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Original Research Paper

Potential adverse effects of heavy metals in Ahvaz oil field

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Abstract

In the present study, the potential adverse effects of heavy metals in the soil of Ahvaz oil field were evaluated. 9 soil samples were collected and chemical digestion was performed. Global standard methods was used to collect samples and measure metals. Heavy metals Ni, Cd, Pb, Zn, Cu were measured. and geochemical indicators were evaluated. Average concentrations of heavy metals in soil samples were Cd 0.16, Pb 16.63, Zn 22.03, Cu 10.39, Ni 62.97 ppm. The igeo index findings demonstrated that the values for the metals Ni, Cd, Pb, Zn, and Cu were at an uncontaminated level. TRI index values of metals were Moderate. EF of Cd and Ni wer moderate. CF index of Pb is considerable and cf of Cd and Ni and Zn were moderate. The results of CD, MCD, PLI indicators showed that heavy metals in the studied soils are at the level of contamination. The amount of this contamination was moderate to considerable. The ecological risk of these metals was considerable.

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1. Background

Heavy metals are ubiquitous in the soil environment and are characterized by refractory degradation, long-lasting harm, irreversible enrichment, and food chain enrichment.Through crop enrichment, they reduce crop quality and yield, indirectly affecting human and animal health and endangering the entire ecosystem (Thomilson 1980; Babaei et al., 2017; Farsani et al., 2022; Wang et al., 2023). Crude oil-associated heavy metals burden in the contaminated land is still considered as one of the major issues around the globe. Previous reports have established that crude oil contains several inorganic and carcinogenic pollutants such as heavy metals that cause heavy risks to the surrounding environment (Khalili Arjaghi et al., 2020; Borah and Deka, 2023). The soil, being the ultimate part of the ecological system, is profoundly polluted by crude oil associated heavy metals (Vane et al., 2020). Moreover, heavy metals persist in the soil for a long time due to their adherent quality and therefore the soil is considered the major sink for HMs (Mostofie et al., 2014; Hardi et al., 2019). The HMs after entering the soil may percolate deep beneath the ground and may lead to groundwater contaminations (Arjaghi et al., 2021; Borah and Deka, 2023; Hosseinzadeh and Parvaneh, 2020; Jafari et al., 2017).

The main sources of heavy metals in the water are atmospheric precipitation, discharge of industrial wastewater and urban sewage,mineralmining, and infusion of surface runoff (Fateai et al., 2012; Gashtasbi et al., 2017; Collin et al., 2021).

Heavy metals have serious complications, including mutagenic effects, carcinogenic effects, toxicity, accumulation in adipose tissue, and long shelf life (Fataei et al., 2011; Maanifar et al., 2015; Hamid et al., 2022). Heavy metal substances endanger the health of living beings (Nikpour et al., 2020; Aguilera et al., 2021). the environmental impact of the petroleum industry is correspondingly extensive and expansive. All activities related to oil & gas exploration, production, storage and transportation involve waste generation associated to potential risk to the environment(Masoumi et al., 2020; Nasir et al, 2021).

The oil industry is one of the key industries in Iran and the rest of the world owing to its critical role in supplying energy and generating raw materials for many other industries. Moreover, a highly significant source of soil heavy metal pollutants exists in this industry. Despite its importance, the oil industry is also considered as one of the polluting industries(Abbaspour et al., 2013; Ghorbani et al.,2020).

The potential hazards of these metals must be assessed (Jalilzadeh et al., 2014; Aguilera et al., 2021; Kowalska et al., 2018).Monitoring and evaluation of HMs associated risk factors in the contaminated lands have been felt essential for adopting the risk-based remediation approach. (Fataei et al., 2012; Kordestani et al., 2020; Mehrdoost et al., 2021; Borah and Deka, 2023).

Oil and gas issues and their pollution in Iran is very complicated especially when it is decided to increase the energy products that can have various impacts on environment components (Karbbasi et al., 2015; Jalilzadeh Yengejeh et al., 2017).

In the Ahvaz oil field, numerous drilling by the oil company in the region causes major pollution, due to drilling operations of oil and gas wells and oil pollution in the region. Afkhami et al., (2013) showed higher concentrations of As, Cd & V are related to oil drilling activities, and also geological structures at different depths(Karbbasi et al., 2015).

In this study, soils of Ahvaz oil field were chemically analyzed in order to determine concentration of 8 heavy metals (Cd, Ni, Pb, Zn, Cu) and also the intensity of pollution the geochemical indices of metals were determined and the quality of pollution in the regions was investigated.

2. Materials and Methods

Table 1. The indicators measured in this study

Geo-accumulation index (Igeo)
Enrichment factor (EF)
Contamination factor (CF) and contamination degree (CD)
Modified degree of contamination (mCD)
Pollution load index (PLI)
Toxic unit analysis (ΣTUS)
Ecological risk factor (Ei)rand potential ecological risk (PER) index
Nemerow integrated pollution index(NIPI)
Toxic risk index (TRI)

Ahvaz oil field (67 km long and about 6 km wide) is Iran's largest oil field located in Khuzestan province, southwest of Iran. It is also Iran's largest crude oil-field in terms of its crude oil storage capacity and the world's third largest oil field after Ghawar (Saudi Arabia) and Burgan (Kuwait). On average, the crude oil production capacity of Ahvaz oil field is 800,000 barrels per day; its gas production capacity (gas plus oil) is over 13 million cubic meters per day. The field's crude oil storage capacity is estimated at more than 65 billion barrels, from which approximately 37 billion barrels can be extracted on average(Ghorbani et al.,2020). In this study, 9 soil samples were collected. The samples were collected and transported to the laboratory and analyzed according to standard methods (Sadigh et al., 2015; Karbasi et al., 2015). The concentration of nickel, zinc, lead, copper, cadmium metals was measured (ppm).The pollution of these metals was evaluated with geochemical indicators. The indicators measured in this study are listed in Table 1(Ghorbani et al., 2020. Sirajul Islam et al., 2022. Wang et al., 2023. Borah and Deka, 2023)

3. Results and Discussion

The average concentrations of the measured metals are presented in Table 2.

Table 2. Average concentrations of heavy metals in soil samples

Metals	Cd	Pb	Zn	Cu	Ni
Average	0.47	62.013	88.8	38.31	170.22
Max	0.78	91.503	118.773	58.76	247
Min	0.26	40.932	52.623	26.55	65
STD	0.16	16.63	22.003	10.39	62.97

1.3. Geo-accumulation index (Igeo)

The Igeo is broadly applied in the appraisal of metal contamination in sediments (Proshad et al., 2019. Ghorbani et al., 2020) simply matching actual quantities to pre-industrial background levels, and it may be derived employing Muller (Muller 1969). The Igeo scale classified as seven classes(Sirajul Islam et al.,2022).
Formula 1

$$I_{geo} = \log_2(C_n / 1.5 \times B_n)$$

The results of the igeo index showed that the value of this index for all the studied metals are in zero class (non-contaminated).

2.3. Enrichment factor (EF)

The enrichment factor (EF) is a useful measure for determining the extent of heavy metal contamination caused by humans. Through using equation below, the EF for every component was determined to assess manmade implications on heavy metals in sediments.The content of Fe was employed as a reference element in sediments in this study since it enables for differentiation across native and enhanced element contents. The grades of enrichment have been recommended with Sirajul Islam et al.,2022(Table3).
Formula 2

$$EF = \frac{(^{C_M}/_{C_{Al}})Sample}{(^{C_M}/_{C_{Al}})Background}$$

Table 3. EF index results

Metal	Cd	Pb	Zn	Cu	Ni
Index	4.40	2.08	0.25	0.54	3.2
Class	moderate	mild	no enrichment	no enrichment	moderate

3.3. Contamination factor (CF) and contamination degree (CD), Modified degree of contamination (mCD) and Pollution load index (PLI)

To explore the contamination level of heavy metal in sediments, CF has been commonly employed by many authors previously (Khan et al., 2020. Wang et al., 2023). The CF is the ratio of each metal's measured concentration in the sediment to its background concentration, as determined by Rudnick and Gao (2014). The following formula was used to compute the CF for each metal stated by Håkanson (1980). The CD was determined by the sum of all the contamination factors for all of the elements to disclose the degree of potential toxic metal in sediments (Håkanson, 1980; Sirajul Islam et al.,2022.). The mCD evaluates every sediment sample using a unique contamination indicator (Håkanson, 1980).

The PLI assesses cumulative poisoning load at multiple places using different metals in soils and sediments, and provides an assessment of the overall toxicity score within each sample site (Islam et al.,2022). PLI was calculated for all sample sites using the given formula proposed by Tomlinson et al. (1980) as the nth root of the product of the contents multiplications. This quantitative indicator provides a quick and easy way to compare the severity of metal pollution, where PLI > 1 point to pollution be present, contrariwise, if PLI < 1 terms as absence metal pollution (Proshad et al., 2021 Borah and Deka, 2023)

Formula 3 $$CF = \frac{C_i}{C_b}$$

Formula 4 Cd=

Formula 5 $$\mathrm{mCD} = \frac{1}{n}\sum_{i=n}^{1} \mathrm{CF}_i$$

Formula 6

$$\mathrm{PLI} = \sqrt[n]{(\mathrm{CF}_1 \times \mathrm{CF}_2 \times \mathrm{CF}_3 \times \ldots \mathrm{CF}_n)}$$

The results of the CF index for each metal are shown in Table 4, and the results of the MCD, PLI, and CD indices are shown in Table 5.

Table 4. CF index for each metal

Metal	Cd	Pb	Zn	Cu	Ni
Index	2.38	4.96	1.26	0.69	2.269
Class	moderate	considerable	moderate	low	moderate

Table 5. results of the MCD, PLI, and CD indices

Index	value	class
Cd	11.57	considerable
Mcd	2.31	moderate
Pli	1.88	point to pollution be present

3.4. Toxic unit analysis (TUS)

Prospective cytotoxic effect of toxic compounds in surface sediments is defined as the sum of toxic units (ΣTUS) (Sirajul Islam et al., 2022). The toxic unit (TU), which is calculated as the proportion of the weighted content of toxic components in sediments to the probable effect level (PEL), reflects the intensity beyond which detrimental effects are supposed to happen often. threshold effect level (TEL) specifies the pollutant concentrations below which no detrimental impacts on sediment-dwelling life forms are envisaged, and a probable effect level (PEL) identifies the concentration above which prospective deleterious effects on sediment-dwelling life forms can be perceived (Sirajul Islam et al., 2022). (Fig1)

Formula 7

$$E_r^i = T_f^i \times C_f^i$$

Formula 8

$$\mathrm{PER} = \sum_{i=1}^{n} E_r^i$$

ΣTUS index = 5.32.

When the aggregate of toxic units (TUs) for all assessed surface sediments exceeds 4, toxic metal toxicity ranges from moderate to severe (Proshad et al., 2019).

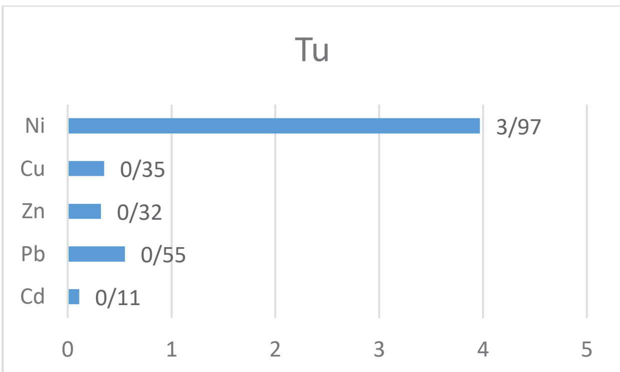

Fig 1. Tu value for each metal

3.5. Ecological risk factor (Eir) and potential ecological risk (PER) index

The potential ecological risk index approach developed by Håkanson (1980) was employed, which reveals benthic population susceptibility to hazardous substances and illustrates the PER induced through cumulative toxicity (Islam et al.,2022; Proshad et al., 2021). The potential ecological risk coefficient Ei r of a particular metal and the potential ecological risk index PER of multi-metals can be determined using the formulae below:(Sirajul Islam et al., 2022):

Formula 9 $$E_r^i = T_f^i \times C_f^i$$

Formula 10 $$PER = \sum_{i=1}^{n} E_r^i$$

The goal of this strategy is to acquire a more precise assessment of the probable dangers of heavy metal contamination in sediments at the index level, not merely the quantity of pollution extent (Zhang et al., 2018).

Table 6. Ecological risk index values of metals

Metal	Index	Class
Cd	71.5	considerable
Pb	24.80	considerable
Zn	1.26	considerable
Cu	3.48	considerable
Ni	11.348	considerable
PER	112.40	considerable

3.6. Nemerow integrated pollution index (NIPI)

An integrated strategy which is compatible with huge value analysing not just work of individual elements but also significance of a component with more severe pollution (Proshad et al., 2021). The Nemerow (1985) composite index was computed as follows:

Formula 11 $$Pi = Cn / Bn$$

Formula 12 $$NIPI = \sqrt{\frac{(Pi_{av})^2 + (PI_{max})^2}{2}}$$

Table 7. NIPI index values of metals

Metal	Cd	Pb	Zn	Cu	Ni
NIPI	3.23	6.25	1.49	0.90	4.95
Class	high level of pollution	high level of pollution	low	warning	high level of pollution

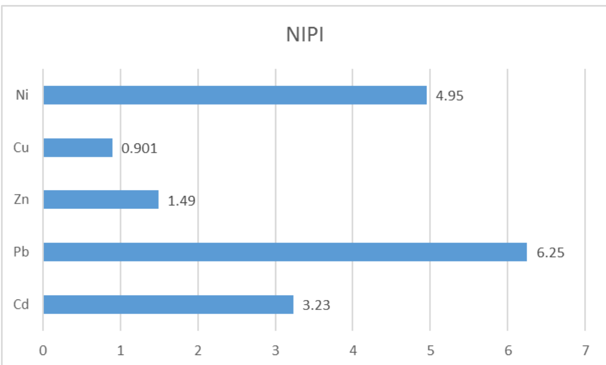

Fig 2. NIPI index values of metals

3.7. Toxic risk index (TRI)

For the toxic risk assessment of heavy metals in sediments, the TRI technique relies on TEL and PEL influences (Hakanson 1980; Zhang et al., 2018). The TRI for a single substance was weighed spending the principle below(Sirajul Islam et al., 2022):

Formula 13 $$TRI_i = \sqrt{\frac{(C_i/TEL)^2 + (C_i/PEL)^2}{2}}$$

Formula 14 $$TRI = \sum_{i=1}^{n} TRI_i$$

Table 8. TRI index values of metals

	value	class
Cd	0.57	low risk
Pb	2.72	low risk
Zn	0.54	low risk
Cu	0.77	low risk
Ni	6.87	low risk
TRI	11.49	Moderate

4. Conclusion

The mean concentrations of the metals Ni, Cd, Pb, Zn, and Cu in the soil of the Ahvaz oil field is shown in Table 2. Compared to other metals, nickel metal has a greater mean concentration. The results of CD, MCD, PLI indicators showed that heavy metals in the studied soils are at the level of contamination (Table 4, 5). The amount of this contamination is moderate to considerable (Table4, 5, 6). These metals are toxic to soil organisms (Fig1). The ecological risk of these metals is considerable (Table6). Nickel, lead and cadmium are three metals that pollute the environment(Tab6, 7, 8 and Fig2). Nickel and lead metals have higher toxicity and pollution(Fig1,2). Ghorbani et al., 2020 investigated the potential hazard to human health from exposure to heavy metals in surface soils of Ahvaz oil field. Metals such as Co, Cr, and V were observed to originate from natural sources and As, Cd, Cu, Ni, Pb, and Zn originated from anthropogenic sources such as petroleum leakage and the pollution caused by drilling mud from oil wells. Pb and Zn were of significantly high EF mean enrichment value, and Co, Cu, Cd, and As had high enrichment in surface soil. Pb, Cr, V, Zn, Co, Cu, Ni, and As had a low potential ecological risk (PER) whereas Cd had a moderate PER.

Karbassi et al., 2015 studied heavy metals in the surface soil of Ahvaz oil field. In this study, oil fields' soils of Ahvaz city (Ab-Teymour) were chemically analyzed in order to determine the concentration of eight heavy elements (Cu, Ni, V, Co, Cd, Zn, Mo and Pb) and intensity of contamination. The results show that concentration of studied metals is higher than earth's crust mean values. According to Muller's geochemical index, intensity of contamination varies from unpolluted to highly polluted ones. Evaluation of the level of pollution and potential ecological risk of some heavy metals in surface Soils in the Ahvaz oil-field in N azarpor et al., 2017. The mean concentration of heavy metals was as follow: Pb (251.20), Ni (94.6), Cu (75.80), Zn (132.84), Cd (0.69), V (4.97) and Cr (141.48) (mg/kg). The average value of enrichment factor in the soil samples decreased as Pb>Ni>Cu>Cr>Zn>Cd>V. Nemrow integrated pollution index (NIPI) indicated high level of pollution for the studied heavy metals except V. The Potential ecological risk of the studied heavy metals showed a low potential ecological risk for V, Cd, Zn and Cr; Cu showed a moderate risk and Ni and Pb indicated a considerable ecological risk. The mean value of the risk index indicated that 27 (55.10%) of the soil samples with a moderate risk, 21 (42.85%) with a considerable risk and one sample (2.05%) with a high ecological risk(Nazarpor et al., 2017).

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