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Pollution of soils in Sulaymaniyah district \ Kurdistan of Iraq with heavy metals: An integrated approach using assessment indices & G.I.S

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***Abstract*---**Sulaymaniyah district is located in northeastern Iraq, Between latitudes (^{o}35,′16,″50-^{o}35,′47,″30) in the north and longitudes (^{o}44,′57,″20-^{o}45,′44,″03) east, its area is (1,407 km^{2}), Administratively represented by the center of The city of Sulaymaniyah and its sub-districts (Bazian, Tanjaro, Bakrajo). The district suffers from high concentrations of polluting elements in the soil due to natural factors and various human activities. Therefore, The research aims to assess the environmental assessment of the soil by identifying the sources of soil pollution with several chemical elements and heavy metals, And the assessment was carried out according to the polluting elements For the soil and according to the administrative units of the Sulaymaniyah district, Due to the dangers of its increasing concentrations and stability in the environment in general and soil in particular. The samples were divided into the center and its sub-districts (Bakrajo, Bazian, Tanjaro) for the month of July of the year (2020), Through which a group of chemical elements polluting soil was studied, amounting to (18) elements and they were analyzed in the laboratory, using the (XRF device) to detect concentrations metal in Soils. Maps showing the extent of pollution in the district were created using the G.I.S (10.8 version) technique. And based on the results of laboratory analyses and statistical analysis for soil assessment, The

research concluded that the soil of the study area suffers from varying pollution from Low to severe pollution according to human activities, as the Industrial soils contain copper, And service soils suffer from pollution with elements (zinc, lead, tin), While the concentration of (thallium) increases in landfill and wastewater soils. The service soils recorded high pollution within the district, And for administrative units, the Bazian district recorded high pollution and Environmental risk limits. Establishment of wastewater treatment plants before discharging it into the river valleys within the study area to ensure the utilization of the treated water in the summer, moving the main waste dump away from the population and human settlements, and increasing the cultivation of trees and plants that reduce pollutants by absorbing part of the pollutants and increasing soil fertility.

***Keywords*---**environmental assessment, Sulaymaniyah, soil pollution, pollution factor, environmental risks.

Introduction

Each of the natural factors and various human activities has a role in changing the physical and chemical properties of the natural soil, which affects it with pollution, especially pollution with chemical elements with great and toxic risks as a result of human misuse by natural factors, in addition to the great acceleration in urbanization, industrial and agricultural, which results in a lot of solid and liquid waste, from which heavy metal elements are liberated, which are harmful to the natural environment and the living environment. Where the chemical elements in the soil vary in varying concentrations according to the nature of the element and the soil sample and according to the location of the sample from the source of pollution, The environmental risks of the soil lie in the high concentrations of harmful elements in it and their longevity and lack of decomposition, as pollutants move long distances from their areas of origin and may be transmitted to humans through the food chain through plants and animals that feed on them. All living organisms need some metallic elements with limited concentrations in their vital processes, including (Iron, copper, and zinc), while some elements have no benefit and are toxic in any concentration (such as mercury, cadmium, lead, thallium, arsenic), These elements as a result of human activities lead to their rise in the soil and other components of the environment. Thus, this rise is a threat to the vital biological system, as its danger lies in the toxic effects of these metals on vital processes and their impact may reach the death of the living organism. For the research to achieve its goal, the following scientific steps were taken:

First: The problem of the study

The problem of the study revolves around the following questions:

1. What is the role of natural and human components in soil pollution?
2. Which geographical elements have the most impact on soil pollution in the study area?

3. To what extent does the amount of pollution in the district vary?

Second: the Study hypothesis

a. The components of the natural environment play a major role in determining the physical and chemical properties of the soil in the district.
b. Human factors contribute to a high degree of soil pollution and variation in the study area.
c. Geographical elements differ among themselves in determining the amount and types of soil pollution in the district from one place to another.

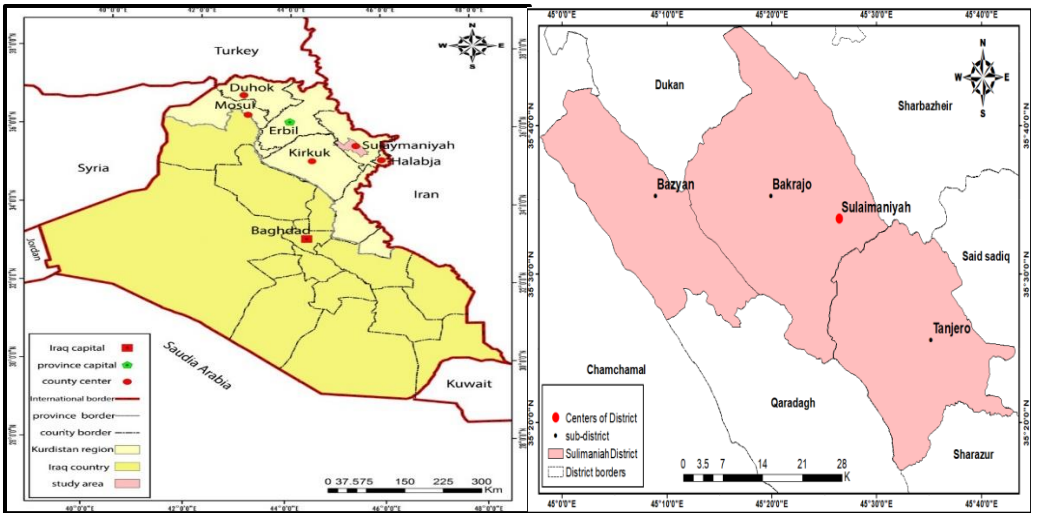
Third: The purpose of the study

The study aims at an environmental assessment of the district's soil, as well as creating a geographical map of the size and types of pollutants using modern technologies.

Fourth: study area

Sulaymaniyah district is the center of Sulaymaniyah Province, and it belongs to the Kurdistan Region of Iraq in northeastern Iraq and is (8-10) miles away from the Iranian border, with an area of (1,407 km), astronomically located between latitudes (35^{o}16.50 - 35, 47.30^{o}) north and longitudes (^{o}44,57,20, - ^{o}45,44,03^{o}) east, the height of the study area is (885 m) above sea level. map(1)

Map(1)Location of Study area from Iraq & Kurdistan



Source: From The Researcher's work using the GIS(10.8) software.

Fifth: The justification for the study

The study area faces some environmental risks, including pollution in light of the increase and diversity of human activities, which calls for the need to stop and study their cases, as the study area lacks a thorough study of soil pollution in

terms of the chemical properties that cause soil pollution and the identification of the most polluted sites, in addition to that it is an attempt from us to detect the extents of pollution and the type of pollution-causing activity.

Sixth: Methods and tools

For the research to achieve its main goal, a set of devices and materials complementary to the field study process were used to take samples and determine the appropriate sites for the research process in the district, as follows:

a. Using the shovel to take soil samples and the plastic containers for storing samples.
b. G.P.S device of the type RINO 110 – GARMIN, to measure the heights and determine the astronomical position of the samples.
c. (XRF.M.7500) device to detect the concentrations of chemical and mineral elements in soil samples.
d. Using the program (Microsoft Excel2010)) for statistical analysis and the program (ARC.Gis10.8) for drawing maps.
e. Soil samples were taken at a depth of (0-20 cm) after removing the surface layer containing the remains of plants. They were numbered and the data of each sample was recorded for processing and sent to reliable laboratories for analysis, then the bottles were sent to the laboratory (laboratories of the University of Technology | Baghdad) for the analysis of chemical elements and heavy metals.
f. The samples were divided into the administrative units and human activities affiliated with the district, according to the approved standards, through an intensive field study, with (16) samples in the Bazian sub-district, (15) samples in the Bakrajo sub-district, (16) samples in Tanjaro sub-district, and (7) Samples for the city center and its sub-districts. The number of sites from which soil samples were taken reached (54) sites. The number of analyzed elements reached (18) elements, which included some mineral elements and are represented by the elements (vanadium V, zinc Zn, molybdenum Mo, selenium Se, arsenic As, copper Cu, cobalt Co, chromium Cr Thallium TI, barium Ba, nickel Ni, tin Sn, mercury Hg, lead Pb, antimony Sb, cadmium Cd, uranium U, in addition to the element iron Fe.

The polluted natural characteristics of the soil of the research area

The district of Sulaymaniyah is located in the high torsional region according to the physiographic division of Iraq (Al-Sayyab et al., 1982: p. 18). Its geological formations extend from the second time, and most of its rocks are marine carbonite rocks and are called the Cretaceous period. Limestone rocks are the most widespread formation and dominate most parts of the study area. (Abdullah Ghafour,2009:p.21) The formation of (Qamchuqa, Kometan, Shiranish, and Tanjaro) is the most important formation that is characterized by its weak resistance to erosion processes, and most of its formations are limestone and chemically composed of calcium carbonate, magnesium carbonate, and siderite. Each other and it is believed that oil may be present in the rock formations of this period (Al-Sanawy et al,1979:pg.586),and among the most important of its

formations are (Kolush, Sinjar, Khormala, Bilasbee), and up to the Quaternary age. The formations of this age consist of ancient and modern river sediments such as gravel, conglomerate, sand, and fine silt. It covers large areas of the study area ((Jassim & Jeremy, 2006:p.188), and the study area is surrounded by a group of mountain ranges (Azmar, K. Wazeh, Bireh Makron, Tasluja, Branan, Bazian, Henjira) works to carry crumbs and sediments from high and sloping areas towards Low and plain areas, which helps in increasing the concentration of some elements in the soil of the study area. This greatly facilitated the process of transporting pollutants and elements spatially (Body, 1980:p.48). The climate has a major role in increasing pollutants in the elimination, as the climate of the study area is generally characterized by a semi-humid climate, with an annual average of temperatures (20°C^{o}) for the period from (1988 to 2020) and rises a lot in the summer to (32.3 m), which increases evaporation processes to reach about (2,235 mm) annually, and total annual precipitation is (706 mm) annually, and a wind speed of about (1.8m/s) (Sulaymaniyah weather, 2021), Which has a major role in transporting exposed and scattered solid pollutants on roads and empty and abandoned spaces (field study). The soil of the district is characterized by a soft to medium texture, represented by the clay and silt textures and limestone with good drainage and one of the most important types of soil that covers large areas of the district (Chest soils) (Buring,1960:p.118) It is one of the good and arable soils. Natural factors play a major role in explaining and changing the mechanical, chemical, and biological properties by increasing the concentrations of minerals and chemical elements in the soil.

Pollution characteristics due to anthropogenic activities in Sulaymaniyah district

Human plays a prominent role in soil degradation and pollution through their various activities, as the soil is the incubator of urban, industrial, and agricultural development and growth, Chemical pollutants are a major source of soil pollution, which is the result of the rapid acceleration in population growth and the increase in their numbers, which amounted to (1,020,367 people) according to estimated statistics for the year (2020), which led to the expansion of the city and urban sprawl on agricultural areas, as the city included the neighboring villages of (11) agricultural villages in the year (2020) (Sulaymaniyah census, 2021). This large increase in population results in tons of Solid and liquid waste per day, which exceeds (31,902 tons) per month of solid waste (Sulaymaniyah waste, 2021), in addition to dumping liquid and solid waste resulting from shops, hospitals, and industrial projects to the Tanjaro River, which takes place in the district, where the district includes more than (703) industrial projects, including (296) construction projects, about (202) for the production of chemicals and plastics, (7) for the production of asphalt and several refineries for the production of oil derivatives (Sulaymaniyah Industry and Minerals, 2021). All waste is disposed of in a private landfill on the riverside of the Tanjaro River. However, due to the expansion of the city, the location of the landfill became within the city municipality's boundaries, It became a major threat to the health and life of the residents in the area. It also causes pollution of the surrounding soil and the water of the Tanjaro River, in addition to the dumping of waste and heavy water into the river. As a result of the use of river water for agriculture, agricultural soils are contaminated with heavy and harmful

metals again, and the soil is the basis on which agricultural and animal production is based, both of which constitute the main source of human food, as (613,315.95 dunams) are available in the district, of which (189,780 dunams) are suitable for agriculture, and more than (5,456) greenhouses, approximately (7,956 tons) of various fertilizers are used for the winter season and (3,174 tons) of fertilizers for the summer season (Sulaymaniyah Agriculture, 2021). In addition to all this, the rapid growth of the population and the increase in the size of cities led to the increased use of highways to transport people and resources from one place to another (Istanbuly, 2018: p208), as the total lengths of roads in the district are (284.6 km), including (91.5 km) the main road, (146 km) secondary roads and (47 km) agricultural roads (Sulaymaniyah Traffic, 2021) Hundreds of vehicles pass through it daily, which emit fumes and gases, including carbon oxides and sulfur, in addition to heavy metals (lead and zinc), causing pollution to the soil near the roads with heavy and harmful metals that are harmful to humans and living things.

Environmental assessment of Sulaymaniyah District soils

The focus was on the environmental assessment of the soil by identifying the sources of soil pollution with some chemical elements and heavy metals. The assessment was carried out according to the polluting elements of the soil and according to the administrative units in the Sulaymaniyah district, due to the risks of increasing their concentrations and stability in the environment in general and soil in particular.

First - Environmental assessment of polluted soils according to land uses

The enrichment factor (enrichment) (EF) was used to assess the concentration of the studied elements above the permissible limits, and this factor is a separating factor between the studied elements and the sources of their origin and concentration, whether they are of natural origin or human. The coefficient (pollution index) (CF) was also used to show and clarify which elements are more polluting to the soil in the study area, in addition to the environmental risk index (PLI). The number of elements included in the evaluation reached (17) elements due to the availability of their standards and the degree of toxicity for each element In addition, these elements are known for their toxicity and high harm to humans and the environment together. We also adopted iron as a fixed reference element in determining the above-mentioned transactions, because iron concentrations are prevalent in all soil samples within the study area, and due to the lack of Iraqi standards for the concentrations of chemical elements in the sectors of activities. Human (industrial, agricultural, service, landfill, and sanitation), in addition to the limited Iraqi standards of the Iraqi Ministry of Environment and for a limited number of chemical elements only, the (Canadian) standard was adopted in the study area ,see Table (1) as an internationally approved and reliable standard To determine the environmental risks of pollutants, the process of evaluating the soil of the study area was carried out according to the following steps:

Enrichment Factor (EF)

It is one of the ways to show and evaluate the effects of human activities and their ability to pollute the soil and its surroundings, and calculate the factor using the following equation $\mathbf{EF} = [\frac{\frac{\mathbf{Cm}}{\mathbf{Cmn}}\mathbf{sample}}{\frac{\mathbf{Cm}}{\mathbf{Cmn}}\mathbf{Earths\ crust}}]$

$\frac{\mathbf{Cm}}{\mathbf{Cmn}}$ sample: It is the ratio of the concentration of an element in a soil sample to the concentration of an element in the earth's crust.

$\frac{\mathbf{Cm}}{\mathbf{Cmn}}$ *Earths crust*: Is the ratio of the concentration of the reference element in the soil sample to its concentration in the earth's crust.

The rates of enrichment factor values (EF) for the polluting elements in the soil of the Sulaymaniyah district, as shown in Table (2), show that the soil samples that exceeded the value of the enrichment factor (the limits of value 5) are contaminated with that element (Abdul et al.,2017:p.7). Five categories of pollution were identified. Depending on the enrichment factor, it is less than 2 = Low enrichment (Low), 2-5 moderate enrichment, 5-20 high enrichment, 20-40 very high enrichment, and more than 40 very polluted (Sezgin ale, 2003: p.981), according to In the table, it was found that soil samples are less polluted, except for copper (Cu), which recorded high pollution values of (10.1), which indicates the human influence in soil pollution with these elements, which use products containing the element, especially iron industries and wastes emerging from them.

Elements	Sb	AS	BA	CD	CR	CO	CU	HG	PB	MO	NI	SE	TL	SN	V	U	ZN
Soil	Antimony	Arsenic	Barium	Cadmium	Chromium	Cobalt	Copper	Mercury	Lead	Molybdenum	Nickel	Selenium	Thallium	Tin	Vandanium	Uranium	Zinc
Agricultural	20	17	750	1.4	64	20	63	6.6	70	4	45	1	1	5	130	23	250
Industrial	40	26	2000	22	87	300	91	50	600	40	89	2.9	1	300	130	300	410
service	20	17	750	3.8	64	20	63	12	70	4	45	1	1	5	130	33	250
Landfill&wastewater	40	26	2000	22	87	300	91	50	600	40	89	2.9	1	300	130	300	410

Table (1) The values of the approved limits for the Canadian standard for a group of chemical elements according to soil uses, in (PPM) unit. Canadian Council of Ministers of the Environment - the companion Tier 2 document (ESRD 2007 as amended).Surface Soil Remediation Guideline Values for Natural Area Land Use - All Exposure Pathways. *assist Tier 2 guideline development.*

While the values decreased in the rest of the elements for industrial soils, the degree of pollution was slight. As for agricultural soils, they did not record high pollution, and for the elements chromium, cadmium, nickel, and tin (Cr, Cd, Ni, Sn), they were moderate pollution, and the remaining elements recorded slight pollution in the study area. As for landfill soils and wastewater, they recorded a high enrichment of Nickel and were moderately polluted with Thallium and Lead

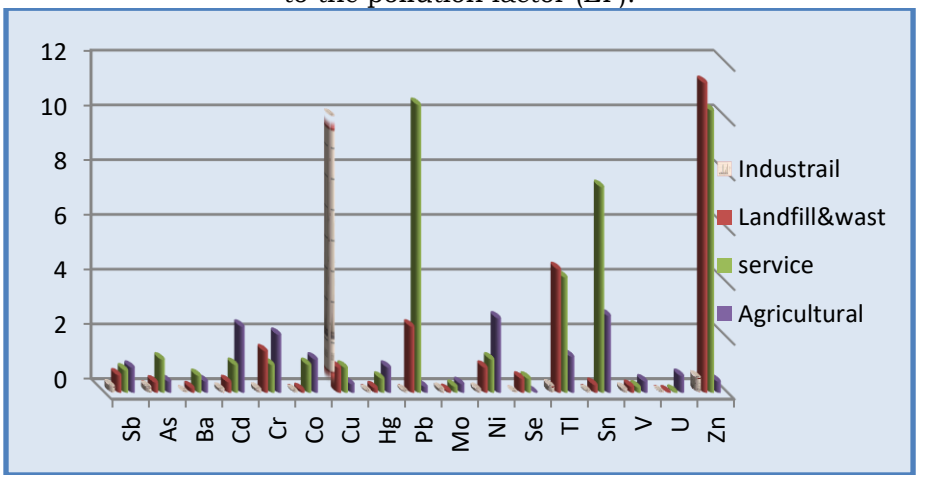
(Tl, Pb), while the other elements recorded slight enrichment. For service soils, the elements zinc, lead, and tin (Zn, Pb, Sn) recorded high enrichment, while Tl was moderately polluted, while the remaining elements were slightly polluted. See figure (1).

Table (2) values of the enrichment factor for the soil of the study area in units (ppm)

Elements	symbol	Industrial			Agricultural			Landfill&wastewater			service		
		concentration	EF	P0llution level	concentration	EF	P0llution level	concentration	EF	P0llution level	concentration	EF	P0llution level
Antimony	Sb	19	0.22	Low	13	0.9	Low	26.9	0.62	Low	22	0.8	Low
Arsenic	As	10	0.18	Low	5	0.4	Low	9.9	0.36	Low	26.2	1.2	Low
barium	Ba	/	/	/	226.3	0.4	Low	324.2	0.15	Low	595	0.6	Low
Cadmium	Cd	4	0.1	Low	2	4.2	Moderate	8.8	0.37	Low	4.3	1	Low
chorum	Cr	174.5	0.1	Low	97	2.1	Moderate	142.2	1.5	Low	86.4	1	Low
cobalt	Co	22	0.04	Low	17	1.2	Low	25.6	0.08	Low	26	1	Low
copper	Cu	2021.3	10.1	High	15	0.3	Low	87.1	0.9	Low	73	0.9	Low
Mercury	Hg	5	0.04	Low	4	0.9	Low	8.2	0.15	Low	8.4	0.5	Low
lead	Pb	58	0.04	Low	11	0.2	Low	1524	2.4	Moderate	953	10.5	High
Molybdenum	Mo	7	0.1	Low	1	0.3	Low	2	0.05	Low	1.1	0.2	Low
Nickel	Ni	89	0.1	Low	86	2.7	Moderate	86.6	0.9	Low	73	1.2	Low
Selenium	Se	/	/	/	/	/	/	1.6	0.5	Low	0.6	0.5	Low
Thallium	Tl	1	0.22	Low	1	1.3	Low	4.8	4.5	Moderate	5.4	4.2	Moderate
Tin	Sn	35	0.04	Low	10	2.8	Moderate	88	0.27	Low	49	7.5	High
Vandanium	V	20	0.1	Low	35	0.4	Low	24.9	0.2	Low	32	0.18	Low
Uranium	U	3	0.004	Low	1	0.6	Low	0.6	0	Low	1.1	0.02	Low
zink	Zn	509.3	0.54	Low	78	0.4	Low	4976	11.3	High	3354	10.3	High

Source: From the researcher's work based on the data of laboratory analyzes of the elements in the soil of theDistrict & Enrichment Factor.

Figure (1) Soil pollution of the human sectors of Sulaymaniyah district according to the pollution factor (EF).



source: from the researcher's work based on the results of the table (2).

Contamination Factor (CF)

This factor was used to classify pollution levels in the soil samples of the Sulaymaniyah district by dividing the concentration of each element by the reference value of the same element and it was calculated by the following equation: (Abdul et al, 2017: p. 6)

CF=(Cm)sample / (Cm)Background

Where (Cm)sample is the concentration of the element in the soil of the study area and (Cm)Background is the concentration of the reference element (standard). The pollution factor is classified on four levels, as follows: Less than (1) a low (slight) polluting factor, from (1-3) a moderate polluting factor From (3-6) a high polluting factor greater than (6) a very high polluting factor. The results of the pollution factor in the soil of the study area in Table (3) show that the service soils suffer from a very high elevation of the elements (Zn, Sn, Pb), but also exceeded the upper limits. Regardless of its harm and toxicity, this is in addition to the use of lead in paints and motor fuels. A large number of civil waste, including it, made its concentration rise in the alleys and residential neighborhoods in the study area, especially in the areas of random household waste dumps. Batteries as well. As for tin, most of the waste consists of tin-coated cans, and tin paper is also used for food packaging. While the element Thallium (Tl) recorded high pollution in the residential and service areas within the study area, this may be due to its various human uses in the manufacture of insecticides to eliminate ants and rodents as a highly toxic substance, in addition to its use in fireworks, whose use has increased in the recent years of Before the population on the occasions of the New Year's Day and Newroz holidays, as for the rest of the elements, their pollution coefficient ranged between low and moderate. As for agricultural soils, the pollution factor for cadmium elements (Sn, Ni, Cr, K, Cd) was moderate. The rest of the elements had a slight pollution factor. As for the factor of cadmium. Pollution of industrial soils, copper (Cu) recorded high pollution and zinc and

chromium (Zn, Cr) moderate pollution. These minerals are included in the iron and cement industries, so their particles often accumulate in the soil of the study area, whether through solid or liquid waste and sometimes through gaseous emissions. As for the rest of the elements in industrial soils, they are slightly polluted, and can often be treated. Landfill and sewage soils recorded one high pollution, which is Thallium (Tl), as in the district there is no wastewater treatment plant, so the concentrations of the element are high in the water, which in turn is transmitted To neighboring lands, especially as they are used in medicines, medical and health materials, which are also mixed with domestic and industrial wastewater, the elements chromium and lead (Cr, Pb) recorded moderate pollution. The agricultural soils were of reasonable pollution and ranged between slight and moderate, and zinc and chromium elements were the most polluted within this sector and are separate from the rest of the other elements. See figure (2).

Table (3) pollution coefficient of some chemical elements polluting the soil of the judiciary in the human sectors

Elements	Symbol	Industrial		Landfill&wastewater		Agricultural		service	
		CF	Pollution level	CF	Pollution level	CF	Pollution level	CF	Pollution level
Antimony	Sb	0.5	low	0.67	low	0.64	low	1.1	Moderate
Arsenic	As	0.4	low	0.38	low	0.27	low	1.5	Moderate
barium	Ba	/	/	0.16	low	0.3	low	0.8	low
Cadmium	Cd	0.2	low	0.4	low	1.7	Moderate	1.3	Moderate
chorum	Cr	2	Moderate	1.63	Moderate	1.5	Moderate	1.35	Moderate
cobalt	Co	0.1	low	0.085	low	0.84	low	1.3	Moderate
copper	Cu	22.2	very high	0.96	low	0.24	low	1.2	Moderate
Mercury	Hg	0.1	low	0.16	low	0.65	low	0.7	low
lead	Pb	0.1	low	2.54	Moderate	0.15	low	13.6	very high
Molybdenum	Mo	0.2	low	0.05	low	0.22	low	0.3	low
Nickel	Ni	0.2	low	0.97	low	1.9	Moderate	1.6	Moderate
Selenium	Se	/	/	0.54	low	/	/	0.6	low
Thallium	Tl	0.5	low	4.8	High	0.92	low	5.4	High

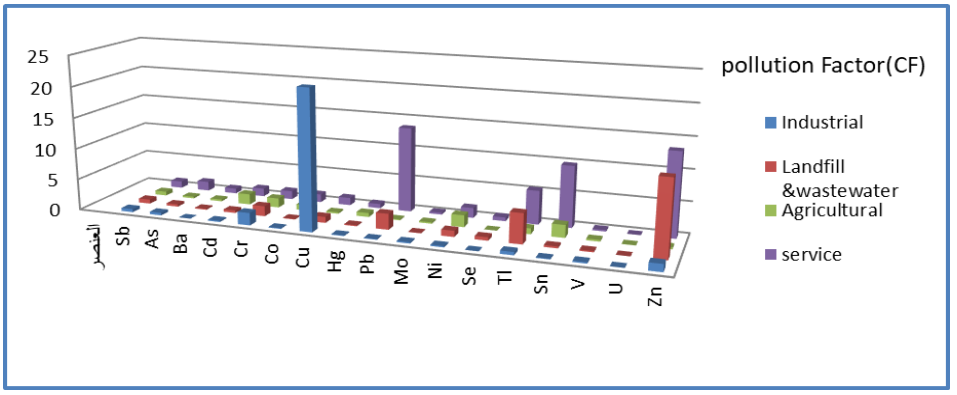
Tin	Sn	0.1	low	0.29	low	2.02	Moderate	9.8	very high
Vandaniu m	V	0.2	low	0.19	low	0.27	low	0.24	low
Uranium	U	0.01	low	0.002	low	0.04	low	0.003	low
zink	Zn	1.2	Modera te	12.1	very high	0.3	low	13.4	very high

Source: From the researcher's work, depending on the results of analyzes and pollution coefficient (CF)

Load Index (Ecological Risk Index) (RI)

Using the equation of the load index, we obtain an assessment of the general pollution status of the studied sites according to the prevailing human activities, which provides an opportunity to estimate how the problem is managed and determine the necessary measures to serve the region. This is if the results of the load index are greater than (1) and it is considered evidence of soil pollution in the area, while the opposite is true and the pollution decreases if the results are

Figure (2) Soil pollution in Sulaymaniyah district according to the pollution factor (CF)



source: from the researcher's work based on the results of the table (2).

lower than the number (1). To reach the desired results, we have depended on the risk index equation (RI), which is extracted after obtaining The results of (Er), which are extracted by obtaining the element pollution factor, as follows**:** (Issa&Alshatteri,2021:p3)

$$\mathbf{IR} = \sum_{1}^{n} \mathbf{Er^i} \quad \text{.....(1)}$$

$$\boldsymbol{Er^i = Tr^i * C_f^i} \quad \text{.....(2)}$$

$$\boldsymbol{C_f^i = \frac{C_o^{i-i}}{C_n^i}} \quad \text{..... (3)}$$

Where: $\boldsymbol{C_f^i}$ = represents the pollution factor, and $\boldsymbol{C_o^{i-i}}$= represents the concentration of the element in the soil, $\boldsymbol{C_n^i}$ = is the reference concentration of the element.

Where:$\boldsymbol{Er^i}$ = is a potential indicator of the Ecological risk index, ($\boldsymbol{Tr^i}$) is a toxicity response factor, and **(**$\mathbf{Er^i}$) is classified into four groups:

Less than (40) light pollution, (40-80) moderate pollution, (80-160) high pollution, and (160-320) severe pollution.The environmental risk index was also classified into four groups: (Abdel et al, 2017: pg. 6)Less than (150) slight risk, (150-300) moderate, (300-600) high risk, and greater than (600) final high risk. Table (4) shows that the value of the pollution index (Er) has little variance between the sectors of human activities, all of them have participated in the fact that light pollution is prevalent and the majority of the polluting elements of the soil, this means that it is currently and in general amenable to treatment before the problem aggravates. Industrial soils concentrations ranged between (0.02-111), which is for the element copper, and in landfill and sewage soils, cadmium was concentrated at the forefront of pollutants and reached (144), which is high pollution, while in agricultural soils, thallium recorded a level of (51) which is the highest concentration and represents the highest concentration. Possible environmental hazard, but according to this criterion, it is considered moderate pollution, while the highest concentration of potential hazard for thallium was recorded in the service sector and elemental (lead and tin) moderate risks in the same soils. With these results from the pollution index, the values of the load index for environmental risks were extracted and were as follows: industrial soils with moderate pollution reached (151) and landfill and sewage soils reached (211.2) also with moderate pollution (see Figure 3), due to the decrease in the number of large industries And huge, as the region is still new to the establishment of major productive industries, which cause the dumping of waste and polluting wastes to the soil. The region and the Iraqi governorates, especially with the economic crisis of the region, which it has been going through since 2015, has led to the deterioration and decline of productivity in general in the industrial sectors and the iron industry in particular, as it relies in its composition on raw materials imported from neighboring countries and international countries. The cost here exceeds the economic return of productivity this prompted the owners of companies and factories, in general, to reduce productivity and turn into a semi-dormant state. It is possible that this is behind the decrease in the amount of waste disposed of, if not it and its sub-districts suffer from an increase in the ruins of factories in the absence of full industrial environmental awareness and local control. Despite this, the value of the risk index has risen a lot to go out of its normal range in service soils, as it reached (402.6) and falls under the category of high risks, and the possibility of this is due to the increase in the number of cars in recent years and the use of polluted and adulterated fuel and the lack of proper filtering, on the one hand, and the other hand. The increase and spread of residential complexes throughout the district, whose construction results in the use of a huge amount of building materials and construction materials, and as a result, large quantities of dust and waste from various and varied sources are thrown here and there. Agricultural soils ranked last in their hierarchy among other sectors of environmental risks, as the value of the risk index reached (142.6), which means that they are minor risks and solutions can be found without exacerbating the problem and trying to fix it. See figure (4).

Table (4) pollution index of mineral elements according to human activities in the soil of the district, unit ((ppm)

Elements	parameter	Industrial		Landfill&wastewater		Agricultural		service	
		ER	Pollution level	ER	Pollution level	ER	Pollution level	ER	Pollution level
Antimony	Sb	2.5	low	3.33	low	3.2	low	0.1	low
Arsenic	As	4	low	3.8	low	2.7	low	15	low
barium	Ba	/	/	0.32	low	0.6	low	1.6	low
Cadmium	Cd	6	low	12	low	51	Moderate	39	low
chromium	Cr	4	low	3.26	low	3	low	2.7	low
cobalt	Co	0.5	low	0.42	low	4.2	low	6.5	low
copper	Cu	111	High	4.8	low	1.2	low	6	low
Mercury	Hg	4	low	6.4	low	26	low	28	low
lead	Pb	0.5	low	12.7	low	0.75	low	68	Moderate
Molybdenum	Mo	1	low	0.25	low	1.1	low	1.5	low
Nickel	Ni	1	low	4.85	low	9.5	low	8	low
Selenium	Se	/	/	1.08	low	/	/	1.2	low
Thallium	Tl	20	low	144	high	27.6	low	162	severe
Tin	Sn	0.5	low	1.45	low	10.1	low	49	moderat
Vandanium	V	0.4	low	0.38	low	0.54	low	0.48	low
Uranium	U	0.02	low	0.01	low	0.3	low	0.15	low
zink	Zn	1.2	low	12.1	low	0.4	low	13.4	low
Ecological Risk Index (RI)		151	Moderate	211.2	Moderate	142.6	slight risk	402.6	high risk

Source: From the researcher's work, based on the results of the table (2&3) and the equation of the environmental risk index.

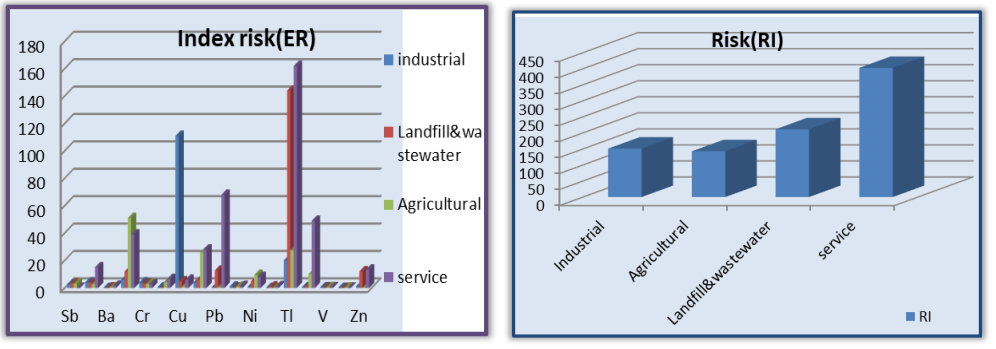


Figure (3) District Soil Pollution by ntamination Index (ER).

Source: From the researcher's work based on the data of Table (3) and using the EXCEL program.

Second: Environmental assessment of the soil according to the geographical distribution of the administrative units of the Sulaymaniyah district

To determine the sites most polluted with chemical elements within the district, a set of steps were followed, including the adoption of the indicators of the enrichment factor (EF) and the pollution factor (CF), and the environmental risk index (ER and RI), which were previously adopted in the evaluation of soils According to the uses of the land, the aim to evaluate the soil of the administrative aspects of the district and to indicate the level of concentration of the studied elements above the permissible limits, as well as to indicate and clarify which administrative units are the most polluted and the polluting activities of soil in the district, and we have adopted the chemical elements and Canadian standards for the evaluation process as presented above. Soil assessment of the study area using the following steps:

1- The enrichment factor: (EF): It is clear from the data in Table (5)&map(1,2,3,4) and according to the administrative units: A- Center and Bakrajo Sub-District: We found that the district of Bakrajo occupied the first place for the enrichment factor for agricultural soils, as the value of the enrichment factor in it was more than (4), and this is considered moderate enrichment, as the enrichment values for the element vanadium were high, reaching (54.3), and this level represents very high pollution and enters the field of danger and toxicity, which indicates the increased use of fertilizers and pesticides that contain this element in their components, which are used in an unscientific manner, followed by nickel and tin elements with slight enrichment values and can be easily treated. And the enrichment in soils for other uses was lower than (1), which is a slight enrichment.

Table (5) represents the values of the enrichment factor (enrichment) for the polluting elements of the soil according to the administrative units that make up the district

Elements		)EF(Bakrajo				)EF (Bazian(				EF)(Tangro			
	parameterl	Agricultural	Industrial	Service	Landfill& wastewater	Agricultural	Industrial	Service	Landfill& wastewater	Agricultural	Industrial	Service	Landfill& wastewater
copper	Cu	0.3	1.2	0.2	0. 9	0.3	23.7	3.5	1.6	0.4	1	0.5	0.28
Nickel	Ni	2.6	0.7	1.5	1.1	3.1	1.1	0.7	0.8	2.7	0.8	1.1	0.7
Lead	Pb	0.1	0.09	0.08	3.6	0.3	0.03	57.1	4	0.3	0.02	0.1	0.009
chromium	Cr	2	0.2	0.8	2	2.4	0.05	2.1	1.9	2.1	0.05	0.7	0.7

cobalt	Co	1	0.09	1.08	0.15	1.9	0.3	2.2	0.03	1	0.09	0	0.06
Cadmium	Cd	1.9	0.1	0.3	0.6	2.3	0.05	3.7	0.65	3.4	0.05	0	0.006
Arsenic	As	0.6	0.1	0.1	0.7	0.3	0.05	5.9	0.3	0.3	0.01	0.1	0.13
Molybdenum	Mo	0.3	0.7	0.1	0.06	1	0.5	0.7	0.03	0	0.04	0	0.04
Mercury	Hg	1	2.2	0.3	0.3	1	0.2	1.9	0.18	0.9	0.4	0.1	0.04
Zink	Zn	0.3	0.09	0.1	17.3	0.1	0.1	56	18.9	0.9	0.02	0.1	0.14
barium	Ba	0.4	0.09	0.2	0.19	0.4	0.05	2.3	0.18	0.4	0.02	0.2	0.09
Vandaniu m	V	54.3	0.2	0.2	0.19	0.3	0.2	0	0.09	0.6	0.2	0.2	0.2
Uranium	U	0.04	0.09	0	0.0018	0.06	0.05	0.07	0	0.09	0.09	0.02	0.00 09
Thallium	Tl	1.4	0	0	8.8	1.4	0	21.5	4.5	1.1	0	0.8	0.7
Antimony	Sb	0.9	0.7	0.6	0.37	0.9	0.2	1.8	0.6	1	0.1	0.6	0
Tin	Sn	2.4	0.07	1	0.7	3.6	0.1	38	0.7	3	0.05	0	0.37
Selenium	Se	0	0	0	2.6	0	0	2.7	0.7	0	0	0	0

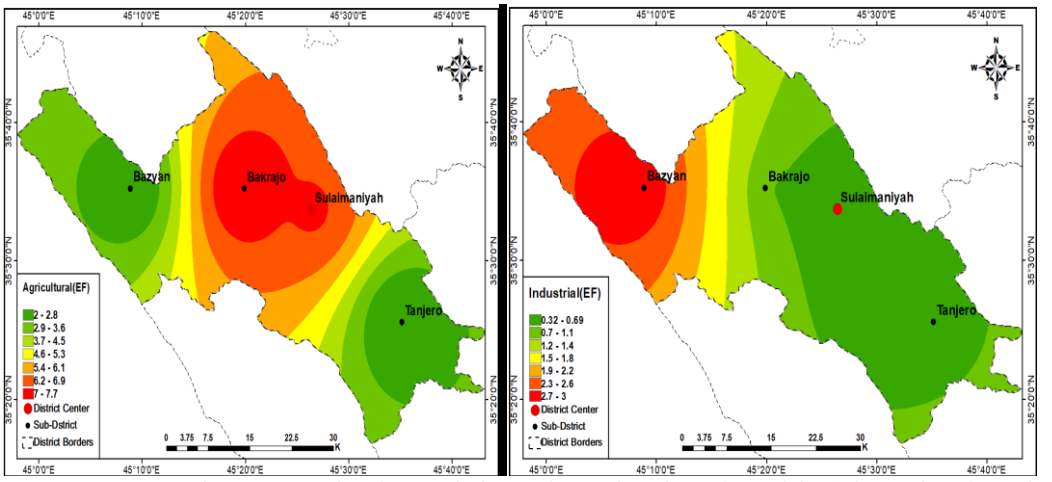
From the researcher's work, based on the results of laboratory analyses & statistical processes, using Excel (2016).

B- Bazian Sub-District: It turned out that it occupies the lead in terms of enrichment factor values for service soils, reaching (11.8), which is a high enrichment, and the enrichment of the elements (lead and zinc) rose above (50), which is considered to be a highly polluting enrichment, in addition to the high values of tin enrichment (38), which is very high, and thallium (21.5) and arsenic are more than (5) and this is also a high enrichment. This is evidence of the frequent traffic of cars and long vehicles with large payloads in the district of Bazian and more intensely than in other parts of the district as a result of the presence of heavy factories in it, in addition to the presence of scrap stores, which are often transported to it from the central and southern regions of Iraq through the Chamchamal-Bazian road. As for the other ground uses, it rose above (1) and this is considered a slight enrichment, but we note the high enrichment of the copper element in industrial soils, reaching (23.7), which is a very high enrichment due to its use in the metallurgical industries, turning and welding works. And the zinc enrichment in the soils of drainage and sanitary landfills increased to (18.9), which is a high enrichment, and the values of lead and thallium enrichment reached more than (4), as a result of dumping heavy water from factories, shops, and hospitals with domestic wastewater towards river valleys in the district.

C- Tanjaro Sub-District: It turns out that the values of the enrichment factor for agricultural soils, drainage, and sanitary landfills are lower than in Bazian, which

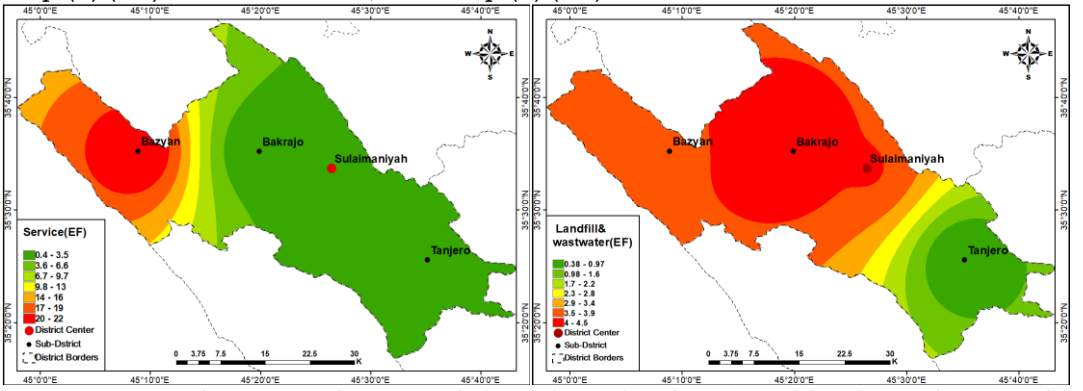
is less than (2) and represents a slight enrichment, and industrial and service soils have lower enrichment than (1), which is a clean enrichment.

Map (1) (EF) for agricultural soils. Map (2) (EF) for industrial soils.



Source: From the researcher's work based on the data in table (5) and using the ARC.GIS (10.8) program.

map (3) (EF) for service soils, and map (4) (EF) for landfill and wastewater soils.



Source: From the researcher's work based on the data in table (5) and using the ARC.GIS (10.8) program

2- Pollution factor: (CF): based on the data of table (6))&map(5,6,7,8), it becomes clear to us:

A- The center & Bakrajo Sub-district: From the extrapolation of a table (6), it turned out that the area is at the forefront of the other aspects in the high values of the pollution factor for agricultural soils, which are more than (3) and it falls within the category of high pollution, where the pollution values of some elements, including vanadium, rise to (38), which is a very high value, and as for the elements (nickel, chromium, cadmium, and tin) their values were higher than (1) and they are in the moderately polluted category. The agricultural areas in Bakrajo district mostly, especially those located on the banks of the Tanjaro Valley and the river valleys that flow into it, depending on the irrigation of crops,

especially in the summer, on the water of the river valleys, which in turn contains sewage and domestic and industrial wastewater without treatment, which carries with it the chemical elements Polluted and in high concentrations causing the resultant pollution of those soils. As for the rest of the uses of soils in the sub-district, they recorded low pollution, with a variation in the values of polluting elements. In industrial soils, mercury recorded high pollution, and copper, nickel, molybdenum, and antimony recorded moderate pollution. The reason for this pollution is due to the presence of an iron and steel plant that uses (copper & nickel) in its production and industrial processes, as well as the spread of many plants producing cement, bricks, and biharton in the region.

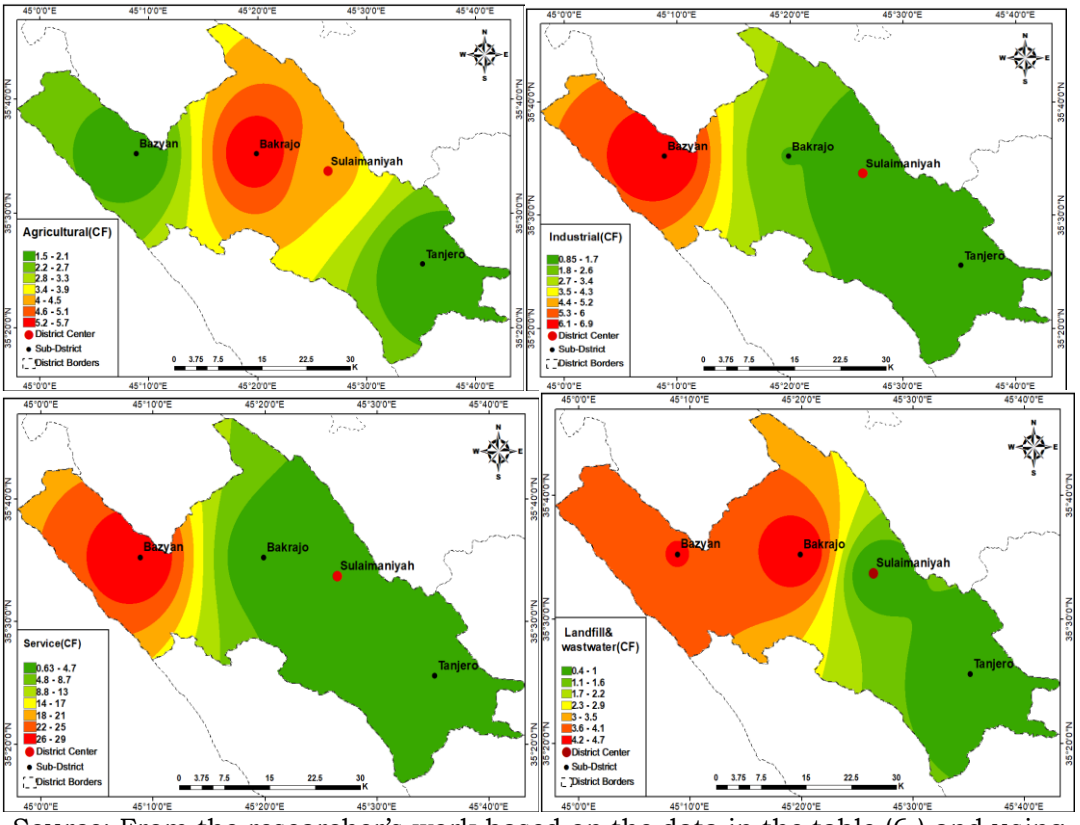
Table (6) Soil pollution by chemical elements according to the pollution coefficient in a unit (PPM)

Elements		EF(Bakrajo)					F (Bazian)				EF (Tangro)		
	parameters	Agricultural	Industrial	Service	Landfill& wastewater	Agricultural	Industrial	Service	Landfill& wastewater	Agricultural	Industrial	Service	Landfill& wastewater
copper	Cu	0.2	2.6	0.3	0.99	0.2	52.1	4.5	1.7	0.3	2.2	0.6	0.3
Nickel	Ni	1.8	1.5	1.9	1.2	2.2	2.5	1	0.9	1.9	1.7	1.48	0.8
Lead	Pb	0.1	0.2	0.1	3.8	0.2	0.07	74.2	4.3	0.2	0.05	0.2	0.01
chromium	Cr	1.4	0.4	1.08	2.2	1.7	0.1	2.7	2	1.5	0.1	0.97	0.8
cobalt	Co	0.7	0.2	1.4	0.16	1.3	0.7	2.9	0.03	0.7	0.2	0	0.07
Cadmium	Cd	1.3	0.3	0.4	0.6	1.6	0.1	4.9	0.7	2.4	0.1	0	0.007
Arsenic	As	0.4	0.3	0.2	0.7	0.2	0.1	7.6	0.3	0.2	0.02	0.2	0.14
Molybdenum	Mo	0.2	1.5	0.2	0.06	0.7	1	0.9	0.04	0	0.9	0	0.05
Mercury	Hg	0.7	4.8	0.4	0.3	0.7	0.5	2.5	0.2	0.6	0.8	0.2	0.05
Zink	Zn	0.2	0.2	0.2	18.5	0.1	0.3	72.8	20.2	0.6	0.09	0.2	0.15
barium	Ba	0.3	0.2	0.3	0.2	0.3	0.1	3	0.2	0.3	0.09	0.3	0.1
Vandanium	V	38	0.5	0.3	0.2	0.2	0.5	0	0.1	0.4	0.4	0.3	0.22
Uranium	U	0.03	0.2	0.01	0.002	0.04	0.1	0.1	0	0.06	0.2	0.03	0.001
Thallium	Tl	1	0	0	9.4	1	0.01	28	4.8	0.8	0.01	1	0.8
Antimony	Sb	0.6	1.5	0.8	0.4	0.6	0.5	2.4	0.6	0.7	0.3	0.8	0
Tin	Sn	1.7	0.2	1.4	0.8	2.5	0.2	49.7	0.8	2.1	0.1	0	0.4
Selenium	Se	\	\	0	2.8	\	\	3.5	0.8	\	\	0	0

From the researcher's work, based on the results of laboratory analyses & statistical processes, using Excel(2016).

B- Bazian Sub-district: Table (6) shows the sub-district for the pollution factor values for service soils where the value exceeded (15), which is a very high category, With a discrepancy between the values of the elements, where the pollution coefficient of lead reached (74,2), zinc (72.8), thallium (28) and arsenic (7). The reason for this is due to some of these elements, such as lead and zinc, as we explained previously, due to the heavy vehicles frequenting the producing factories in the district. Concerning the high coefficient of zinc contamination (20.2), it was in soils with landfills and sewage and others affected by them. As for the copper element, its contamination coefficient reached (52) and these values are very high and denounce the risks.

C- Tanjaro Sub-district: From extrapolating the data shown in Table (7), it turns out that there is an increase in the pollution coefficient values for landfill and sewage soils for more than (1), that is the moderate pollution category, The elements zinc and thallium recorded a very high pollution coefficient and the reason for this is due to the mixing of wastewater and heavy water containing high concentrations of the elements in the river valleys. The(CF) pollution factor according to the administrative units of the study area (5) agricultural soil, map (6) industrial soil, map (7) service soil, map (8) landfill soil, and wasewater.



Source: From the researcher's work based on the data in the table (6) and using the ARC.GIS (version 10.8)

Environmental Risk (ER) and Load Index (RI)

The center & Sub-district (Bakrajo)

From Table (7), it is clear to us that the area, in general, suffers from slight pollution for all types of land uses, with a difference between the polluting elements. The antimony element recorded an increase in the pollution index and reached the level of moderate pollution in industrial soils.

Table (7) The results of the equation of the load index, pollution, and environmental risks in Sulaymaniyah district

Elements	parameter	Er (Bakrajo)				Er (Bazian)				Er (Tangro)			
		Agricultural	Industrial	Service	Landfill & wastewater	Agricultural	Industrial	Service	Landfill & wastewater	Agricultural	Industrial	Service	Landfill & wastewater
copper	Cu	1	13	1.5	4.95	1.5	260.5	22.5	8.5	2	11	3	1.5
Nickel	Ni	9	3	9.5	6	15.5	5	5	4.5	13.5	3.4	7.4	4
Lead	Pb	0.5	1	0.5	19	1.5	0.35	371	21.5	1.5	0.25	1	0.05
chromium	Cr	2.8	2	2.2	4.4	4.8	3	5.4	4	4.2	3	1.94	1.6
cobalt	Co	3.5	2	7	0.8	9.5	7	14.5	0.15	5	2	0	0.35
Cadmium	Cd	39	0.6	12	18	69	0.2	147	21	102	0.2	0	0.21
Arsenic	As	4	1	2	7	3	0.5	76	3	3	0.1	2	1.4
Molybdenum	Mo	1	7.5	1	0.3	5	5	4.5	0.2	0	4.5	0	0.25
Mercury	Hg	28	4.8	16	12	40	1.1	100	8	36	0.8	8	2
Zink	Zn	0.2	1	0.2	18.5	0.1	1.5	72.8	20.2	0.9	0.25	0.2	0.15
barium	Ba	0.6	8	0.6	0.4	0.8	4	6	0.4	0.8	2	0.6	0.2
Vandanium	V	76	2.5	0.6	0.4	0.6	2.5	0	0.2	1.2	2	0.6	0.44
Uranium	U	0.2	0.4	0.3	0.01	1.8	0.2	3	0	0.45	0.4	0.9	0.005
Thallium	Tl	30	0	0	282	7	0.05	140	144	33	0.05	5	24
Antimony	Sb	3	45	4	2	4.5	0.5	12	3	5	9	4	0
Tin	Sn	8.5	1	2.8	4	12.5	60	99.4	4	15	0.5	0	2
Selenium	Se	0	0	0	5.6	0	0	7	1.6	0	0	0	0
) RI(Risk Index		207.3	92.8	60.2	385.4	177.1	351.4	1086	244.25	223.6	39.5	34.6	38.16
sum		745.7				1858				335.86			

Source: From the researcher's work is based on the results of the equation of the load index, pollution, and environmental risks.

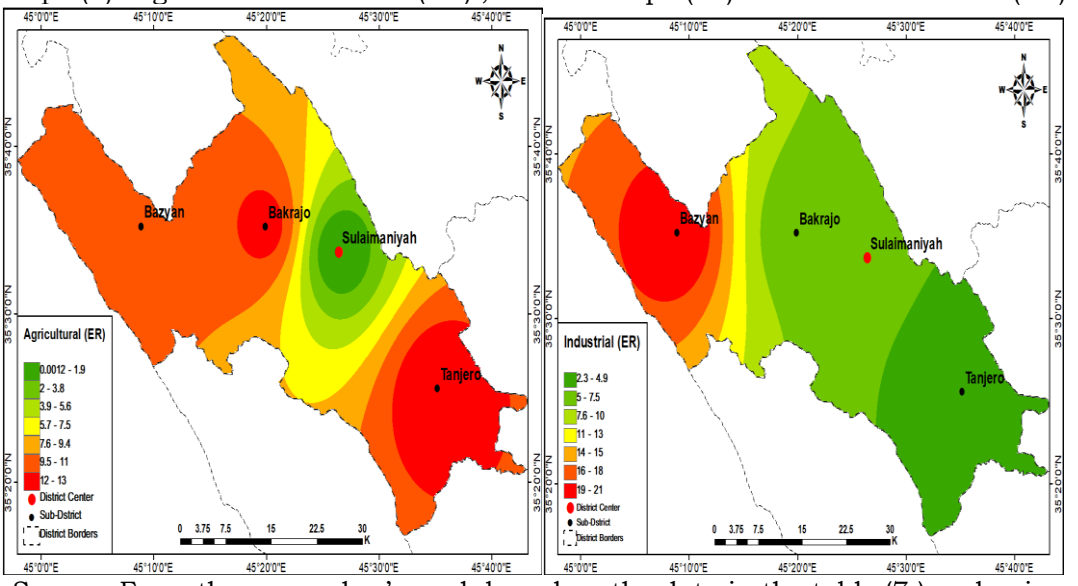
Bazian Sub-district

By extrapolating Table 7, it becomes clear to us that the pollution of the district, in general, is more than the rest of the other districts, as the district leads the rest of the other districts with soil pollution for service use, and the load index reached (63.888), which is within the moderate category of pollution, but some elements recorded high pollution, including (cadmium, mercury, thallium, tin) while the lead index exceeded the severe pollution category, This is due to the frequent movement of vehicles, fuel combustion, and oil derivatives leaks. The same case with soils of industrial use, where the rest of the aspects topped the list and the load index reached the equivalent of (20,670) and the copper index recorded severe pollution and its return is mostly due to the large concentration of factories and industrial projects in the district and a large number of their polluting waste thrown into the soil. Despite the low indicators of soils with agricultural use and sanitation compared to Tanjaro, they remain within the polluted soils, even if they are considered minor.

Tangro Sub-district

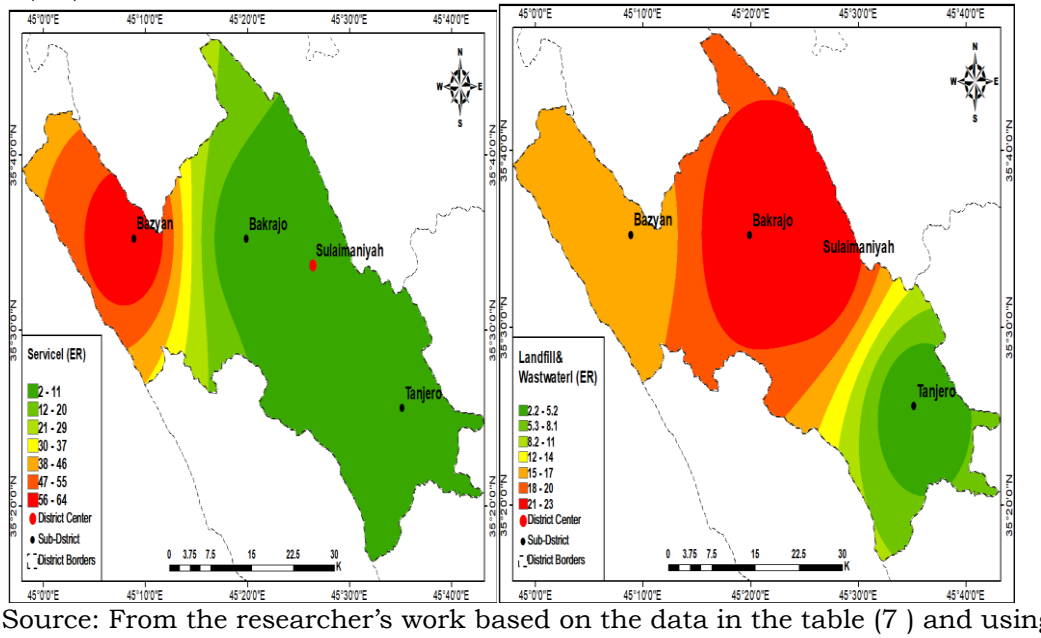
After extrapolating Table (7), it was found that the district, in general, suffers from light pollution, the highest value recorded is for cadmium in agricultural soils, in the high pollution category, and thallium recorded high pollution in landfill and sewage soils. By comparing the pollution index of the administrative units in the district with the enrichment factor and the pollution factor, it was found that the results matched each other, and this can be seen through the extraction of the risk value (RI), where the Bazian district takes the lead in pollution and risks, as it reached the final danger in service soils and It has decreased in soils for other uses to moderate to high risks that require moving quickly and working to find adequate solutions, Next comes the Tanjaro district, as it suffers from moderate pollution about agricultural soils, landfill soils and sewage, and the Bakrajo district suffers from moderate environmental risks for agricultural soils to slight for other uses.

Map (9) agricultural soil BY(ER)., map (10) industrial soil BY(ER).



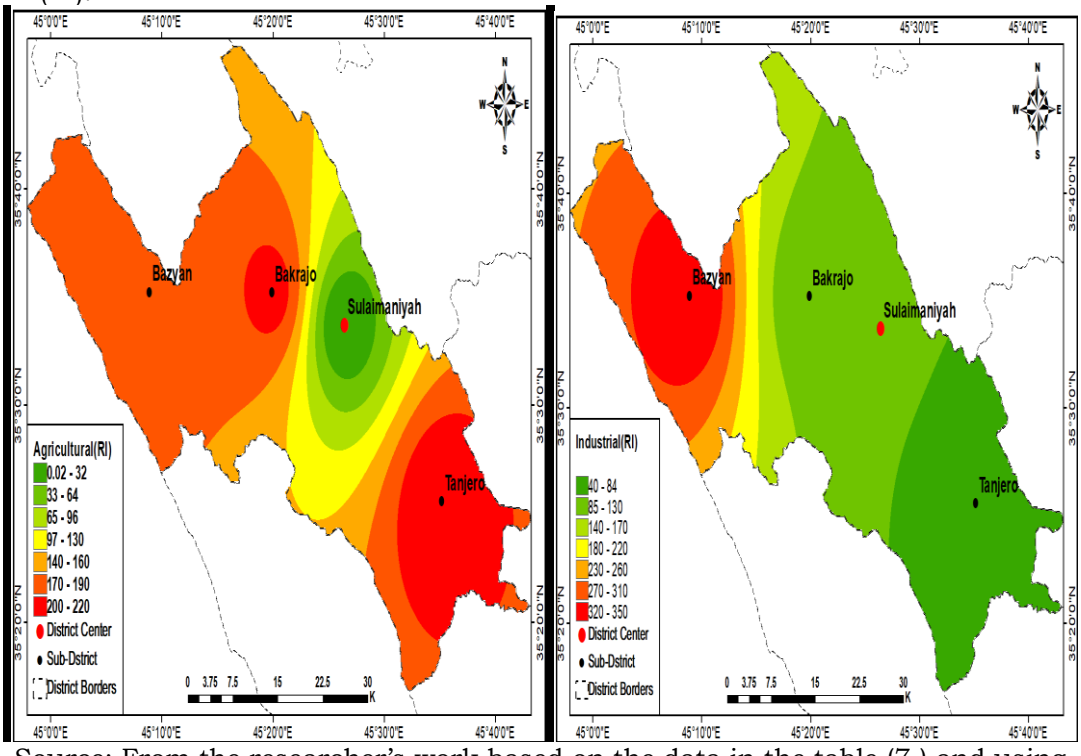
Source: From the researcher's work based on the data in the table (7) and using the ARC.GIS (10.8) program

Map(11) service soil BY(ER). Map (12) landfill soil and sanitation BY(ER).



Source: From the researcher's work based on the data in the table (7) and using the ARC.GIS (10.8) program

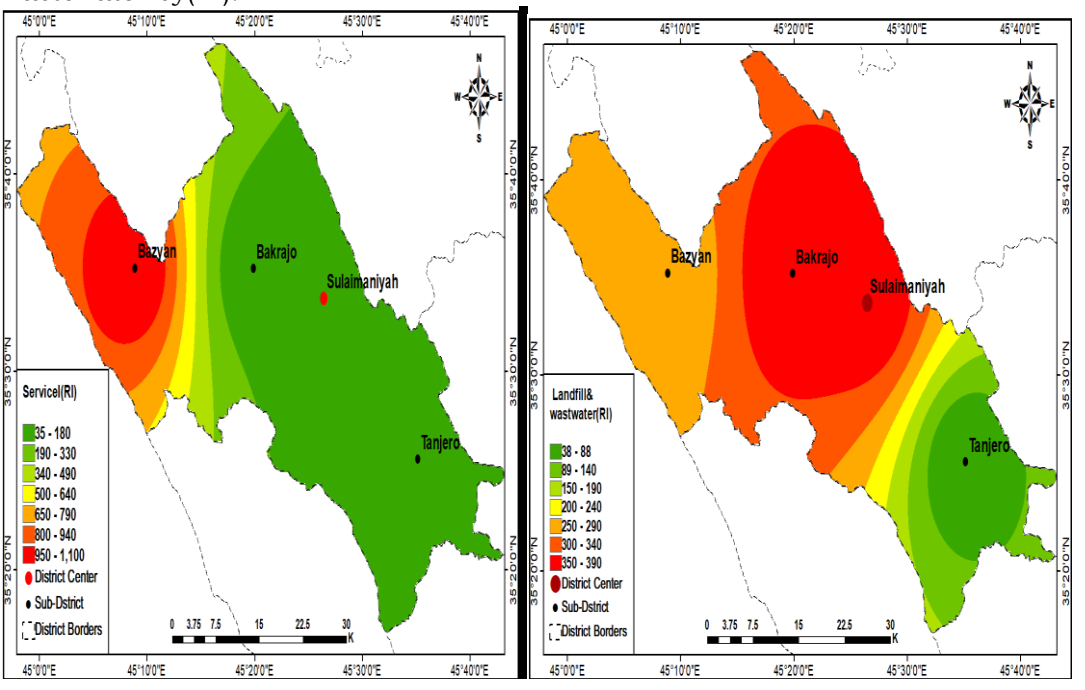
Map (13) agricultural soil BY(RI)., Map (14) industrial soil BY(RI).



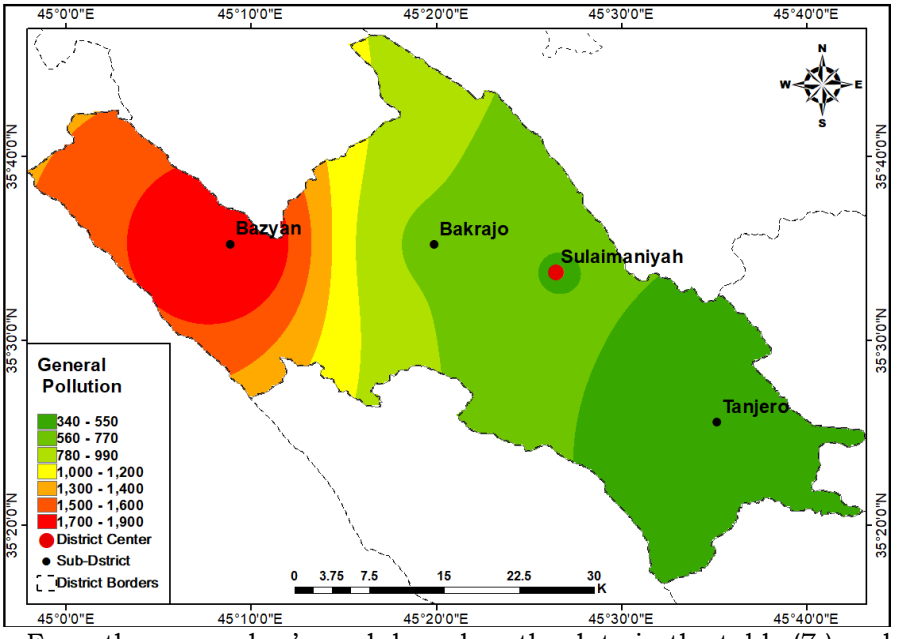
Source: From the researcher's work based on the data in the table (7) and using the ARC.GIS (version 10.8)

Map(15) service soil by(RI) wastewater by(RI).

Map (16) landfill soil and



Map(17)of the general pollution of Sulaymaniyah district by administrative units.



Source: From the researcher's work based on the data in the table (7) and using the ARC.GIS (version 10.8)

Conclusions

First - From the results of the environmental assessment of the soil of the district, according to the soil polluting elements:

a. The copper element recorded high values of pollution amounting to (10.6), while (zinc, lead, and tin) recorded a high enrichment in the service soils. And a very high pollution coefficient for the same elements in the service soils, in addition to the high values of thallium for very high pollution in the service soils and copper in industrial soils.
b. The majority of the elements participated as light pollution concerning the load index, while the load index recorded high pollution of copper in industrial soils, cadmium in landfill soils, and sewage and thallium in agricultural and service soils.
c. Using the risk index (RI), the pollution varied between slight to severe pollution, as the service soils recorded high risks, whose values reached (402.6), followed by industrial soils, then landfill and sewage soils with moderate pollution.

Second- The results of the environmental assessment of the soil of the district according to the administrative units in the district:

a. Bazian district occupied the lead in the high pollution of service soils according to the enrichment factor and the pollution factor, while the Bakrajo district recorded high pollution in its agricultural soils according to the pollution factor, while the Tanjaro district recorded enrichment and a slight pollution factor except for the elemental (zinc and thallium) whose values increased in soils Landfill and sewage.
b. According to the load index, it was found that the Bazian district suffers from severe pollution, especially in the service soils, while the pollution was slight in the areas of Tanjaro and Bakrajo.
c. The environmental risks showed that the Bazian district occupies the lead in pollution, especially the service soils, as it reached the state of final danger, then followed by the Tanjaro district, which suffers from moderate pollution in agricultural soils, landfills, and sewage, and as for the district of Bakrajo, its agricultural soil suffers from slight pollution to moderate.

Recommendations: The study recommends the following

a. Not to use the soils near the Tanjaro River and the soils adjacent to factories and large factories, as well as those located in industrial neighborhoods, due to the high concentrations of harmful elements in them that are transmitted to humans through crops, until they are treated or alternative solutions are found.
b. Allocating a landfill for waste away from residential and populated areas by at least (30 km), and the current waste on the banks of the Tanjaro River, which is scattered from it on the external roads, as well as construction waste inside the residential shops, must be removed and used in filling the depressions and leveling the roads.

c. Establishing several industrial projects, making use of solid and liquid waste, and using practical methods that guarantee the recycling of such waste based on type to ensure the entry of an economic resource.
d. Establishment of (3) stations for the treatment of waste and heavy water, and to benefit from them in the summer to spray crops. It is preferable to establish them at the main boxes of the drainages at the river (Serjnar, Qliasan, Tanjaro). Here the specter of pollution is removed from the waters of the Tanjaro River.
e. Putting laws and legislation into practice to deter violations of agricultural lands, prevent the establishment of industrial projects within the agricultural space, and try to remove industrial projects that transgress lands unsuitable for agriculture, east of Sulaymaniyah.
f. Planting trees and increasing plant density, which reduces pollutants by absorbing part of the pollutants and increasing soil fertility.

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