentration in the earth's crust.

The maximum, minimum, and average levels of Cr concentration in salt DSS are 83, 20, and 52.93 ± 17.62 (mg kg^{-1}), respectively, with 0.33 as the variation coefficient. All of the obtained values are of a concentration less than the CRC level (102 mg kg^{-1}). Among these, the maximum concentration is in the Gachin DSS. The study conducted by Davoodi et al. (2017) in Nayband Bay also indicates a similar level of contamination. Moreover, the Cr enrichment of the study area is minimal and the I_{geo} index of Cr is in the unpolluted range (Fig 9). The maximum, minimum, and

average concentration of Zn in surface sediments is 67 ± 35 and 50.47 ± 11.66 (mg kg^{-1}) with 0.23 as the variation coefficient. Conditions indicate imperceptible changes in concentration of Zn in the sediments of salt domes, with amounts less than CRC level (70 mg kg^{-1}) in all samples (Fig 6). The studies of Janadeleh and Jahangiri (2016) also reports similar contamination level in the sediments of the Persian Gulf, so that, the disagreement between this study and that by Farsad et al. (2011) is due to the rise in the concentration of Zn in bio-structures and contaminations resulted by the sea vessels (Table 2). The

enrichment of Zn in the Hormuz DSS is moderate, while minimal in other DSS (Fig 9A). The I_{geo} index of Zn is in the unpolluted range (Fig 9B). The high concentration of Zn in biological components, reported by Farsad et al (2011) implies to carrying of this element and accumulation in the organisms of the Hormuz Strait.

The concentration of Pb in the sediments ranges from 44, 19, and 31.4 ± 8.63 (mg kg^{-1}) as maximum, minimum, and average, respectively with 0.27 as its variation coefficient. All of the samples have concentrations more than the CRC (14 mg kg^{-1}) (Fig 7). Nowrouzi and Pourkhabbaz (2014) also reports a similar contamination level of Pb in this area (Table 2). Additionally, the enrichment of Pb is significant and in contrast, the I_{geo} index of Pb is in the unpolluted range in all samples (Fig 9). It indicates the adsorption of Pb by adsorbents in the

environment. The concentration of Ni ranges from 73, 14, and 26.73 ± 14.32 (mg kg^{-1}) as maximum, minimum, and average values, with 0.54 as the variation coefficient. Results report that all of the samples possess a concentration less than CRC (84 mg kg^{-1}) (Fig 8). Research conducted by Janadeleh and Jahangiri (2016) and Davoodi et al. (2017) also report a similar level of Ni contamination in the sediments of the north coasts of the Persian Gulf (Table 2). The enrichment factor of Ni is alternatively; between minimal to moderate in the study areas and also the I_{geo} index of Zn is in the unpolluted range in all samples (Fig 9). The high concentration of Ni in biological components, reported by Farsad et al (2011) and Nowrouzi and Pourkhabbaz (2014) implies to carry of this element and accumulation in the fauna and flora of the Hormuz Strait.

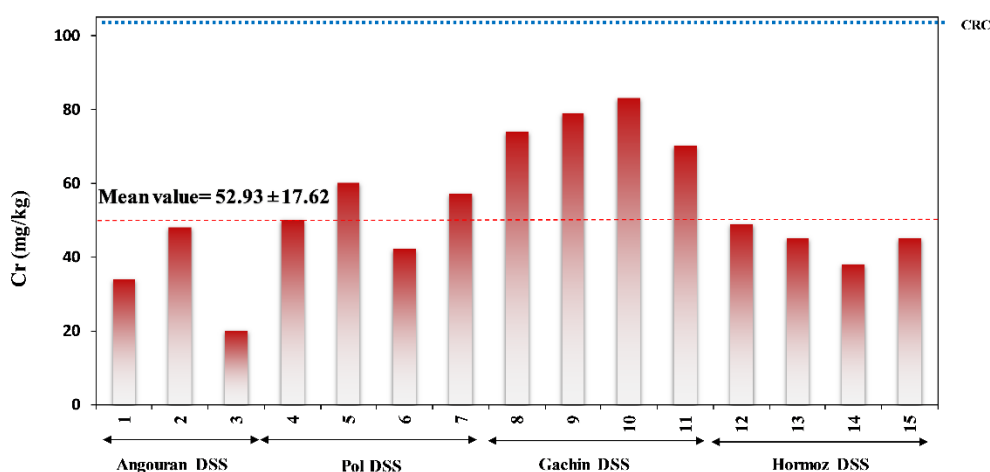


Fig 5. Comparison of Cr concentration in surface sediments of salt domes with an average concentration in the earth's crust.

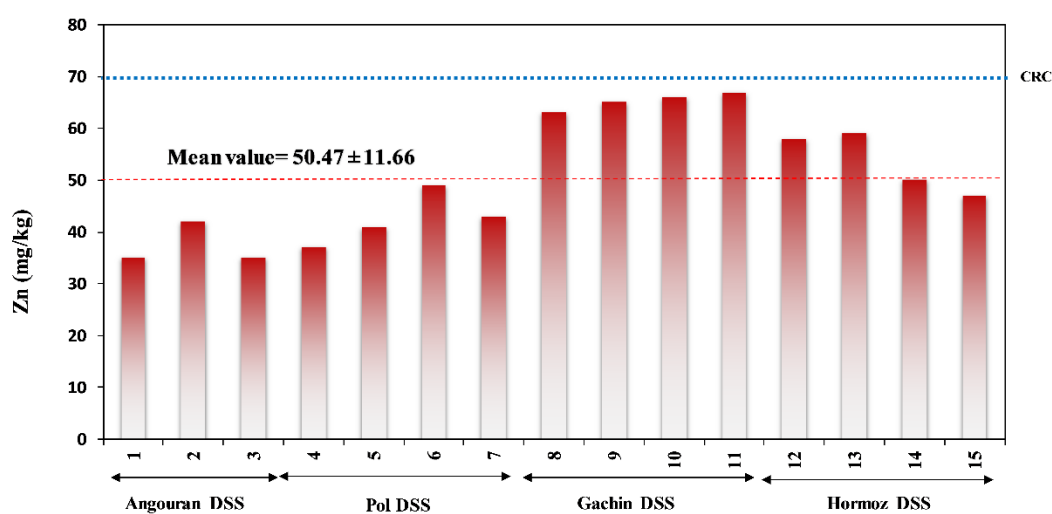


Fig 6. Comparison of Zn concentration in surface sediments of salt domes with an average concentration in the earth's crust.

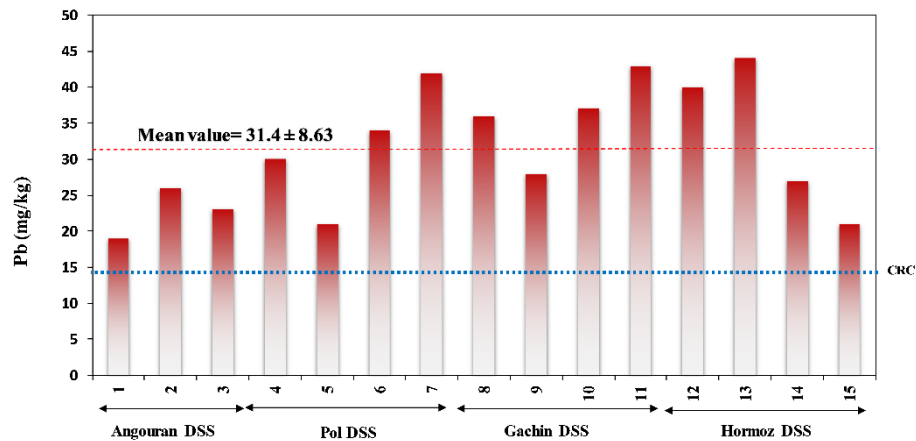


Fig 7. Comparison of Pb concentration in surface sediments of salt domes with an average concentration in the earth's crust.

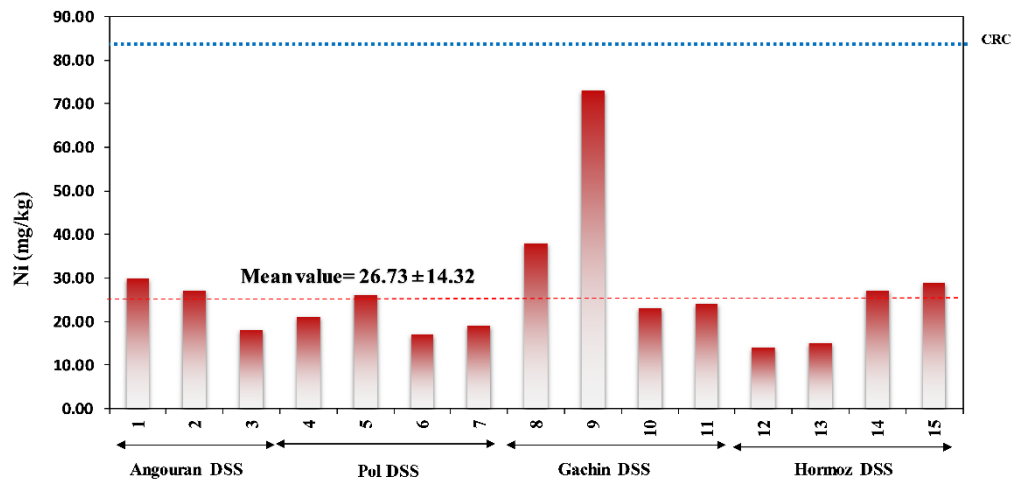


Fig 8. Comparison of Ni concentration in surface sediments of salt domes with an average concentration in the earth's crust.

Table2. Comparison with the result of this study (mg kg^{-1}) and the other research.

Area	As	Cd	Cr	Cu	Zn	Ni	Pb	Reference
North of Hormuz strait	Angouran	8.8	1.1	34	26.7	37.3	25	This study
	Pol	13.9	0.4	52.3	59.5	42.5	20.8	
	Gachin	8.5	0.3	76.5	46.8	65.3	39.5	
	Hormuz	22.9	0.5	44.3	34	53.5	21.3	
Northern Persian Gulf	9	0.5	54	7	-	38	-	Davoodi et al. (2017)
Persian Gulf	-	0.2	-	-	64.9	34.1	7.7	Janadeleh and Jahangiri (2016)
Persian Gulf, Hara Biosphere	-	3.54	-	-	-	79.8	36.6	Nowrouzi & Pourkhabbaz (2014)
North of Persian Gulf	-	-	-	-	139.9	138.5	18.2	Farsad et al (2011)

To discern and dissociate the absorbent and carrier of elements were undertaken AHC of elements, sulfur, and clay particles in the present research (Fig 10). Results indicate similarities and dissimilarities in the major absorber and carrier of elements in the sediments of salt domes, in which clay particles and sulfur have a strong

correlation with some elements and absorb or carry them. In contrast, the elements that do not have a strong correlation with these carriers are present in the combination of lithic fragments' minerals and have not entered the geochemical sedimentary phases.

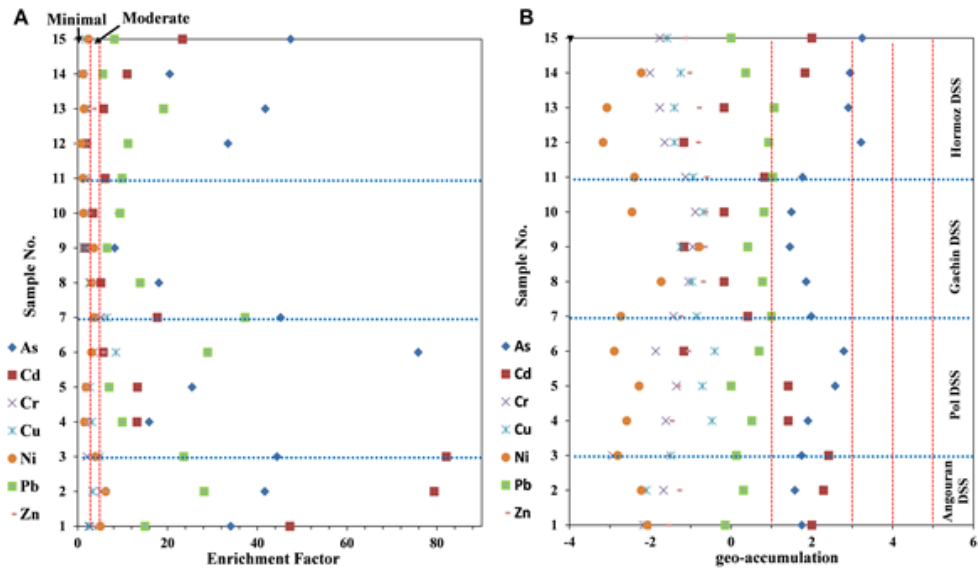


Fig 9. Enrichment factor (A) and I_{geo} level (B) of toxic elements in surface sediments of the study area.

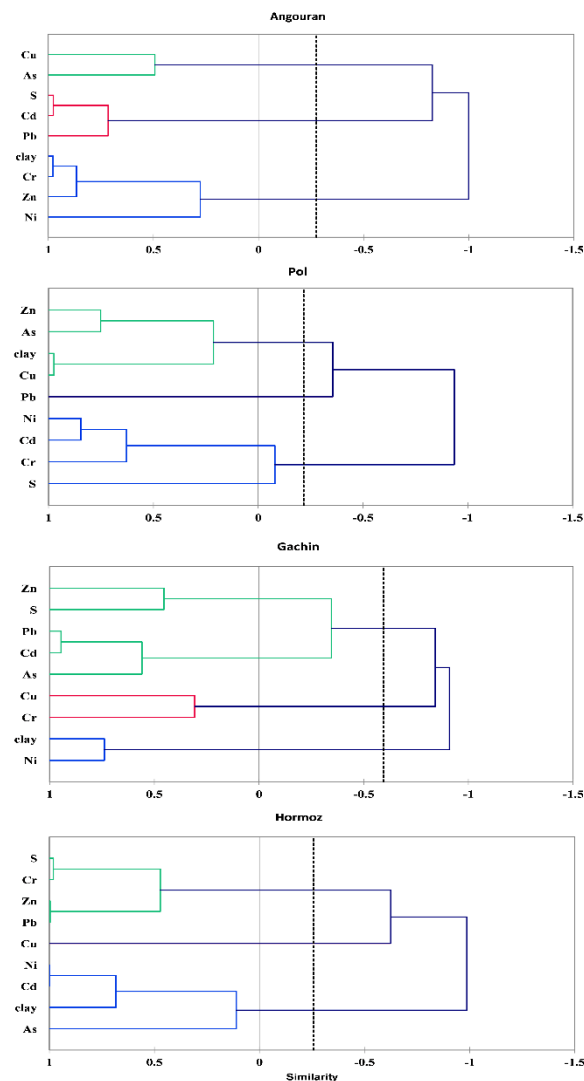


Fig 10. AHC of toxic elements, clay particles, and Sulfur in sediments of studied areas

Among these, the relation between the Enrichment factor and I_{geo} indicates the absorption or carry of elements. Moreover, it should be noted that all samples lacked organic material due to the lack of significant vegetation and other sources of organics. Based on the agglomerative hierarchical Clusters, Sulfur's Pearson's correction coefficient is 0.98 with Cd and 0.85 with Pb, which has a meaningful relation, being the major absorber of these chalcophile elements. The enrichment factor and I_{geo} level of Pb also confirm this result. Besides, Pearson's correction coefficient of clay particles with Cr, with Zn, is 0.97 which has a strong correlation and is the major carrier of these lithophile elements. In the Pol DSS, Clay particles have a strong correlation with Cu, As, and Zn with 0.97 Pearson's correction coefficient. So, it is the major absorber of these chalcophile elements due to the Enrichment factor and I_{geo} level of these elements. Pearson's correction coefficient of Sulfur has a strong correlation (0.75) with Zn in Gachin DSS and is the major carrier of this

chalcophile element, while clay particles are the major carrier of Ni siderophile element, which have a strong correlation with 0.74 Pearson's correction coefficient. Sulfur has meaningful relation respectively 0.55 and 0.98 Pearson's correction coefficients with Cu and Zn Chalcophile and Cr lithophile elements in the Hormuz DSS. Thus, being the major absorber of these elements. Clay particles with 0.70 Pearson's correction coefficient are the carrier of Cd and Ni in this area. The concentration of elements in sediments depends on the mineralogy of the source rocks in addition to geochemical processes. Therefore given the geochemical behavior and concentration of elements like as the studies by Levinson (1980); du Bray (1995); Smith and Huyck (1999); Butterman and Plachy (2002); Kądziałko et al. (2008); Dehbandi et al. (2019); Han et al. (2020) and Nyström et al. (2021) have been introduced the minerals forming source rocks, which have played a role in the geochemistry of DSS (Table 3).

Table 3: Source minerals of studied DSS as per elements percentage.

	Angouran	Pol	Gachin	Hormuz	Mineral resource
As	0.000X	0.00X	0.000X	0.00X	Fe-oxide and hydroxide, Sulfates
Cd	0.000X	0.0000X	0.0000X	0.0000X	Sulfides, Carbonates
Cr	0.00X	0.00X	0.00X	0.00X	Fe-oxide, Muscovite
Cu	0.00X	0.00X	0.00X	0.00X	Pyroxene, Plagioclase, Amphibole, biotite
Zn	0.00X	0.00X	0.00X	0.00X	Pyroxene, Plagioclase, K-feldspar
Ni	0.00X	0.00X	0.00X	0.00X	Plagioclase, K-feldspar, Sulfides
Pb	0.00X	0.00X	0.00X	0.00X	Plagioclase, Amphibole, biotite, K-feldspar, Sulfides

The concentration of As in the studied DSS was measured at about thousandth percent. Nyström et al. (2021) have measured the concentration of the As (semi-soluble element) (Taylor and Mc Lennan, 1995) at ~ 0.001 to 0.019 % in sulfidic and calcareous minerals/rocks. Dehbandi et al. (2019) argue that the average concentration of As in the evaporates of the Sirjan salt pan is 0.005% which has a strong correlation with SO_4^{2-} and HCO_3^- . Smith and Huyck (1999) have unveiled As in the Fe-bearing, mafic volcanic minerals. Given the concentrations of As in the sediments of the study area, Fe-oxide and -hydroxide minerals, gypsum, and anhydrite of HS are the main mineralogic source of this element (Table 3). The concentration of Cd in the studied DSS fluctuates ~0.000X% and less. Levinson (1980) has measured the concentration of Cd as a chalcophile element in minerals and rocks of the upper continental crust at ~0.0007%, which is related to sulfidic fluids. Butterman and Plachy (2002) believe that Cd and Zn have the capability to replacement in sulfides and carbonates. Nyström et al. (2021) have measured the concentration of Cd in sulfidic rocks/minerals at ~0.0002. Taylor and Mc Lennan (1995) and Rudnick and Gao (2014) have measured the average concentration of Cd in rocks and minerals of the upper continental crust at ~0.0009%. Concerning the concentration of Cd in the sediments of the studied area, the carbonate minerals in limestone and marl allied with the sulfidic volcanic of HS, and

carbonate rock units adjacent to salt domes, are suggested as the major mineralogic sources of Cd (Table 3). The concentration of Ni, Zn, Cu, Cr, and Pb in the studied DSS was measured at ~0.001%. Taylor and Mc Lennan (1995) measured their concentration 0.004, 0.007, 0.002, 0.008, and 0.002% respectively in the rocks/minerals of upper continental crust. Moreover, the measurement made by Rudnick and Gao (2014) indicates 0.005, 0.007, 0.003, 0.009, and 0.002%. Values measured by Nyström et al. (2021) for Cr, Cu, Pb, and Zn in sulfidic rocks and minerals are 0.002, 0.002, 0.005, and 0.007%. The concentration of Ni and Cu in deposits resulting from mafic-ultramafic minerals of the Tarim area in China was measured at ~0.004 and 0.003% by Han et al. (2020). In addition, they maintain that source minerals are a result of chalcogen and metalogen magmas. The concentration ranges of Cr in non-chromitic rocks belonging to volcanic-ophiolitic rock units of Poland's SW are between ~0.001-0.002%, being pertained to magnetite and hematite measured by Kądziałko et al (2008). Further, Levinson (1980) has related Cr, Cu, Zn, Ni, and Pb to the mineralogic sources of plagioclase, K-feldspar, pyroxene, amphibole, biotite, Fe-oxides, and muscovite as per their ~0.000 frequency. Concerning the concentration of such elements (~0.00X) in the studied DSS, mafic and ultramafic volcanic minerals of HS are suggested as the major mineralogic source of these elements (Table 3).

5. Conclusion:

The geochemical and environmental status of the sediments resulting from salt domes regarding their toxic elements were investigated in this study. The geochemical characteristics of the seasonal stream/waterway sedimentary environment as the sediment supply source of the coastal and shallow sea environments were assessed. Generally, As, Cd and Pb have the potential for toxicity because of the higher CRC level concentration around the salt domes of the Hormuz strait area. Given the proximity of Gachin, Pol, and Hormuz salt domes to the coast and the confrontation between sediments with coastal ecosystem and deposits, the intoxication contingency by As, Cd, and Pb in these areas is significant. The most major sources of As and Pb elements are minerals of the sulfate salts, Fe-oxides/sulfides and volcanic rocks of HS, and carbonate rocks (Asmari and Mishan Neogene formations) for Cd. Their significant enrichment has confirmed these elements accumulated in the sediments by sulfur and clay mineral adsorbents. In contrast, Cu, Cr, Zn, and Ni have lower concentrations than CRC levels around the salt domes of the Hormuz strait area. Therefore, the intoxication contingency by these elements in the study areas is minimal. The major sources of Cu, Zn, and Ni are mafic/ultramafic minerals of the volcanic rocks of HS, and Hematitic rocks and red soil are for Cr. Their low enrichment has confirmed these elements are carried from the sediments to the coastal area by sulfur and clay mineral adsorbents. It can cause the entry of these elements into the biological cycle in the coastal area. In this regard, it is recommended to conduct additional research on the environmental factors of coastal and shallow marine sediments of the Hormuz strait, also its fauna and flora.

Acknowledgment

The authors would like to thank Professor Stefan Dultz from the Institute of Soil Science, the Leibniz University of Hanover for his contribution to the analysis.

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