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Assessment of heavy metals pollution in surface soils in the industrial town of Urmia phase 1-2 and expansion

Evaluación de la contaminación por metales pesados en suelos superficiales de la ciudad industrial de Urmia fase 1-2 y ampliación

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Abstract

The surface soil pollution of the three industrial towns of Urmia, 9 km northeast of this city, is the subject of this article. For this purpose, samples were taken from 9 points, and heavy metals such as iron, manganese, cadmium, copper, zinc, and lead has been analyzed to calculate the indicators of Geoaccumulation Index and pollution factors for these heavy metals. The background element concentration should be calculated for each element to calculate these factors. 59 samples for each element were used in the pristine areas of Urmia Plain by atomic absorption method. The presented research results show that the soil of the region is contaminated with heavy metals, so the amount of contamination for heavy metals manganese and cadmium is meager, and for the heavy metals iron and copper, they are in the middle range and for the heavy metals zinc and lead, they are in the high range. The pollution concentration around the town of expansion phase and phase 2 is more than the town of phase 1, which seems to be the cause of the food industry activity in the town of phase 1 and the activity of electronics, paint and metal industries in the expansion phase and phase 2. It seems that the high amounts of lead and zinc heavy metals in the soils around the industrial towns of Urmia are due to the activities of production units such as electronic industry, ceramics industry, metal industry, paint industry and battery production. The aforementioned industries dump their industrial waste water into the surroundings of the towns and cause soil pollution. Figure 7 shows the discharge of industrial wastewater from the expansion phase town to surrounding area. It seems that the creation of a wastewater treatment plant for polluting units and increasing the capacity of the existing treatment plant in the industrial town is important in reducing pollution.

Resumen

La contaminación del suelo superficial de las tres ciudades industriales de Urmia, a 9 km al noreste de esta ciudad, es el tema de este artículo. Para ello, se tomaron muestras en 9 puntos y se analizaron metales pesados como hierro, manganeso, cadmio, cobre, zinc y plomo para calcular los indicadores del índice de geoacumulación y los factores de contaminación de estos metales pesados. Para calcular estos factores, debe calcularse la concentración de fondo de cada elemento. Se utilizaron 59 muestras para cada elemento en las zonas prístinas de la llanura de Urmia mediante el método de absorción atómica. Los resultados de la investigación presentada muestran que el suelo de la región está contaminado con metales pesados, por lo que la cantidad de contaminación para los metales pesados manganeso y cadmio es exigua, y para los metales pesados hierro y cobre, están en el rango medio y para los metales pesados zinc y plomo, están en el rango alto. La concentración de contaminación en los alrededores de la ciudad de la fase de expansión y de la fase 2 es mayor que en la ciudad de la fase 1, lo que parece deberse a la actividad de la industria alimentaria en la ciudad de la fase 1 y a la actividad de las industrias electrónica, de pinturas y metalúrgica en la fase de expansión y en la fase 2. Parece que las elevadas cantidades de metales pesados de plomo y zinc en los suelos de los alrededores de las ciudades industriales de Urmia se deben a las actividades de unidades de producción como la industria electrónica, la industria cerámica, la industria metalúrgica, la industria de pinturas y la producción de baterías. Las industrias mencionadas vierten sus aguas residuales industriales en los alrededores de las ciudades y provocan la contaminación del suelo. La figura 7 muestra el vertido de aguas residuales industriales de la ciudad en fase de expansión a los alrededores. Parece que la creación de una planta de tratamiento de aguas residuales para las unidades contaminantes y el aumento de la capacidad de la planta de tratamiento existente en la ciudad industrial son importantes para reducir la contaminación.

Introduction

Heavy metal (HM) contamination of soils is one of the major environmental problems prevalent worldwide[1]. In recent decades, due to the expansion of various industrial activities, various industrial processes along with the wide variety of production of materials and compounds in the industrial sector and other sectors, in particular, industrial effluents in the place of industrial towns have created much pollution for the environment. Therefore, identifying environmental pollutants caused by industrial unit activity, especially in water and soil resources, seems essential. Therefore, identifying the source and factors influencing the pollution of water and soil resources can be effective in the management of these resources. Also, to prevent and control various pollutants in industrial towns, necessary measures can be taken by designing a monitoring network. Pollution occurs when the concentration of the pollutant element or compound exceeds the threshold limit and disrupts the organism's activity[2].

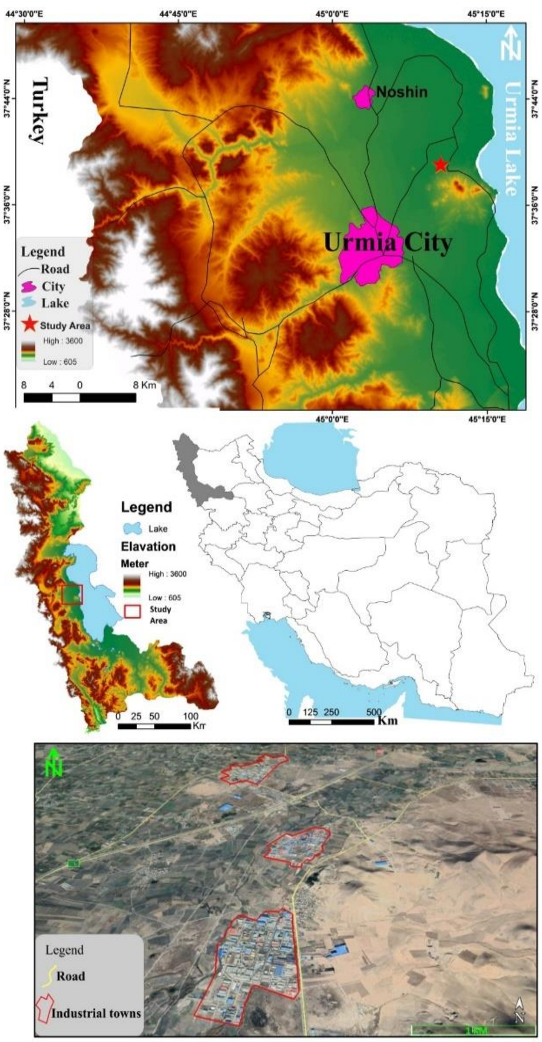
Identifying the source of metal pollutants entering the soil can help to control soil pollution, prevent the transfer of pollutants to other parts of the biosphere, and finally to the rings of the human food chain, as well as designing plans for the remediation of contaminated soils. Therefore, many recent researches have focused on the elements of chromium, cobalt, nickel, copper, zinc, and lead[3-5]. In the on other research conducted in the northwest of Spain, they investigated the origin of HM in the soil, to distinguish the effects of human activities compared to the natural process of entering these elements into the soil.

To identify the possible sources of increasing metal pollutants to the soil, it is considered to investigate the statistical characteristics of the data distribution and the use of multivariate statistical techniques in different studies; However, investigating the ratio of HM caused by human activities to the amount of metals derived from natural factors, in the form of enrichment index and pollution factor (PC), is one of the most common methods used by researchers[6]. Due to the continuity of the spatial changes of soil parent materials and the concentration of environmentally destructive human activities in specific and limited places, there is no doubt that the ratio of natural and human factors on the concentration of HM in the soil has significant changes in the spatial dimension. At the same time, having correct information about the pattern of spatial changes in the concentration of HM in the soil is a prerequisite for designing pollution control programs as a result, it seems that mapping the trend of spatial variability of polluting metal pollution, useful information can be obtained to separate the areas of the earth that are polluted by any of the natural or human factors[7].

Due to the activity of various industrial complexes, the three industrial towns of Urmia located in the northeast of Urmia have been considered as a target for investigating the level of HM contamination in the soil of these towns and their surrounding areas. According to the research method of the plan, the soil sampling location is on the route of the Rozeh Chai River and based on the location of the pollution centers of Rozeh Chai (rural sewage, sivil sewage, industrial sewage), which has been announced by the General Administration. The environment of West Azerbaijan has been identified and then sampled the path of this river is made of soil. Therefore, sampling and study intervals depend on the location of these centers. In this article, pollution indices, the Geoaccumulation Index, and the PF coefficient have been used to investigate surface soil pollution due to industrial activities[4,5,8,9].

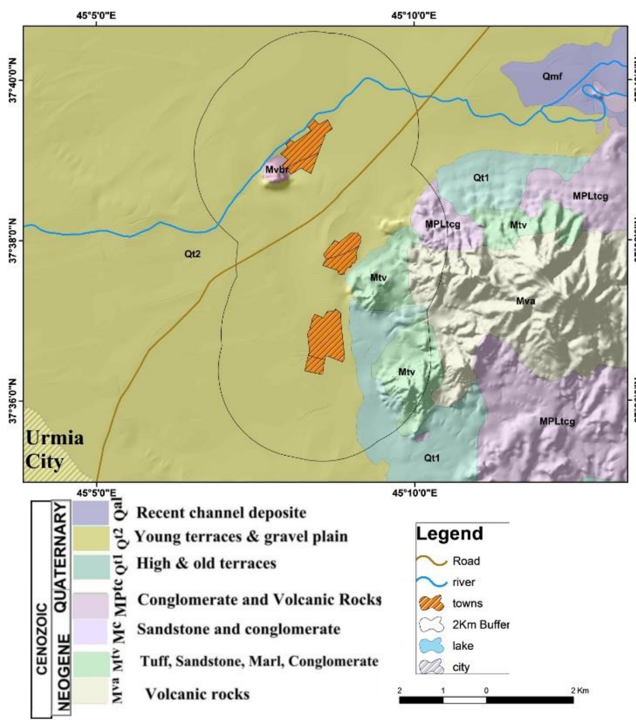
Materials and methods

Figure 1 Geographical location of the study area



The three industrial towns of Urmia are located 9.5 km northeast of Urmia city in geographical coordinates 45°07'56" to 45°08'39" east longitude and 37°38'52" to 37°39'17" north latitude. The average slope of the studied area and surrounding areas is less than 1 % and the general direction of the slope is northeast and towards Lake Urmia. The average height of the settlements is 1290 meters above sea level. According to the statistics of the ten years (2003-2013) of the Urmia synoptic station, the average annual temperature in this area is 11.75° C. The average annual maximum temperature of the region is 18.36 and the average minimum temperature is 5.12° C (Figure 1).

Figure 2 Geological map of the study area

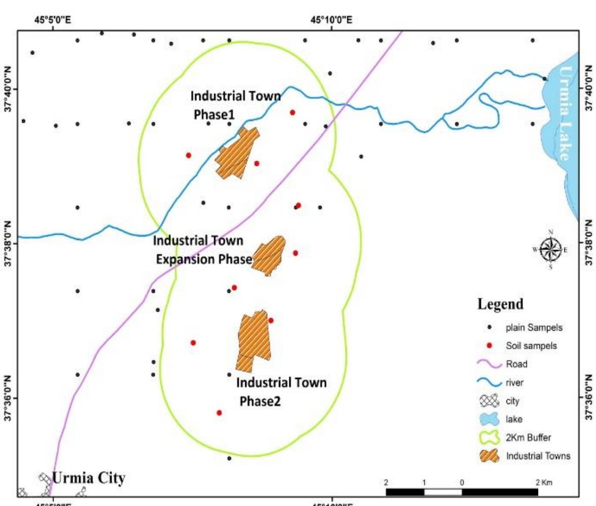


According to statistics, the coldest month of the year is January with an average temperature of (-6.1) and the hottest month of the year is July with an average temperature of 30.6° C. In terms of climate, this city has cold and dry winters and hot summers[10]. According to Figure 2, the majority of the studied area is located in the Quaternary geological units of young terraces and gravelly plains. Figure 3 shows a view of the Urmia's industrial towns and expansion phase.

Nine samples were taken from the soils of the study area. The location of the samples, Figure 4. The samples were transported to the laboratory for the analysis of HM. The sample has been analyzed by atomic absorption method.

Figure 3 A view of Urmia's development phase industrial town

Figure 4 Location of soil sampling points and industrial towns of Urmia



Index of geoaccumulation (Igeo) To determine the intensity of soil pollution with HM, the soil Igeo and PC were used. Igeo has been introduced to evaluate soil pollution by comparing the amount of HM currently and before industrialization[11].

This index is used to determine the degree of pollution and the degree of influence of human factors from natural factors in the soil and sediment environment[12] and is calculated through equation 1:

$$Igeo = \log 2 \left[{C_n}/{1.5 * B_n} \right] \quad \text{equation 1}$$

where C_n is the measured concentration of the element in the sample and B_n is the concentration of the base element in the reference sample. In equation 1, a coefficient of 1.5 is used to correct the effects of soil parent materials, natural fluctuations, and very small changes caused by human activities. Based on this index, soils are classified into 7 different groups (Table 1)[4,11].

Table 1 Geoaccumulation Index (Igeo) classification

Values	Classification
Igeo < 0	practically uncontaminated soil
0<Igeo<1	Uncontaminated to slightly contaminated
1<Igeo<2	Moderately contaminated
2<Igeo<3	moderately to heavily contaminated
3<Igeo<4	heavily contaminated
4<Igeo<5	Very contaminated to severely contaminated
Igeo≥5	severely contaminated

Contamination factor. The amount of metals can be measured relative to their natural amount and determine the amount of soil pollution[13]. The CF relationship is according to equation 2.

$$CF = {[C]\ sample}/{[C]\ background} \quad \text{equation 2}$$

In this regard, CF is the CF, [C] sample is the concentration of the investigated element and [C] background is the concentration of the base element in the reference sample. In terms of HM pollution, soils are divided into 4 groups (Table 2)[4,14,15].

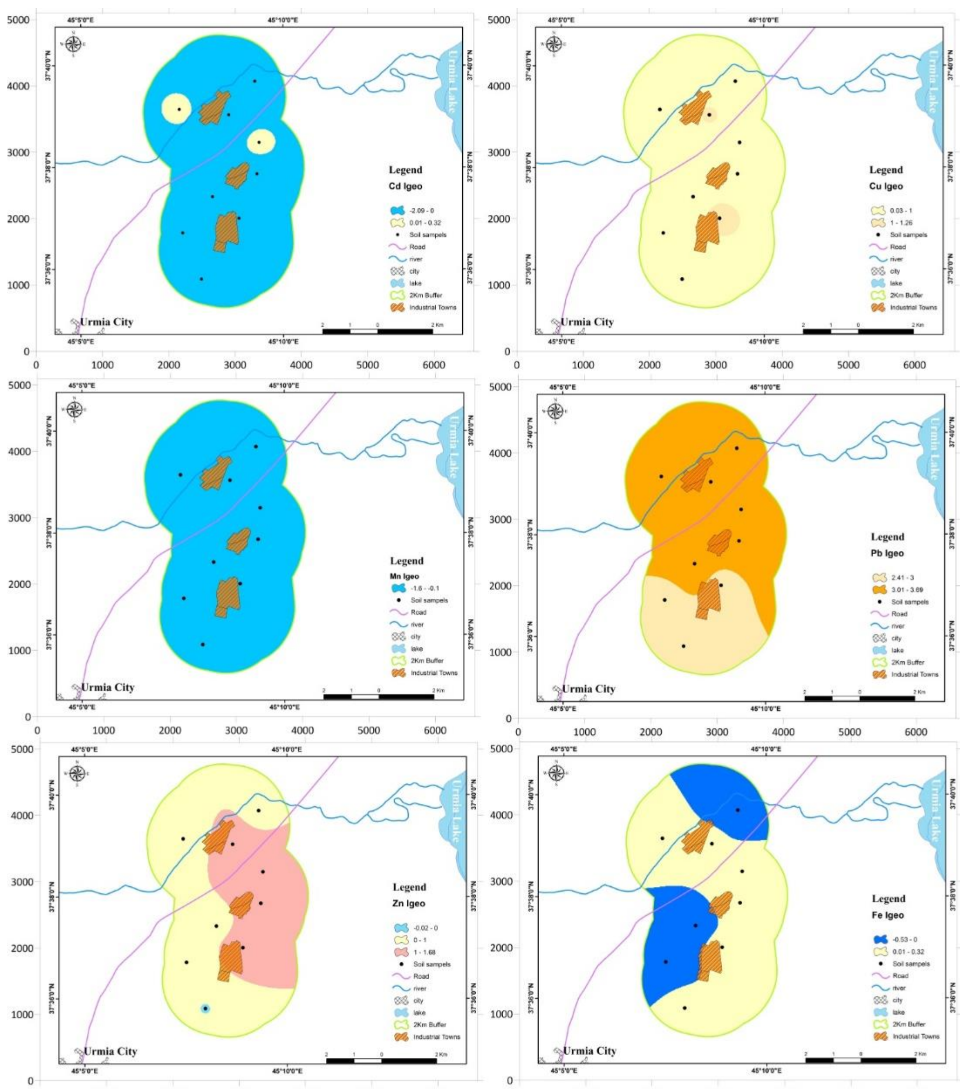
Table 2 HM pollution Contamination factor classification

Values	Classification
CF<1	low contamination degree
1<CF≤3	moderate contamination degree
3 ≤CF< 6	considerable contamination degree
CF ≥ 6	very high contamination degree

Results

To calculate the PF and Igeo, first of all, the concentration of the base element in the reference sample or the concentration of the background element for each element should be calculated. These values are in the relationship between the FC and the reference Igeo, the amount of pollution created in the studied sample which have been explained in the previous section, therefore, to calculate the background element concentration, the soil monitoring data of Urmia measurement of HM by atomic absorption method was used with Perkin Elmer 4100 device. has been used, in this way, the number of 59 samples for each element in the virgin areas of Urmia plain has been used by the averaging method. In the samples taken, only one sample was taken due to financial issues.

Figure 5 Index of soil accumulation for heavy metals in the industrial areas of Urmia



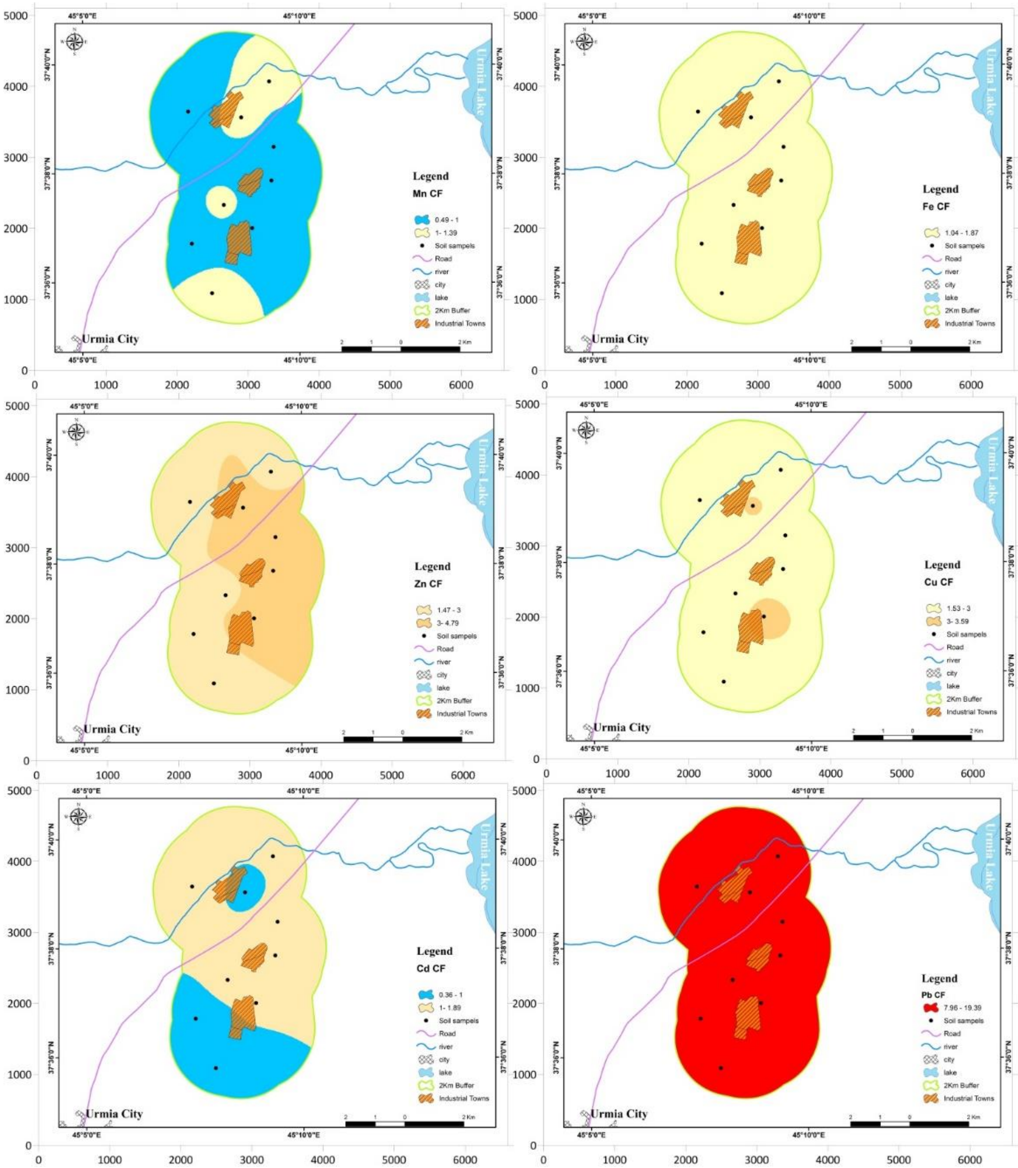
In the studied area (The boundary area of 2 km of the three settlements is about 44 km^2), 9 sampling locations were used to evaluate the Soil digestion method nitric acid digestion method, the indicators of land accumulation, and the PF around the industrial towns, and the results of HM analyzes were used to calculate the mentioned indicators. Figure 4 shows the location of soil sampling points and industrial settlements in Urmia. According to Figure 4 of the soil map of the province, soil samples are available from the areas adjacent to the 2 km boundary of the settlements, which can be used as a reference sample. (Figure 4)

After the calculation, the Igeo was entered into the ARC GIS with version 10.8.2, software environment to create a zoning map of the Igeo of various metal elements to cover the study area of the IDW method in the ARC GIS software environment for each of the elements iron, manganese, cadmium, copper, zinc and lead, they are created according to Figure 5, the Igeo for iron in the studied area is has been estimated in the non-contaminated category for the northern and eastern areas of the area, and for other areas in the non-contaminated to slightly contaminated category.

The Igeo for manganese has been estimated in the non-contaminated category for all areas. Also, the Igeo for cadmium metal in the studied area for all areas are in the non-polluted category except for 2 points which are in the non-polluted to slightly polluted category. The situation for the HM copper in the studied area for most of the areas is evaluated in the non-contaminated to slightly contaminated category in terms of the Igeo only in 2 points near town No. 1 and 2, the land index of copper metal has been assessed as slightly contaminated. According to Figure 5, the Igeo for HM zinc has been assessed in the non-polluted to slightly polluted category for most areas, except in the eastern areas and around the expansion phase town, where this index has been evaluated in the slightly polluted category, and as a point in the south of the study area, the zinc metal accumulation index is in the non-contaminated category. According to Figure 5, the Igeo for lead HM in the northern and central areas of the study area, that is, in the areas of phase one town and expansion phase, is in the highly polluted category and the southern parts, i.e. the areas around the town of the second phase, are in the polluted to very polluted category.

The CF index was entered into the ARC GIS software environment after the calculation like the PF and a zoning map of the PF index of various metal elements to cover the study area of the IDW method in the ARC GIS software environment for each of the elements iron, manganese, cadmium, copper, zinc and lead according to Figure 6, the index of the PF for the HM iron in the entire study area has been evaluated in the medium pollution category. Also, the index of the PF for the HM manganese in most areas of the study area has been calculated in the category with low pollution, except for the parts in the north of the area, i.e., around Phase I Industrial Town, and in the south of the study area, i.e., in the south of Urmia Industrial Town No. 2. and a small part in the center of the study area, i.e., the vicinity of the expansion phase town of the PF index, has been evaluated as medium pollution category. According to Figure 6, the index of the PF for the HM cadmium is in the medium pollution category for most areas of the study area, except for the southern areas of the study area and the south of Industrial Town No. 2. The PF index for the HM cadmium has been evaluated in the low pollution category. The index of PF for HM copper in the study area has been evaluated as a medium pollution category for most of the areas, except in the area in the form of points in the vicinity of industrial towns 1 and 2, the index of PF is in the category of high pollution. The PF index for the HM zinc has also been evaluated in the high pollution category in the eastern areas of the study area of more, and it has been evaluated in the moderate pollution category for the eastern areas. The PF index for lead metal in the studied area has been evaluated in the category of very high pollution. (Figure 5 and 6)

Figure 6 index of soil pollution factor for heavy metals in the industrial areas of Urmia



The indices of land accumulation and PF according to Figures 5 and 6 show a good convergence in describing the amount of pollution of different HM, so that they show the highest amount of pollution related to copper and zinc HM compared to other HM evaluated in this research. Also, the lowest level of pollution is related to HM cadmium and manganese, HM iron and copper are placed with average levels of pollution compared to other, HM evaluated in this research.

Discussion

For the calculation of Igeo and PF, the background element concentration must be calculated first, which is explained in detail in the previous section. Therefore, soil accumulation indicators and PF are a good measure to understand the enrichment of these elements in the soil of the study area, or in other words, the soil pollution of the study area with HM, and the lower the value of these indicators the lower the soil pollution.

By examining the indicators of soil Igeo and PF for different HM, it can be concluded that the soil of the studied area is polluted by HM. Therefore, the amount of pollution for the HM manganese and cadmium is very low, and for the HM iron and copper, they are in the medium range, and for the HM zinc and lead, they are in the high range. Based on the interpolated maps in the study area, the areas adjacent to Phase 1 and 2 towns are more polluted than the expansion phase. The values of both Igeo and PF for different metals show a good convergence between these two indices the production and use of paints is one of the main factors of soil contamination with lead HM. It seems that this is one of the factors of soil contamination with lead HM in the industrial areas of Urmia. The pollution concentration around the town of expansion phase and phase 2 is higher than the town of phase 1, which seems to be the cause of the food industry activity in the town of phase 1 and the activity of electronics, paint, and metal industries in the expansion phase and phase 2.

It seems that the high amounts of lead and zinc HM in the soils around the industrial towns of Urmia are due to the activities of production units such as the electronic industry, ceramics industry, metal industry, paint industry, and battery production. The aforementioned industries dump their industrial wastewater into the surroundings of the towns and cause soil pollution. Figure 7 shows the discharge of industrial wastewater from the expansion phase town to the surrounding area.

Figure 7 Discharge of industrial wastewater

According to the results that the pollution contamination factor for HM, iron, cadmium and manganese is in the range of moderate contamination degree in most regions.

Also, for the HM zinc in the eastern areas of the study area, there is a considerable contamination degree, and there is also a considerable contamination degree for the HM copper around the phase 2 industrial town.

The HM lead is the most contaminated, taking into account the range of very high contamination degree in the entire studied area (Figure 6).

The results of the study indicate that the industrial activities in the industrial towns of Urmia have caused the accumulation of HM in the soil of the areas adjacent to the industrial towns.

The risk of transferring HM to plants, surface and underground water, animal food chain and finally entering the human food chain is very serious and dangerous. Considering that the most contamination in the soils of the study area is due to HM of lead and zinc. If these HM enter the human food cycle, it can cause dangerous diseases.

It seems that the creation of a wastewater treatment plant for polluting units and increasing the capacity of the existing treatment plant in the industrial town is important in reducing pollution. Also, proper waste management practices can be very efficient in reducing soil contamination with HM.

Source of funding

Own resources were used to implement the research.

Conflicts of interest

The authors declare that this research was carried out at the Islamic Azad University of Urmia and presents no conflicts of interest.

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Ethical considerations

The research was approved by the Environmental Protection Agencies of West Azerbaijan and Islamic Azad University of Urmia.

Research limitations

The authors note that there were no limitations in the Present research work.

Authors' contributions

Neda Rostamlou, data collection, mapping, statistical analysis, systematisation and interpretation of data. *Zahra Ghodrati*, statistical analysis, systematisation and interpretation of data and revision of the document. *Nosrat Aghazadeh*, literature review for material, methods and results, experiment planning and revision of the document. *Amir Asadi Vaighan*, interpretation of data. *Reza Sokouti Oskoei*, data collection, mapping, GIS and revision of the document.

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