RESEARCH ARTICLE

Evaluation of Chemical contaminate of soil and salt collected from Al Shiqqah mining area

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Abstract: The mining soils in Kingdom Saudi Arabia have accumulated heavy metals, causing considerable contamination and grave environmental danger. This research highlights the amount of metal pollution in the central part of Saudi Arabia, especially in Al Shiqqah mining area at Qassim region. The study aims to evaluate the level of trace metal contamination in the Surface soil. Also, the objective of this study to determine the degree of pollution and potential ecological harm posed by trace metals.

Soil and salt samples were taken at random for four soil profiles at the surface (0–25 centimeter) and surface (25–50 centimeter). Heavy metals like manganese, nickel, cadmium, cobalt, chromium, copper and lead were measured in Al-Shiqqah mining samples by using atomic absorption spectroscopy instrument and the results were statistically analyzed. The study determined the concentrations of manganese, nickel, cadmium, cobalt, chromium, copper and lead in the surface and surface soils, to evaluate the degree of pollution and possible ecological hazards by utilizing the geo-accumulation index, contamination factor, degree of contamination and statistical analysis.

Overall, the metals' geo-accumulation index values in soil under investigation show: the subsequent downward tendency manganese> nickel> cadmium> cobalt> chromium> copper> lead. In the studied area, the geo-accumulation index associated with the seven investigated metals was high for manganese and was significantly too low for lead, cobalt, and copper. Cadmium and nickel give moderate pollution levels. Contamination levels of trace elements were calculated by contamination factor suggesting that soil was very highly contaminated with manganese and cadmium and extremely low in copper, chromium, and lead contamination, polluted with cadmium is moderately, and strongly with nickel. The degree of contamination, the readings for the soil samples showed that they were very low in lead, chromium, and copper, very high in degree of contamination with cobalt, moderately polluted with manganese and nickel, and highly contaminated with cadmium. According to the findings, the manganese concentrations in soil samples for the surface, salt, surface at depth 25 centimeter and surface at depth 50 centimeter were determined to be 5427.7998, 656.6250, 7037.7002, and 6853.7002 milligram per kilogram, respectively. These results were discovered to be greater than the WHO-permitted limits, which are 740 milligram per kilogram for soil.

The result illustrated that the contamination with heavy metals was high when in contrast to the soil's standard concentration of trace elements. Generally, it is possible to determine the natural or anthropogenic sources of heavy metals in soils by using multivariate analysis in conjunction with geo-accumulation index, contamination factor, degree of contamination value as helpful tools. The information gained can be used to better plan and implement remediation efforts and enhance the environmental conditions in areas affected by mining soil.

Keywords: Acidity, Al shiqqah mining, contamination, electrical conductivity, heavy metals, soil, statistical analysis

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1 Introduction

Metal pollution, especially in regions undergoing rapid development, is a growing environmental problem worldwide. (Koptsik and Koptsik, 2022; Samimi and Mansouri, 2023; Samimi et al., 2024). Excessive concentrations of heavy metals in a mining area's soil can endanger residents' health and seriously harm the environment (Birch and Olmos, 2008; Shohel et al., 2023). Soil contaminated by heavy metals poses a significant risk to the ecology and is among the world's most pressing environmental problems (Foley et al., 2011; Xu et al., 2019; Zhao et al., 2022). It is a large extent by human-caused operations including transportation. The usage of insecticides and fertilizers produced from sewage sludge, the extraction and processing of metal ores, the burning of fossil fuels, and several other industrial processes (Kabata-Pendias, 2011; Bradl et al., 2005; Zhongchen et al., 2019). The interaction of soil physio-chemical properties can influence heavy metal content such as soil granularity, potential of hydrogen (pH), and organic matter content (Ga siorek et al., 2017; Priya et al., 2023) which are essential for heavy metals' retention, mobilization, and transport in soil (Nazzal et al., 2014). Environmental and social problems are caused by pollution from mining activities (Shohel et al., 2023). There is growing proof that pollution caused by heavy metals in the mining sites has harmed the local population's health (Roba et al., 2016; Nawab et al., 2016; Wang et al., 2017; Nuapia et al., 2018; Priya et al., 2023) as well as the soil's health (Wahsha et al., 2016). There is no denying that the state of the soil affects the environment (Halecki and Ga siorek, 2015; Solgi, 2016). Heavy metal effects on soil ecosystems and human health have been the focus of attention in recent years (Zhou et al., 2014). The main causes of the formation of heavy metals (HMs) in soil are human production activities such mineral mining, chemical manufacturing, and fertiliser use in agriculture. (Angon et al., 2024) Mining is one of the main causes of heavy metal contamination in the soil. Large amounts of trash are produced during mining and are dumped close to the mine as tailings and overburden (Bhuiyan et al., 2010; Sadhu et al., 2012). Metallic ores are frequently abundant in these wastes which can be preserved for a very long period (Gebre and Debelie, 2015; Sana et al., 2023). Al Shiqqah, an area with high mining potential and agricultural activities, was a matter of concern that needed investigation to define the negative effect of mining activities on the area. The salt mining in the Al Shiqqah area in the Qassim region is considered one of the marshes or sabkha that are commonly related to terrestrial lands that are often exposed to flooding with rain(Amundson et al., 2015). The water in this area can stay for a few weeks or longer. The evaporation of water from shallow depressions leaves a crest of salt on top of the soil. This salt presents harsh environmental circumstances like high salinity and high temperature. The local people have been gathering salt for many years to use in cooking and other applications. In shallow water capture, where the sun evaporates most of the water, solar salt production typically occurs. After that, the accumulated salt precipitates (sodium chloride). The researcher noticed that the salt was only deposited in this apartment area and that there were no other nearby areas. This suggests that there may be radiation processes in the ground here, which could cause the salt to leach to the surface and mix with rainwater; when it dries, the salt precipitates. Additionally, some research in this area has revealed that fungal diseases are common among the local population, so the purpose of this research is to shed light on determining the causes. However, there are not enough environmental studies related to soil contamination in the Al Shiqqah area. According to a previous study done to investigate the microbiological studies of the fungi existing in this area (Mona et al., 2014). The heavy metal in the soil with high content in the Al Shiqqah mining area can cause serious environmental damage and can threaten the surrounding population's health. This study observed that there are high heavy metals content in soil and rural salt in the Al Shiqqah mining area. In air, soil, and water, heavy metals that can bioaccumulate and harm both the ecosystem and all living things include nickel (Ni), cobalt (Co), cadmium (Cd), copper (Cu), lead (Pb), chromium (Cr), and manganese (Mn). (Samimi and Shahriari-Moghadam, 2021; Samimi and Mansouri, 2023; Mueller et al., 2012). Numerous methods have been used in the literature to measure pollution because the soil concentrated heavy metals, including enrichment factor, contamination factor, and geo-accumulation index (Lu et al., 2014; Diyah et al., 2024). In addition, the threat that trace metals in soil pose to the ecology can also be measured using the ecological risk index, which provides a means of determining the quality of the soil environment (Bortey-Sam et al., 2015; Diyah et al., 2024). It is also possible to identify heavy metals in soil using a correlation matrix or multivariate analysis (principal component analysis) (Lu et al., 2014; Bai et al., 2011; Bai et al., 2011b; Diyah et al., 2024). Little effort has been made within the Kingdom Saudi Arabia (KSA) to monitor the accumulation, pollution levels, or heavy metal deposits in the Al Shiqqah mining region. Therefore, the necessity for research is urgent to provide information on the origins of heavy metals sources in soil and the ecological risk they pose, using principal component analysis in addition to ecological and pollution indices. A review of the literature shows that there is a lack of research on soil quality in KSA and no previous attempt has been made to specifically investigate metal contamination of Al Shiqqah mining soils and salt products in the Qassim region (Nazzal et al., 2014). This appears to be a worrying oversight, as identifying the quality of salt production and the side-effect of the mining process of soil contamination will help people who work in mining to apply scientific rules so that they are not exposed to the harmful effects of traditional mining, such as disease and soil damage.

Particular geological and meteorological factors, as well as particular circumstances like increasing urbanization and an increase in industrial, municipal, agricultural, residential, medical, and technological applications, seem to be the primary causes of heavy metal contamination in the environment at the moment. But the problem is more acute in many poor countries, presumably due to the lack of knowledge about the potentially harmful effects of these substances on human health and agricultural productivity. Heavy metal contamination and related biogeochemistry are major study topics worldwide in terms of exposure and health concerns. Heavy metal contamination, exposure toxicity, research gaps, effects on soil and plant health as well as human health implications are rarely assessed in current literature. (Angon et al., 2024). The study is recommended using more modern basins to receive salt water in the apartment area so that salt is not deposited on it after drying and reduces the rate of its mixing with heavy metals in the soil. The aims of this study are to achieve 1) Monitoring of trace metal levels in surface soils, 2) assessment of the level of contamination and the potential ecological risk posed by trace metals. This study has been carried out in Al Shiqqah mining soils, in 2022.

2 Materials and Methods

2.1 Study region and sample collection

The Al Shiqqah salt mining region served as the research site, where the most common salt rural industrial product for many purposes. It is located in a sabkha flat where large amount of water stagnate in this area after raining, and as it dries the salt are left behind on the soil surface. Where the salt in the selected studied area collected randomly from salt basins produced by miners. This area was chosen for study because it is the only region among the regions of Qassim in which salt is produced in a primitive manner by the local people, and as previous studies have shown the spread of fungal diseases among residents around this region.

Al Shiqqah traditional mining lies between longitude 43.40.0 east (E) and latitude 26.30.30 North (N) in Burydah City at Qassim region in KSA. The study area is situated 12 kilometers (km) (N) of Burydah city. The typical desert climate of Al-Qassim is characterized by hot summers, cold winters with lots of rain, as well as low humidity, around 20 percent (%). In the Qassim region, midsummer temperatures range from 36 to 41 degrees Celsius, while the wintertime average is only 11 degrees. The climate condition of the selected area of study was hot summers, colds in the winter. The area receives 100 millimeters (mm) of rain on average each year. Samples were taken in the summer season, and because of the rainy climate in the winter and spring, the rain will accumulate and remain stagnant in the study area for a long period of time.

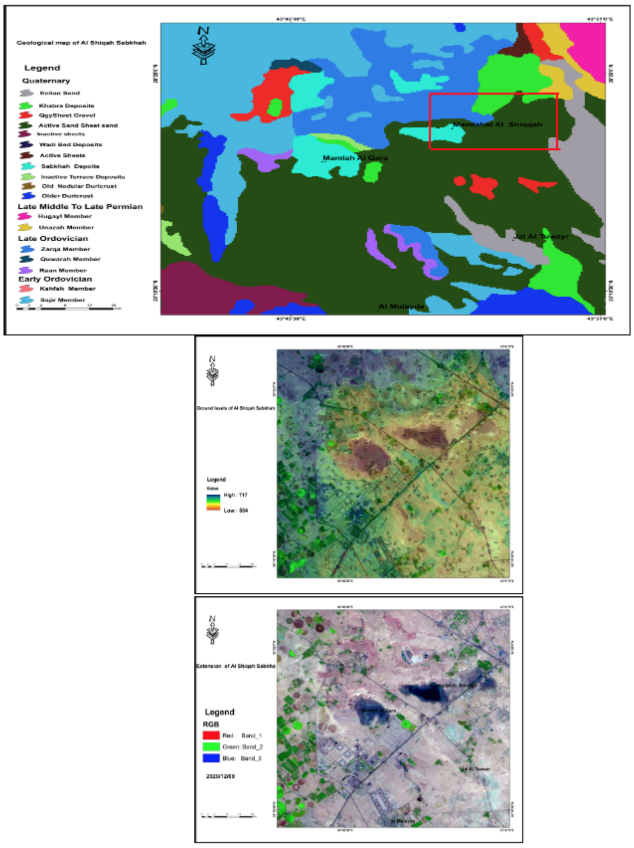

Figure 1. Geographic location of the study area along with the sample in studying area of Al Shiqqah mining for soil collection in Saudi Arabia.

The sampling location is precisely 1.5 km from the industrial site and 1 km from the discharge point of Al Shiqqah Mining. A global positioning system (GPS) was used to record all relevant environmental information about the sampling site at each sampling point. Geological data and the status of land use were recorded in order to guarantee that the sampled sites accurately reflect the quality of the soil throughout the monitored area. This gave background information. The Al Shiqqah mining sample sites included the salt mining region, the neighborhood along the major highway, the farms, and the pastoral areas (Figure 1).

2.2 Soil characteristics

The physical characteristics of soil are significantly impacted by mining activities. Changes in soil water content, cohesiveness, porosity, bulk density, and dry density are among these consequences, as are altered soil surfaces, reduced soil productivity, compaction, erosion, and sedimentation. The variability of mine soil qualities is increased by the randomization of soil dumping during mining.

2.3 Sampling procedure

In September 2022, soil samples were collected randomly based on mining. The majority of the locations were chosen in order to determine the current environmental pollutant. Since this is the primary route by which the heavy metal enters the body, the sites with the least amount of salt formation were chosen second. The soil samples were chosen because soil is the primary medium through which heavy metal contamination is produced. Hand gloves were worn to prevent contamination. Next, a steel shovel was used to scoop up the dirt after it had been dug up with a medium-sized knife. The sample of the soil was collected from the area study from 4 surface as 0-25 centimeter (cm) and surface as 25-50 cm soil profiles, and soil horizons. Each sample was given a unique number, carefully selected based on where it was located, to help identify it. Every 4 samples weighed between 0.5 and 1 kg. Within a sampling site, four distinct spots were chosen at regular intervals to collect soil samples. After being packed in polyethylene bags, the samples were brought to the lab, washed, left at air dry at room temperature for 14 days, and crushed, after this procedure, they were disaggregated, homogenized, and sieved < 2 mm fraction for the following physical and chemical analysis by using atomic absorption spectroscopy (AAS), UV range as 200-400 nanometer (nm) with detection limit of 0.0045 mg/kg. In cooperation with the central lab of Khartoum University, an AAS 6800, SHIMADZU, KYOTO, JAPAN, was employed to determine the overall heavy metal concentration in the soil. The current study compared the measured values with the limits set by the international standard. AAS was used to evaluate the presence of soil samples' heavy metals; such as Pb, Cd, Cu, Mn, Ni, Cr and Co. To put it briefly, a 2:1 water-to-soil ratio was achieved by combining each 25 gram (g) using 40 millilitres (mL) of deionized water for every soil sample. (Mohammad et al., 2017). To determine the levels of heavy metal pollution and the richness in the study area grown in the Qassim region, the following different pollution indicators for Cd, Co, Cr, Cu, Ni, Pb, and Mn were measured.

2.4 pH and electrical conductivity (EC)

A PH meter was used to measure the pH of 20 g of soil combined with 50 mL of 1 M KCL solution to determine the acidity of the samples whose findings are displayed in Table 2. The EC of the soil sample was measured with an EC meter in a 1:1 soil-water solution. (Bibi et al., 2023).

2.5 Contamination and accumulation assessment

To evaluate the levels of heavy metal accumulation and pollution in the cultivated study area in the Qassim region, the following metrics were used: the degree of contamination (DC), the contamination factor (CF), the geo-accumulation index (I_{geo}), and the measurements for Cd, Cu, Co, Ni, Pb, Cr, and Mn. Analytical techniques including AAS were used to identify elements such as Cd, Cu, Co, Ni, Pb, Cr, and Mn. When it comes to environmental indices such as the baseline values for the I_{geo}, CF, and DC are essential for figuring out how much of each element is present in soil samples (Raca et al., 2010; Szefer et al., 1996; Shohel et al., 2023).

2.6 Geo-accumulation index (I_{geo})

The degree of trace element pollution is measured using a variety of techniques. The single-factor index assessment, I_{geo}, and geo-statistics are the primary methodologies utilized to evaluate soil contamination by heavy metals from an environmental geochemistry perspective. I_{geo}, also known as the Muller index, was developed as a quantitative index in Europe by the German scientist Muller to study the contamination of sediments by heavy metals and other substances. The I_{geo} offers a pollution evaluation by contrasting pre-industrial and present concentrations, using Eq. 1 (Rayhan et al., 2019; Zhao et al., 2022):

$$I_{geo} = log_2 \left(\frac{C_n}{B_n \times 1.5} \right)$$

Where; Cn represents the content of the heavy metal in the surface and surface of the soil sample in the investigated area, Bn represents the geochemical background concentration of metal and the factor utilized to reduce the impact of any potential lithogenic changes in the soil which is equal to (1.5). Based on the I_{geo} readings, the following standards were used to assess the degree of soil metal contamination as shown in Table 1. (Weber et al., 2018; Bowen et al., 1982; Shohel et al., 2023).

2.7 Contamination factor (CF)

CF is one technique for tracking sediment pollution over time. It is defined as the ratio of the concentration of each metal in the current sample to its background values, using Eq. 2 (Rayhan et al., 2019; Diyah et al., 2024).

$$CF_i = \left(\frac{C_{metal\ of\ sample}}{C_{metal\ of\ background}} \right)$$

Where; the C metal of the background represents the background value and the C metal of the sample represents the observed value of the individual metal. This one pollution index indicates the level of contamination for each metal. The contamination factor of individual metals is denoted by CF_i. as follows: Low = ≤ 1, moderate = $1 \leq$ CF <3, significant = $3 \leq$ CF <6, and very high ≥ 6 are the possible outcomes.

2.8 Contamination Degree (CD) and contamination factor (CF_i)

The CD, which is the contamination factor of all metals in a sample, can be used to calculate the degree of contamination using the approach described by Hakanson(1980). The overall level of heavy metal pollution as of right now is shown by this index. The CD is intended to give an estimate of the total level of contamination in surface layers at a certain sampling location, using Eq. 3 (Mandal et al., 2022).

$$CD = \sum_{i=1}^{n=6} CF_i$$

In addition, to (Likuku et al., 2013) dividing the CD into four categories, the investigator in this investigation modified the element employed by Krzysztof et al. (2004), who employed a soil sample collected at a distance of 20 km (from an agricultural region) as a reference value, equivalent to the other variables.

Additionally, CD was measured as the sum of the CF_i for the identification of heavy metal content as follows (Hakanson, 1980; Mandal et al., 2022). The degree of contamination was assessed using the following criteria:

low levels of contamination CD ≤ 8 Moderate level of contamination, $8 \leq$ CD < 16 Significant levels of pollution $16 \leq$ CD < 32 extremely high levels of pollution CD ≥ 32

Table 1. Descriptive statistics of soil contamination indices for soil trace metal

Index class	I_{geo}	An explanation of the classes
1	$I_{geo} < 0$	Uncontaminated
2	$0 < I_{geo} \leq 1$	Moderately contaminated
3	$1 < I_{geo} \leq 3$	Considerably contaminated
4	$3 < I_{geo} \leq 5$	High contaminated
5	$5 < I_{geo}$	Extremely contaminated

3 Results and Discussion

The descriptive analysis results of the heavy metals concentration, EC, PH, and soil acidity in surface (0–25 cm) and surface (25–50 cm) soil samples in the Al Shiqqah mining area at Qassim region are displayed in Table 2, which represents the physical and chemical features of the soil in the research area.

Table 2. Result of pH and EC of soil samples at surface 25-50 and salt

Samples ID	pH	Electrical conductivity (EC) (ms/cm)
Surface	8.70	341
Salt	9.03	355
25 cm	9.40	111
50 cm	9.15	50.6

The examination of soil samples reveals that the EC was 341 and 355 milliSiemens per centimeter (mS /cm) in the surface soil and salt samples while EC was 111 and 50.6 mS/cm in the surface soil at depth of 25 and 50 cm respectively.

The mobility and storage of heavy metals are mostly influenced by the soil's pH. In cooperation with the Khartoum University Center lab, the total amount of heavy metals in the soil was ascertained (Zhao et al., 2012; Bibi et al., 2023). The average PH value in the research region ranged from 8.70 to 9.40, indicating highly alkaline soil in the analyzed area. Table 2 shows the result of PH and EC in the soil at Al Shiqqah area. The pH, and EC values of the soil revealed that the soils in Al-Qassim are typical of an Arab region, meaning they are calcareous, alkaline, saline, and arid.

Table 3. Shows the concentration of heavy metal in milligram per kilogram (mg/kg) of the surface soils of the Al Shiqqah mining area using AAS

Heavy metals	Concentration of heavy metal in samples			
	Soil surface mg/kg	Salt surface (mg/kg)	Soil dump 25 cm (mg/kg)	Soil dump 50 cm (mg/kg)
Cd	1.0350	1.2450	0.8300	0.1400
Pb	2.5700	21.0100	8.2450	8.9550
Ni	46.9700	8.9950	70.9950	108.9300
Co	4.2550	1.0650	7.4450	12.2350
Cr	3.7700	10.3250	1.2500	5.8150
Cu	6.5100	8.1400	37.4400	125.1400
Mn	5427.7998	656.6250	7037.7002	6853.7002

Table 3 shows the analysed result of Al Shiqqah soil samples by AAS and presents the total trace metal content in the surface as follows (Cd, Pb, Ni, Co, Cr, Cu, and Mn). Average total of Cd, Pb, Ni, Co, Cr, Cu, and Mn concentrations in surface soils were as follows: 1.0350, 2.5700, 46.9700, 4.2550, 3.7700, 6.5100, and 5427.7998 mg/kg respectively. Similarly, average total Cd, Pb, Ni, Co, Cr, Cu and Mn concentrations in the salt surface were as follows 1.245, 21.0100, 8.9950, 1.0650, 10,3250, 8.1400 and 656.6250 mg/kg correspondingly. These findings demonstrated that the surface soil had elevated average concentrations of Mn and Ni while Mn and Pb concentrations were slightly higher on the salt surface. According to Tabata-pandas (Hinojosa et al., 2004), toxicity can be reported when manganese levels exceed 1500 mg/kg. In this research, the content of manganese in the soil surface is 5427.7998 mg/kg while the content of manganese as salt was 656.6250 mg/kg and 7037.7002, 6853.7002 mg /kg at soil depths of 25 and 50 respectively. Ni, Pb, and Mn may be more toxic than other heavy metals (Järup, 2003; Rudnick and Gao, 2003), their environmental risks and the demand for remediation have greatly increased. Table 4 displays the trace metal content in mg/kg in surface soil at the tested region, along with the minimum, maximum, mean, and standard deviation (SD).

Table 4. The statistical analysis of the min, max, mean and SD of the heavy metals in soils of the KSA. From the table Mn has high level of contamination, Ni significant level, Co, Pb, Cu and Cr moderate level

Elements	Min	Max	Mean	SD	Worldwide values [40]	Background
Cd	0.205	1	0.447	0.19	0.62	0.17
Co	0.65	4.5	2.55	1.16	-	2.589
Cu	2	12	5.7	2.9	25.8	48
Pb	2	5.5	3.33	1. 9	29.2	29.84
Mn	5.5	100	39.01	52.8	760	159.54
Cr	1.45	7	3.65	2.579	84.0	92.0
Ni	2.7	10.5	6.167	3.46	33.7	4.760

3.1 Assessment of trace metal contamination

3.1.1 Result of geo-accumulation index (I_{geo})

I_{geo}, CF_i, and DC were the different pollution indices for Cd, Pb, Ni, Co, Cr, Cu, and Mn that were measured. This made it possible for researchers to evaluate the subject area's richness and heavy metal pollution levels in the Qassim region. According to I_{geo}, the following parameters are used to analysed the DC of the salt samples and soil surface in the investigated area according to criteria mentioned in Table 1, ($3 < I_{geo} < 4$) moderately to highly contaminated, ($3 < I_{geo} < 4$) very contaminated; ($I_{geo} < 1$) uncontaminated to moderately contaminated. The highest I_{geo} values presented in Table 5 showed that Mn contamination of the surface soil was highly (I_{geo} =6.827). However, the I_{geo} values indicated that soil sample had slightly Cd contamination (I_{geo} = 1.22175) and moderately contamination with Ni (I_{geo} = 1.980). The other heavy metals of the soil sample in the investigated area are Co, Pb, Cr, and Cu which indicate that the soil surface has not been contaminated according to I_{geo} values.

Table 6 shows that the other heavy metals of salt samples in the investigated area are Ni, Co, Cr and Cu which indicate that the salt surface has not been contaminated according to I_{geo} values. However, I_{geo} values indicated that the salt

Table 5. Shows the I_{geo} values of the sample at surface soil

Heavy metals	Mining side surface (C_n) (mg/kg)	constant	B_n	Constant* B_n	Log 2* C_n/ Constant* B_n	I_{geo}
Cd	1.0350	1.5	0.17	0.255	1.22175	1.22175
Pb	2.5700	1.5	29.84	44.76	0.01728	0.01728
Ni	46.9700	1.5	4.76	7.14	1.980	1.980
Co	4.2550	1.5	2.589	3.8835	0.3298	0.3298
Cr	3.7700	1.5	92.0	138	0.0822	0.0822
Cu	6.5100	1.5	48.0	72	0.0272	0.0272
Mu	5427.7998	1.5	159.54	239,31	6.827	6.827

Table 6. Shows the I_{geo} values of the salt sample

Heavy metals	Mining side salt (C_n) mg/kg	constant	B_n	Constant x B_n	Log2xC_n/ Constant x B_n	Igeo
Cd	1.245	1.5	0.17	0.255	1.4697	1.4697
Pb	21.0100	1.5	29.84	44.76	2.8307	2.8307
Ni	8.9950	1.5	54.60	7.14	0.379	0.379
Co	1.0650	1.5	5.5	3.8835	0.082548	0.082548
Cr	10.3250	1.5	92.0	138	0.0225	0.0225
Cu	8.1400	1.5	48.0	72	0.0340	0.0340
Mu	656.6250	1.5	159.54	239,31	0.8259	0.8259

sample was moderately contaminated with Cd (I_{geo} = 1.4697) and moderately to strongly contaminated with Pb (I_{geo} = 2.8307) and slightly contaminated with Mn (I_{geo} = 0.8259).

According to I_{geo} values presented in Table 7, the soil samples at depth of 25 cm has not been contaminated with pb, Co, Cr and Cu, while the soil was slightly contaminated with Cd, moderately contaminated with Ni and heavily contaminated with Mn.

Table 7. Shows the I_{geo} values of the soil sample at depth of 25 cm

Heavy metals	Mining side depth 25 cm (C_n) (mg/kg)	constant	B_n	Constant x B_n	Log2xC_n/ Constant x B_n	Igeo
Cd	0.8300	1.5	0.17	0.255	0.9795	0.9795
Pb	8.2450	1.5	29.84	44.76	0.05545	0.05545
Ni	70.9950	1.5	54.60	7.14	2.99	2.99
Co	7.4450	1.5	5.5	3.8835	0.577	0.577
Cr	1.2500	1.5	92.0	138	0.00273	0.00273
Cu	37.4400	1.5	48.0	72	0.1565	0.1565
Mu	7037.7002	1.5	159.54	239,31	8.852	8.852

The CF_i values of a single metal in the soil surface and salt samples were between 0.04097 - 34.02156 and 0.1122 – 7.323 respectively (Table 9). The highest values of CF_i were observed with Mn, Ni and Cd, based on the CF_i values, this result showed that the research area's soils are highly contaminated with Mn, Ni and Cd. On the other hand, the other trace metal worrying was Co with an average value of 1.643 in the soil sample which indicates that the sample investigated in the region had a moderate level of Co pollution. Based on CF_i values presented on Table 9, the salt samples strongly contaminated with Cd and high level of Mn contamination. While the CF_i values of the soil samples at depth of 25 cm show that the soil was strongly contaminated with Mn and Ni, highly contamination with Cd and moderate contamination with Co. On the other hand, the CF_i values of the soil samples at depth of 50 cm show that the soil was strongly contaminated with Mn and Ni, highly contamination with Co and moderate contamination with Cu. The other heavy metals like Cr and Pb are less than (1) illustrating that the soil is uncontaminated with this heavy metal based on CF_i values.

Table 8. Shows the I_{geo} values of the soil sample at depth of 50cm

Heavy metals	Mining side depth 50 cm (C_n) (mg/kg)	constant	B_n	Constant x B_n	Log2xC_n/ Constant x B_n	Igeo
Cd	0.1400	1.5	0.17	0.255	0.1653	0.1653
Pb	8.9550	1.5	47.00	44.76	0.0602	0.0602
Ni	108.9300	1.5	54.60	7.14	4.59	4.59
Co	12.2350	1.5	5.5	3.8835	3.683	3.683
Cr	5.8150	1.5	92.0	138	0.01268	0.01268
Cu	125.1400	1.5	48.0	72	0.523	0.523
Mn	6853.7002	1.5	159.54	239,31	8.62	8.62

For the seven analysed heavy metals, the CD was calculated in Table 10 for the soil surface, surface (25 and 50 cm) and salt sample of the investigated area. The CD indicate that the soil sample and soil samples at depth of 25 and 50 cm have been extremely high degree of contamination.

Table 9. Illustrates the contaminant factor for Al Shiqqah mining

Elements	CF_i			
	Soil surface sample mg/kg	Salt sample mg/kg	Soil surface sample mg/kg at depth of 25 cm	Soil surface sample mg/kg at depth of 50 cm
Cd	6.088	7.323	3.647	0.823
Pd	0,086	0.704	0.276	0.30
Ni	9.867	1.8897	14.799	22.884
Co	1.643	0.411	2.8756	4.72576
Cr	0.04097	0.1122	0,01358	0.0632
Cu	0.1356	0.1695	0.78	2.607
Mn	34.02156	4.1157	44.1124	42.959

Table 10. Illustrates the degree of contamination for Al Shiqqah mining area

CD			
Soil surface sample (mg/kg)	Salt sample (mg/kg)	Soil surface sample mg/kg at depth of 25 cm	Soil surface sample mg/kg at depth of 50 cm
51.88213	14.624	66.20358	74.36196

3.2 Statistical analysis of heavy metal content soil samples

The figures below display the findings of the statistical study of seven heavy metals found in Al shiqqah mining soil in the AL Qassim district. The sample's description statistics indicate that the range of heavy metal element content in the study area's soil is from high to low Mn > Ni > Cu > Co > Cr > Pb> Cd.

The soil surface had a cadmium level of 1.035 mg/kg in soil surface, 1.245 mg/ kg as salt product, 0.83 mg/ kg in soil surface at dump 25 cm and 0.14 mg/ kg in soil surface at dump 50 cm. The lead content in the soil surface was 2.5700 mg/ kg in soil surface, 21.0100 mg/kg as salt product, 8.2450 mg/ kg in soil surface at dump 25 cm and 8.9550 mg/ kg in soil surface at dump 50 cm. Ni and Mn may be more toxic than other heavy metals. In mining soil in the Al shiqqah area, the background value can be obtained. Explicatory statistics of elemental abundances (mg/ kg) in soil samples. Figure 3 to 8 show the statistical analysis of sample concentration for Pb, Cd, Ni, Co, Cr, Cu, and Mn.

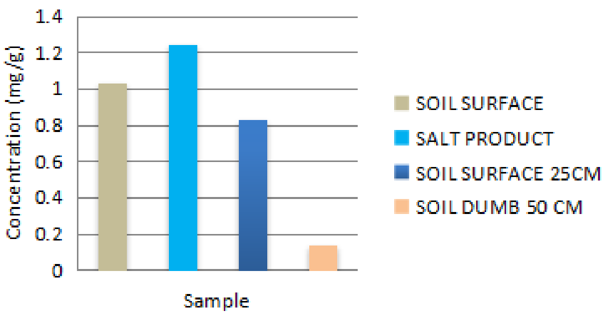

Figure 2. Cd concentration in Al shiqqah soil samples.

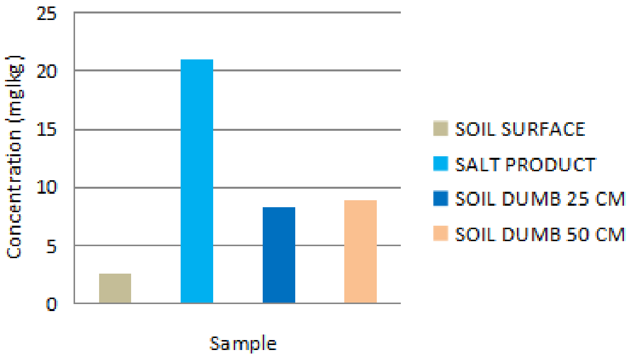

Figure 3. Pb concentration in Al shiqqah soil samples.

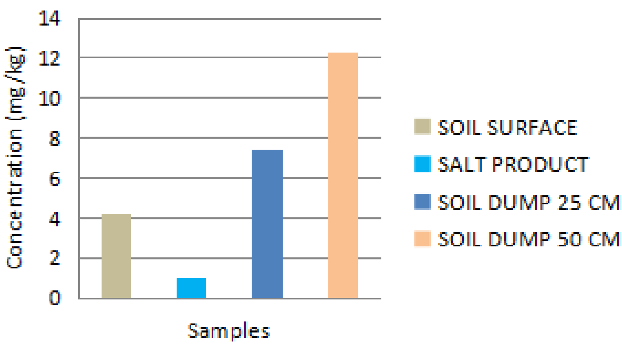

Figure 4. Ni metal concentration in Al shiqqah soil samples.

4 Conclusion

Heavy metal contamination in mining soil is a crucial environmental assessment and management aspect. The conclusion drawn from such evaluations typically depends on several factors, including the specific heavy metals present, their concentrations, the extent of contamination, and the potential risks posed to the environment and human health.

The study of heavy metal evaluation in Al Shiqqah Mining Soil and Salt presents critical insights into the environmental

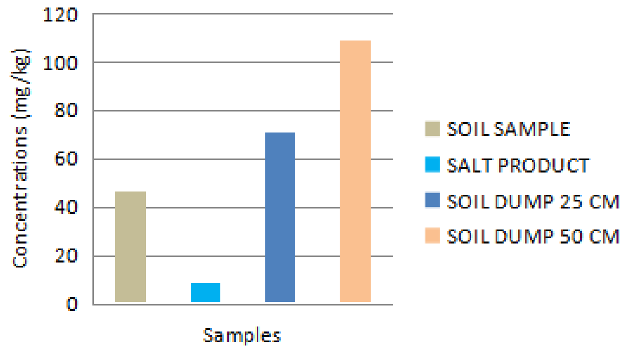

Figure 5. Co concentration in Al shiqqah soil samples.

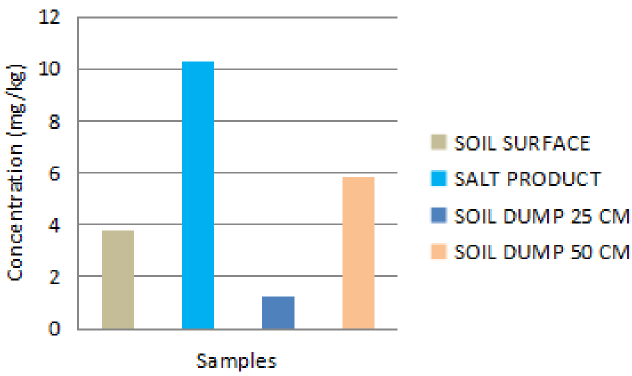

Figure 6. Cr concentration in Al shiqqah soil samples.

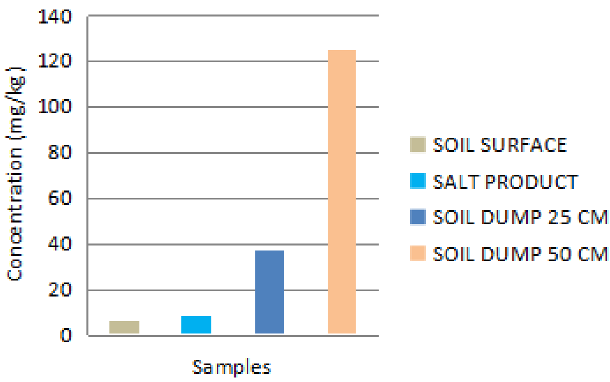

Figure 7. Cu concentration in Al shiqqah soil samples.

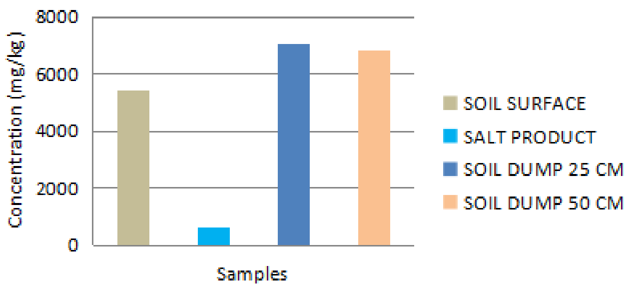

Figure 8. Mn concentration in Al shiqqah soil samples.

impact of mining activities on soil and salt quality. Through meticulous analysis, it has been revealed that heavy metal concentrations in both soil and salt samples surpass permissible limits, indicating significant contamination. This contamination poses a threat not only to environmental integrity but also to human health, as these heavy metals can accumulate in the food chain. This study sheds light on the significant presence of heavy metals in mining soil, highlighting the environmental repercussions of mining activities. Through rigorous sampling and analysis, elevated levels of metals such as lead, chromium, cadmium, copper, Nickel, cobalt, and manganese exceeding permissible limits set by environmental regulations in several sampled sites were identified.

The Al Shiqqah mining area of the Qassim region was studied to assess the degree of heavy metal pollution using AAS analysis, and theoretical statistical agents like DC, CF_i, and I_{geo}. Based on I_{geo} values, The findings indicated that the soils had a very high level of Mn contamination and a moderate level of Ni contamination. The overall soil concentrations in the samples from Al Shiqqah are shown to be the outcome indicates that the amount of heavy metal present in salt mining samples Mn >Pb > Cr> Ni> >Cu > Cd >Co but in soil sample (surface the highest metal concentration is Mn > Ni > Cu> Co > Cr > Pb > Cd, soil sample dep 25 cm, Mn > Ni > Cu> Pb > Co > Cr> Cd and soil sample dep 50 cm, Mn > Cu> Ni > Co > Pb > Cr > Cd. Overall, the analysis's findings demonstrated that, in comparison to the criterion for soil trace element concentration, the rate of heavy metal contamination was high. The concentrations of Mn are increasing in each specimen. Nevertheless, the concentrations of Pb, Ni, Cu, and Co are moderate, whereas Cd is lower. Human activities that release trace metals into the environment include mining, and wastewater disposal. The tar sands and diamond and metal mining can release trace metals into the surrounding environment. This often occurs when contaminated waste is not properly disposed of or when a lot of dust from the mine site blows around. The findings underscore the urgent need for remediation measures to mitigate the adverse effects of heavy metal contamination in the Al shiqqah Mining area.

Implementing effective soil and water management strategies, such as phytoremediation and sedimentation ponds, can help alleviate the spread of contamination and restore ecological balance. Furthermore, the results of this study emphasize the importance of sustainable mining practices that prioritize environmental conservation and community well-being. By adopting responsible mining techniques and adhering to stringent environmental standards, it is possible to minimize the negative impacts of mining activities on surrounding ecosystems and safeguard the health and livelihoods of local populations.

Interprofessional collaboration between the domains of toxicology and soil science is required for these research topics. Scientists can help create long-term strategies to reduce heavy metal pollution and protect ecosystems and human health. (Angon et al., 2024).

Through the results of the study obtained, it was clear that the high concentrations of heavy elements in the apartment's soil and the salt produced in a primitive manner by the miners, which draws attention to the use of more modern methods in the salt extraction process and benefits scientists interested in the environmental field to take the necessary measures to get rid of these Pollutants, which contribute to local environmental sanitation.

Author Contributions

Muneera Alrasheedi, the corresponding author, has contributed in data curation, formal analysis, funding acquisition, investigation, resources, writing, editing and manuscript preparation. A. Elhassan, participated in the conceptualization, data curation, formal analysis, supervision, investigation, resources, writing and editing.

Conflict of Interest

The authors declare that there is no conflict of interest regarding the publication of this manuscript. In addition, the ethical issues, including plagiarism, informed consent, misconduct, data fabrication and/or falsification, double publication and/or submission, and redundancy, were observed by the authors.

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