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Original Article

Evaluation of Cancer Risk Index of Cadmium, Lead, and Nickel Heavy Metals in Agricultural Lands of Some Cities of Khuzestan Province, Iran

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Abstract

Background & Aims: This study aimed to assess the health risks and ecological hazards of heavy metals cadmium, lead, and nickel in agricultural soils of Khuzestan province in 2018.

Materials and Methods: In this study, sampling was gathered from three farms in three cities (Baghmalek, Shavur, and Shushtar) and five points with three replications. A plot with dimensions of 10×10 m was considered in the field, and four soil samples were taken from four sides of the plot and one from the center of the plot with 0-30 cm depth, and finally the composite sample was obtained.

Results: The average of cadmium, nickel, and lead in the soils of Baghmalek, Shavur, and Shushtar was 5.04, 83.44, and 312.64 mg/kg, respectively. The mean values of cadmium and nickel in the soils of the studied fields were higher than the global average values, but the amount of lead in the studied soils was lower than the global average. Moreover, the ecological risk of heavy metals in soil showed that the farms in Baghmalek and Shavur have an extremely high ecological risk, and Shushtar had a severe ecological risk.

Conclusion: Based on the calculation of pollution indices, soils in Baghmalek, Shavur, and Shushtar had heavy metal contamination of cadmium, lead, and nickel and had human origin. In this study, the risk index of heavy metals was less than 1, and it was only higher than 1 in the case of lead metal in children absorbed by ingestion. The carcinogenic risk index of metals also indicated that nickel has the potential for carcinogenesis in children.

Keywords: Soil pollutants, Metals, Heavy, Neoplasms, Risk

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1. Introduction

Agricultural soil pollution with heavy metals is a serious and growing problem. The entry of toxic metals through human activities contaminated many natural ecosystems [1,2], so the pollution intensity in these soils is higher than normal or will soon exceed the standard limit [3]. The permissible limit of heavy metals in soil may be high in some soils and lower in others because heavy metals can generally enter the soil from rocks near the soil floors and take a toll on human health [4,5]. Many heavy metals may exist in soil and rocks in different chemical compositions. These changes in the structure of heavy metals may be due to oxidation processes and reduction in different acidity [6]. Heavy metals are naturally present in the environment with different concentrations, among which toxic and dangerous metals are also observed [7]. Heavy metal pollution can be of natural origin and anthropogenic origin and ultimately affect the environment [8].

The contamination of water and soil resources by heavy metals and pseudo-metals causes fundamental changes in ecosystems and can have destructive effects on the environment by entering into the life cycle [9,10].

The main source of soil pollution by heavy metals is due to human activities such as mining, industrial activities, and the infusion of fertilizers and enriching materials. Mineral activities also cause soil erosion as a result of exposure to a wide range of heavy metals [11,12]. Heavy metals in soil can have different levels depending on the soil layer and class. Moreover, the type and amount of chemical fertilizers added to the soil affect the accumulation of heavy metals in the soil [13].

The harmful effects of heavy metals on human health have been proven in different ways. Exposure to these pollutants causes acute and chronic poisoning as well as numerous diseases including neurological disorders, food poverty, hormone imbalance, obesity, abortion, respiratory and heart disorders, liver and kidney damage, allergies and asthma, chronic viral infections, reduced tolerance threshold, gene degradation, premature aging, memory loss, osteoporosis, hair loss, insomnia, cancer, and death [14,15].

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The most destructive effect of heavy metals is due to increased free radical oxidation. A free radical is a free and energetic molecule that has an unpaired electron and absorbs another electron from other molecules to achieve equilibrium [16]. In the presence of toxic metals or the lack of antioxidants, free radicals are produced in an uncontrolled manner. Free radicals can destroy different tissues and tissue corruption [17]. This study aimed to assess health risks and determine the ecological hazards of heavy metals such as cadmium, lead, and nickel in some agricultural soils of Khuzestan province.

2. Materials and Methods

In this study, samples were taken from three regions in Khuzestan province, including agricultural farms in Shushtar, Shavur, and Baghmalek counties. Shushtar is located in the north of Khuzestan province, between 48° and 35 minutes to 49° and 12 minutes east longitude from the Greenwich Half Lunch and 31° and 36 minutes to 32° and 26 minutes north latitude from the equator. Baghmalek is located in the east of Khuzestan province and is located at 49° 53 minutes in geographical length and 31° 31 minutes latitude. Furthermore, Shavur is one of the suburbs of Shush, 15 km away from this city, and is located on Ahvaz Andimeshk road.

In September 2018, three farms in each city were visited, and soil samples were taken from each farm from five points with three replications (Figure 1). For sampling a plot with dimensions of 10 × 10 m in range, four soil samples were taken from four sides of the plot and one from the center of the plot from 0-30 cm depth, and finally the composite sample was obtained. Soil samples were then encoded, recorded, and transferred to the laboratory using nylon bags.

Soil samples were placed in polyethylene beakers and were heated in an aqueous bath at 100 °C until approaching the drying stage by adding some drops of hydrochloric acid and hydrofluoric acid at 7 cc level. After cooling, 7 cc of nitric acid and hydrochloric acid were added to each and heated in the water bath until near drying. After the chemical digestion of all samples and by adding some distilled water to each one and gentle heat, a completely transparent solution was obtained [18].

All samples were injected with normal hydrochloric acid in a volumetric flask to a volume of 50 cc and were injected into ICP-OES model Varian 710-ES, located in Alborz Chemical Laboratory of Shahrekord (Trustee of Environment Organization) which had been calibrated to determine the amount of desired elements in each sample [19].

To evaluate the contamination of the studied soils, the contamination factor (Cf) was used, in which *Co* was the concentration of each element in the soil, and the average concentration of each element in the field was *Cn* [20].

$$Cf = Co \div Cn$$

The pollution factor of less than 1 category is low, in the

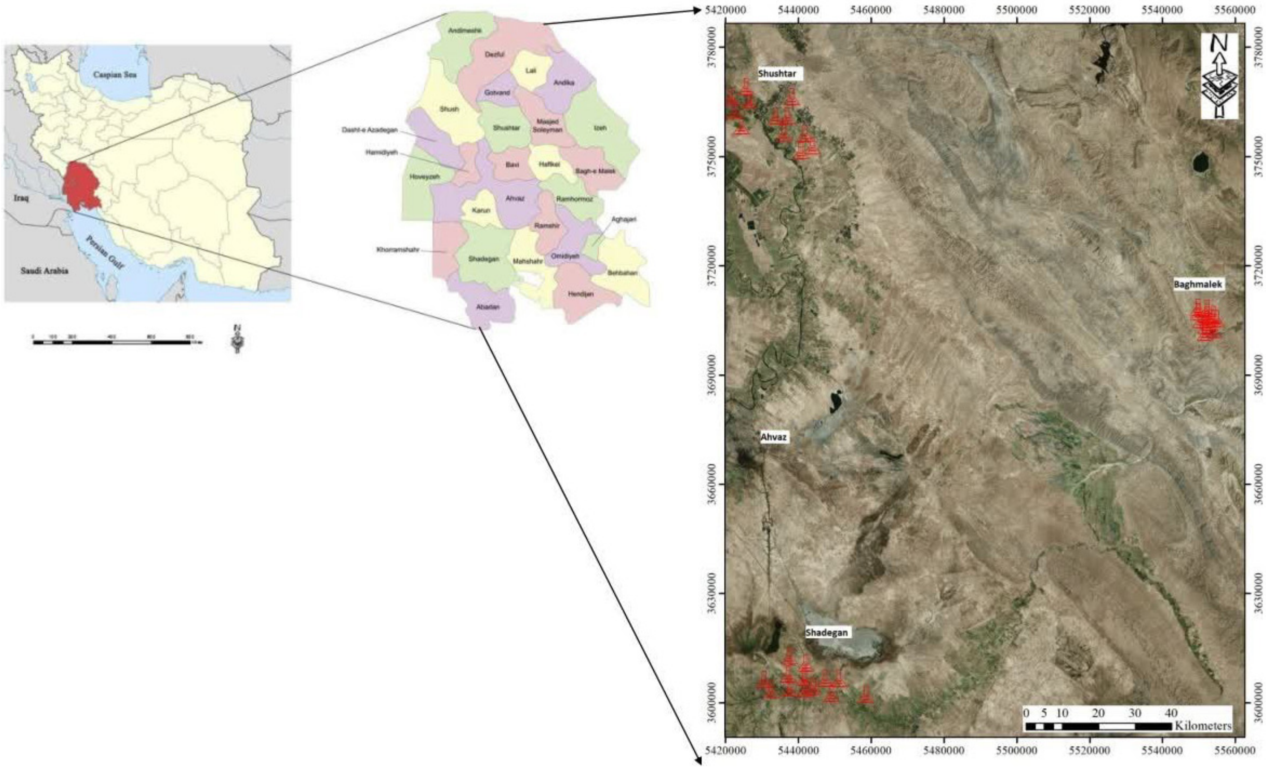

Figure 1. Geographical Location of Soil Sampling Sites from Agricultural Fields of Khuzestan Province

range of 1-3 is moderate pollution, between 3-6 is high pollution, and higher than 6 is a highly polluted category. The sum of pollution factors for the studied elements indicates the degree of contamination (Cdeg) that was obtained from the following equation. Regarding the degree of contamination, the values of less than 8 show low pollution categories, the range of 8-16 levels is moderate pollution, the range of 16-32 is high pollution, and higher than 32 indicates highly contaminated categories [20].

$$Cdeg = \Sigma\ Cf$$

Based on the limitations of the *Cdeg* equation, Abrahim introduced the modified contamination degree, obtained from the following equation [21]:

$$mCd = \Sigma\ Cf \div n$$

Modified levels of pollution of less than 1.5 non-contaminated represent an extremely small degree of pollution, between 1.5-2 is low pollution, between 2-4 depicts medium pollution, between 4-8 shows high pollution, between 8-16 is extremely high pollution, between 16-32 indicates ultra-high pollution, and greater than 32 represents an extremely high degree of environment pollution based on modified pollution grade [21]. The pollution load index was calculated using the following equation. In this formula, CF is the pollution factor which was obtained from the equation of the pollution factor for each metal. The pollution load index values vary from zero (uncontaminated) to 10 (highly polluted). Typically, values smaller than 1 indicate non-contamination, and values greater than 1 indicate contamination relative to heavy metals [20]:

$$PLI = \sqrt[3]{CFCd \times CFNi \times CFPb}$$

The enrichment factor for each metal was calculated from the ratio between the normalizing element to the base value of the elements according to the following equation [22]:

$$EF = (Metal\ /\ Fe)_{Sample} \div (Metal/\ Fe)_{Background}$$

The range of changes of less than 2 enrichment is low, the range of 2-5 is medium enrichment, 5-20 is high enrichment, 20-40 is extremely high enrichment, and above 40 is highly enriched according to the enrichment factor [22].

Ecological risk assessment and biohazard potential index (RI) of rice fields were calculated from the following relationships. In this regard, CF is the pollution factor, Er illustrates the ecological risk of each studied element, and RI ecological risk represents the sum of elements. Hakanson defined the value of TR, which is a toxicity index of heavy metals, for analyzing the values obtained by four different groups [20].

$$Er = TR \times CF$$
$$RI = \Sigma\ Er$$

Ecological risk less than 150 represents low ecological risks, ranges between 150-300 indicates moderate ecological risk, 300-600 shows extreme ecological risk, and more than 600 reflects extremely severe ecological risks. Moreover, the potential RI has several classifications: RI of less than 40 shows low risk, between 40–80 is moderate risk, 80-160 illustrates high risk, 160–320 represents extreme risk, and higher than 320 reflects extremely high risk [20].

The health risk assessment of heavy metals was based on the health risk assessment method provided by the US Environmental Protection Agency. For this assessment of carcinogenic and non-carcinogenic risks, exposure to metals from all three pathways of ingestion, respiration, and skin absorption is considered. The average daily dose of heavy metals in each of the pathways was calculated using the following equations [23]:

$$ADD_{ing} = \frac{C \times IngR \times CF \times EF \times ED}{BW \times AT}$$

$$ADD_{inh} = \frac{C \times InhR \times EF \times ED}{PEF \times BW \times AT}$$

$$ADD_{dermal} = \frac{C \times SA \times CF \times AF \times ABF \times EF \times ED}{BW \times AT}$$

In this regard, ADD_{dermal}, $ADD_{inh,}$ and ADD_{ing} are respectively the average daily absorption of metals (mg/kg-day) through ingestion, breathing, and skin absorption.

C is the concentration of metals in soil (mg/kg), ingestion rate (IngR), and soil respiration rate (InhR) (mg/day and m^3/day), EF is frequency of metal exposure (day/year), ED is time of exposure (year), BW indicates body weight of the exposed person (kg), AT reflects the duration of exposure to any amount of metals on average (day), EF is diffusion factor ($/m^3/m^3$), SA is the surface area of the skin exposed to metals (cm^2), AF indicates dirt-to-skin adhesion factor (mg/cm^2-day), and ABF represents skin-surface absorption factor (without units). The non-carcinogenic risk of total ingestion, respiration, and skin absorption pathways for children and adults was determined from the total daily intake of heavy metals in each pathway to the reference value of that metal by the following relationship [23]:

$$HQ = \Sigma \frac{ADD}{R_f D_i}$$

In this regard, the non-carcinogenic hazard of metals in each pathway is ADDi of the daily absorption of metals in each of the metal exposure pathways (mg/kg-day). If the HQ is less than 1, it is not inconsistent with human health, and if the HQ is higher than 1, it has adverse and worrying effects on human health. The value of the total non-carcinogenic accumulation index for both adults and children was obtained from the following relationship [13]:

$$HI = \sum HQ_i$$

Carcinogenic risk assessment of each of the three pathways for these metals was performed using the following relationship [23]:

$$RI = \sum ADD_i \times SF_i$$

Regarding the high RI of carcinogenicity, ADDi is the daily absorption of metals in each metal exposure pathway (mg/kg-day), and SF_i is the risk factor for cancer per unit of exposure to metals (mg/kg/day). Data analysis was then performed using SPSS 24 software, the mean of treatments was compared using one-way ANOVA, and the presence or absence of significant difference was determined at the level of 5% ($P=0.05$). The normality of data was evaluated by the Kolmogorov-Smirnov test, and Excel 2007 software was used to draw charts and tables.

3. Results

Statistical parameters of cadmium, lead, and nickel in the soil of agricultural fields are presented in Table 1. Skewness and elongation values of heavy metals showed that the data are homogeneous and normal for statistical analysis.

There was no significant difference in the mean cadmium content in fields 1, 2, and 3 in Baghmalek, Shavur, and Shushtar counties ($P>0.05$), but there was a significant difference between fields 1 and 2 in Baghmalek ($P<0.05$). The mean cadmium in the soils of Baghmalek, Shavur, and Shushtar was 7.22 ± 0.42, 5.89 ± 0.43, and 2.02 ± 0.71 mg/kg, respectively. The mean lead content in fields 1, 2, and 3 in Shavur and Shushtar had a significant difference ($P<0.05$); however, there was no significant difference between fields 2 and 3 in Baghmalek farm 1 ($P>0.05$). The mean lead in the soils of Baghmalek, Shavur, and Shushtar was 10.72 ± 1.29, 530.52 ± 25.73, and 396.68 ± 34.19 mg/kg, respectively. Furthermore, the mean amount of nickel in fields 1, 2, and 3 in Baghmalek, Shavur, and Shushtar counties had significant differences ($P<0.05$), and the mean of nickel metal in the soils of Baghmalek, Shavur, and Shushtar was 89.69 ± 8.39, 76.49 ± 3.12, and 84.14 ± 4.39 mg/kg, respectively (Table 2).

Cadmium (24.06) and nickel (1.31) in soil samples of Baghmalek were higher than those in Shavur and Shushtar. The highest amount of lead CF was 26.52, and

Table 1. Statistical Parameters of Heavy Metals (mg/kg) in the Soil of Fields in Some Cities of Khuzestan Province

Metals	Mean ± SD	Variance	Variance	Skewness	Kurtosis
Cadmium	5.04 ± 0.38	0.63	10.797	1.353	1.702
Lead	312.64 ± 22.82	43.45	5995.26	-0.518	-1.564
Nickel	83.44 ± 5.84	10.55	3008.399	0.984	-0.231

Note. SD: Standard deviation.

Table 2. The Average Concentration of Heavy Metals (mg/kg) in the Soil of Farms in Some Cities of Khuzestan Province

Heavy Metals	Study Area	Farm 1	Farm 2	Farm 3
Cadmium	Baghmolek	4.0 ± 66.01[a]	4.0 ± 14.02[a]	12.0 ± 86.05[b]
	Shavur	6.0 ± 41.03[a]	5.0 ± 42.02[a]	5.0 ± 84.03[a]
	Shushtar	2.0 ± 75.11[a]	2.0 ± 18.07[a]	1.0 ± 13.03[a]
Lead	Baghmolek	12.0 ± 28.61[a]	9.0 ± 45.19[b]	10.0 ± 42.33[b]
	Shavur	503.1 ± 18.93[a]	526.1 ± 30.62[a]	562.1 ± 07.49[a]
	Shushtar	402.2 ± 99.16[a]	354.2 ± 55.28[b]	432.4 ± 51.49[a]
Nickel	Baghmolek	28.0 ± 24.65[a]	44.0 ± 35.82[b]	196.0 ± 48.49[c]
	Shavur	177.2 ± 23.02[a]	49.2 ± 50.02[b]	62.0 ± 75.62[c]
	Shushtar	142.1 ± 98.87[a]	34.2 ± 92.69[b]	74.2 ± 52.70[c]

Note. Different letters in each row showed significant differences between the studied farms ($P<0.05$).

the lowest amount of nickel in Shavur soil samples was 1.12. The highest amount of lead enrichment factor in soils cultivated in Shushtar was 71417.25, and the lowest amount of this index was 902.96 in the cultivated soil of Baghmalek. In the case of cadmium metals, the highest values of enrichment factor in the soil cultivated in Shavur were 46166.53. In addition, the highest amount of nickel in the soil of Shushtar was 4460.34, and the highest ecological risk assessment values of cadmium and nickel in the soil of Baghmalek farms were 721.80 and 6.55, respectively. Moreover, the highest ecological risk (132.60) was observed in the agricultural soil of Shavur, and the highest ecological risk potential index in agricultural soil samples cultivated in Baghmalek was 731.03 (Table 3).

The results of the calculation of the pollution grade index and modified degree of pollution showed that the amount of these indices in Shavur soil samples (47.27 and 15.75) was higher than those in Baghmalek and Shushtar soil samples, and the lowest level of this index was observed in Baghmalek soil samples (25.90 and 8.63). Additionally, the highest and lowest indices of pollution load were obtained in Shavur and Baghmalek soil samples, respectively (Table 4).

The daily absorption of nickel by ingestion in Kurkan (1.06×10^{-3} mg/kg/day) was higher than other ways of entering the body and than other metals. The lowest absorption rate was related to cadmium in adults through breathing (8.13×10^{-9} mg/kg/day).

In this study, the amount of heavy metals, namely, cadmium, lead, and nickel in adults and children was

Table 3. Contamination Factor, Enrichment Factor, and Ecological Risk Assessment of Heavy Metals in Soil Samples of Farms in Khuzestan Province

Index	Study Area	Cadmium	Lead	Nickel	RI
Pollution factor	Baghmalek	24.06	0.536	1.31	
	Shavur	19.63	26.52	1.12	
	Shushtar	6.73	19.83	1.23	
Enrichment factor	Baghmalek	40543.57	902.96	2224.45	
	Shavur	46166.53	62374.19	2647.95	
	Shushtar	24245.04	71417.25	4460.34	
Ecological risk assessment	Baghmalek	721.80	2.68	6.55	731.03
	Shavur	588.90	132.60	5.60	727.10
	Shushtar	201.90	99.15	6.15	307.20

Note. RI: Risk index.

Table 4. Degree of Pollution, Modified Degree of Pollution, and Load Index of Heavy Metals in Soil Samples of Farms in Khuzestan Province

Study Area	Degree of Pollution	Corrected Pollution Degree	Pollution Load Index
Baghmalek	25.90	8.63	2.56
Shavur	47.27	15.75	8.35
Shushtar	27.79	9.26	5.47

higher than that in respiration and skin by ingestion. The highest RI was related to lead in children (1.142), and the lowest was related to cadmium in adults (8.13×6^{-10}), as depicted in Table 5. The non-carcinogenic and carcinogenic RI indicated that the highest values are lead (1.154) and nickel (3.29×10^{-4}) in children, respectively. The lowest RI of carcinogenesis was obtained in adults on cadmium metal (2.98×10^{-6}), while the lowest non-carcinogenic index in adults was related to cadmium metal (3.49×10^{-2}), as illustrated in Table 6.

4. Discussion

The mean cadmium content in the soils of Baghmalek, Shushtar, and Shavur in Khuzestan province was higher than the global mean (0.41 mg/kg) [24]. The concentration of cadmium in the soils of Baghmalek, Shushtar, and Shavur farms was lower than the quality standard of soil resources in Iran (3.9 mg/kg). Industrial, urban, and agricultural activities significantly affect total cadmium concentration [25]. In addition, regardless of atmospheric subsidence, the most important route of the entrance of cadmium to urban dust is phosphorous fertilizers of agricultural lands in the countryside and around cities. Furthermore, cadmium enters the environment from the rupture and wear of the tires [26]. Cadmium is one of the most well-known pollutants in the environment, which enters the environment through both natural and artificial sources, especially the lithosphere. The most important artificial sources of soil contamination and consequently agricultural products with cadmium can be the discharge of industrial sewage sludge, application of superphosphate fertilizers, landfill of non-ferrous waste in the land, and the location of agricultural lands limited to lead and zinc mines or refineries [27,28]. The mean concentration of lead in the soils of Baghmalek, Shavur, and Shushtar had a significant difference ($P < 0.05$), and it was lower than the global average (27 mg/kg) [23]. Furthermore, the concentration of lead in the fields of Baghmalek, Shushtar, and Shavur in Khuzestan province was lower than the quality standard of soil resources in Iran (300 mg/kg).

The effect of urban activities and industrial use is one of the reasons for the high lead content in the soil of this region. Moreover, fossil fuels, coal fuels, vehicle traffic, and red-lining materials are also factors that increase lead in soil [29,30]. The use of fertilizers with no production and expiration dates, which forces farmers to overuse these fertilizers due to reduced crop efficacy and subsequently pollute the environment, crops, and ultimately humans, can be one of the causes of lead in soil [31].

Moreover, the mean amount of nickel in the soils of Baghmalek, Shushtar, and Shavur in Khuzestan province was higher than the global average (80 mg/kg) [23]. The concentration of nickel in the soils of Baghmalek, Shushtar, and Shavur in Khuzestan province was higher than the standard of quality of soil resources in Iran from the environmental point of view (50 mg/kg). The total amount of nickel in the soil is 1 to 200 mg/kg and is 20 mg/kg on average, and the toxicity level of this element in the soil is typically 40 mg/kg [32].

Heavy metal (e.g., nickel) precipitation from the atmosphere to the earth owing to the combustion of fossil fuels, exhaustion of automobiles, metal smelting, chemical industries, burning of waste, and large fires is due to the chemical contamination of soil to this element. Chemicals used in agriculture, drainage of sewage, abandoned industrial places such as gas plants, electrical industries, tanneries or leather industries, and even sports and recreational activities such as shooting are highly effective in nickel metal contamination in soils [33,34].

The highest amount of nickel in the soils of farms in the Perlis area of Malaysia was 3.87 mg/kg, while the lowest amount of this metal was 2.04 mg/kg, and nickel was lower than the permissible limit [35]. Nickel concentration in agricultural field soil of Enugu state in Nigeria was reported to be 3.46 mg/kg [36]. Tasrina et al reported the concentration of nickel in Japanese soil to be 18.36-22.77 mg/kg, respectively (5), and comparing the amounts of these metals in the present study indicates that the amount of soil in Japan is lower than that in the present study. This is due to differences in soil sex and structure, differences in the type of contamination, and even the quality of irrigation water [37]. Nickel-producing resources include the combustion of fossil fuels and oil used in cars [38]. The cadmium and nickel CF in soil samples in Baghmalek was higher than that in Shavur and Shushtar. The highest concentrations of lead

Table 5. Daily Absorption Rate (mg/kg-day) and Health Hazard Index of Heavy Metals in Soil Samples of Fields in Khuzestan Province

Heavy Metals	Health Risk Indicators	Swallow		Breathing		Skin	
		Adults	Children	Adults	Children	Adults	Children
Cadmium	Daily absorption rate	8.64×10^{-5}	6.44×10^{-4}	8.13×10^{-9}	1.80×10^{-8}	2.63×10^{-6}	1.03×10^{-6}
	Risk index	0.008	0.064	8.13×10^{-6}	1.80×10^{-5}	0.026	0.010
Lead	Daily absorption rate	5.36×10^{-4}	3.99×10^{-3}	5.04×10^{-7}	1.12×10^{-6}	1.63×10^{-4}	6.39×10^{-5}
	Risk index	0.153	1.142	1.43×10^{-4}	3.18×10^{-4}	0.031	0.012
Nickel	Daily absorption rate	1.43×10^{-4}	1.06×10^{-3}	1.34×10^{-7}	1.44×10^{-4}	4.35×10^{-5}	1.70×10^{-5}
	Risk index	0.047	0.355	0.0004	0.001	0.072	0.028

Table 6. Non-carcinogenic and Carcinogenic Risk Index of Heavy Metals in Farm Soil Samples in Khuzestan Province

Heavy Metals	Non-carcinogenic Risk Index		Carcinogenic Risk Index	
	Adults	Children	Adults	Children
Cadmium	3.49×10^{-2}	7.47×10^{-2}	4×10^{-7}	2.98×10^{-6}
Lead	1.84×10^{-1}	1.154	1.65×10^{-7}	1.23×10^{-6}
Nickel	0.120	0.385	4.42×10^{-5}	3.29×10^{-4}

CF were found in Shavur soil samples, while the lowest amount of nickel CF was observed in Shavur soil samples. Considering that the amount of cadmium CF in the soil of Baghmalek, Shavur, and Shushtar farms was more than 6, this metal is highly contaminated at the highly contaminated surface.

Based on the results of nickel, less than 1 was obtained in the soils of Baghmalek, Shavur, and Shushtar farms, indicating low contamination of this metal in the soils of the studied areas. Lead contamination in Shavur and Shushtar cities was higher than 6 which was highly contaminated, but the lead CF in Baghmalek farms was less than 1, indicating the absence of this metal. The amount of heavy metal contamination showed that the soils of Baghmalek and Shushtar farms were highly polluted, and the soils from the farms of Shavur were highly contaminated. Based on the calculation of soil contamination degree in Baghmalek and Shushtar farms, the range of 8-16 was obtained which indicates a high level of soil pollution. The soil pollution index of the farms of Baghmalek, Shavur, and Shushtar was higher than 1, indicating that soil pollution in studied areas was higher than heavy metals of cadmium, lead, and nickel. Moreover, pollution load index values vary from zero (uncontaminated) to 10 (highly contaminated). Normally values smaller than 1 indicate non-contamination, and values larger than 1 display contamination relative to heavy metals [39].

The highest amount of lead enrichment factor was related to lead in soils cultivated in Shushtar, and the lowest amount of this index was related to lead in the cultivated lands of Baghmalek. In the case of cadmium metals, the highest values of enrichment factor were obtained in soils cultivated in Shavur. In addition, the highest amount of nickel metal index was observed in soils cultivated in Shushtar. Moreover, the highest amount of lead enrichment factor was related to the soil under cultivation in Shushtar, and the lowest amount of this index was related to lead in the cultivated lands of Baghmalek. In the case of cadmium metals, the highest values of enrichment factor were obtained in soils cultivated in Shavur.

Furthermore, the highest amount of nickel metal index was observed in soils cultivated in Shushtar. The concentrations of heavy metal enrichment factors for cadmium, lead, and nickel in the soils of Baghmalek, Shavur, and Shushtar showed that the soils of these regions are highly polluted. According to the results, the enrichment of cadmium, lead, and nickel can be attributed to human origin. The main source of heavy metal entry is through anthropogenic activities, industrial and industrial operations, agriculture and urban wastewater, and human activities [40].

Moreover, fires in forests, plains, wetlands, and rangelands are also one of the main factors causing the entry of these metals into the atmosphere and finally into aquatic and soil ecosystems [41]. The highest ecological risk assessment values of cadmium and nickel were obtained in the soil of the cultivated lands of Baghmalek, while the highest ecological risk was observed in the soil of the cultivated lands of Shavur. Additionally, the highest ecological risk potential index was obtained in soil samples of cultivated lands in Baghmalek.

Ecological risk of cadmium showed an extremely high risk in the soil of Baghmalek and Shavur farms and in the soil of the farms of Shushtar. The ecological risk of lead was classified as low risk in Baghmalek soils and high risk in the soils of Baghmalek and Shushtar. In the case of nickel metal, the ecological risk of soils was obtained in the low-risk category.

In this study, the RI of heavy metals was less than 1, and it was higher than 1 only in the case of lead metal in children absorbed by ingestion. The carcinogenic RI of metals also revealed that nickel has carcinogenic potential for children. According to the US Environmental Protection Agency, if the daily absorption of metals exceeds the reference value of metal toxicity in each pathway, the non-carcinogenic risk of metals in each route will be higher than the permissible limit, which has adverse and worrying effects on human health [23].

In a study on health risk assessment of heavy metals in surface soils of Bojnourd, it was reported that the highest intake and absorption of lead and cadmium in children was through ingestion [42] which is consistent with the results of this study. Furthermore, the health risk assessment of heavy metals in agricultural soils in Bangladesh showed that the total RI for each metal was lower than 1, and the amount of carcinogenic risk was less than 6-10 [43]. In the study on soil contamination by heavy metals such as cadmium, nickel, and lead in Nigeria, the risks of lead carcinogenesis for children and adults were higher than acceptable [44]. The average agricultural soil RI in China due to exposure to nickel, cadmium, and lead had non-carcinogenic risks for children because the RI was higher than 1 [45].

5. Conclusion

The results of this study showed that the mean values of cadmium and nickel in the soils of Baghmalek, Shushtar, and Shavur farms in Khuzestan province are higher than the global average, but the amount of lead in the soils of the studied regions was lower than the global average. Based on the calculation of pollution indices, soils in Baghmalek, Shavur, and Shushtar have heavy metal contamination of cadmium, lead, and nickel and have anthropogenic origin. The potential ecological risk of heavy metals in the soils of Baghmalek and Shavur farms showed an extremely severe ecological hazard, and there was a severe ecological hazard in the soils of the farms of Shushtar. In this study, the RI of heavy metals was less than 1, and it was higher than 1 only in the case of lead metal in children absorbed by ingestion. The carcinogenic RI of metals also indicated that nickel has carcinogenic potential for children.

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Funding acquisition: Khoshnaz Payandeh.
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Methodology: Khoshnaz Payandeh.
Project administration: Seyed Mehran Mousavi Mourd Ghafari.
Resources: Seyed Mehran Mousavi Mourd Ghafari.
Software: Seyed Mehran Mousavi Mourd Ghafari.
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