Iraqi Geological Journal

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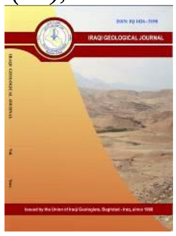

Environmental Geochemistry and Bioavailability and Health Effects of Chromium in Topsoil and Cauliflower Plant in Kirkuk, Northern Iraq

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Received: 30 December 2021

Accepted: 10 March 2022

Published: 31 May 2022

Abstract

The content of chromium in the surface soil as well as its content in cauliflower plants in Kirkuk was studied to investigate the environmental geochemistry of this element. 30 samples of surface soil were collected from inside the study area at a depth of 0-20 cm. Eight samples of cauliflower were collected from the same study area, soil and plant sampling sites were determined using a GPS device . Using ICP-MS technology we were able to analyze these samples. The results of ICP-MS showed that the average concentration of chromium in the soil samples was 78.59 mg/kg and its highest concentration was in the sample A12 (93.4 mg/kg), the increase in the concentration of chromium in the soil is due to agricultural fertilizers, irrigation with sewage water, the impact of traffic, commercial activities and industrial workshop. The mean of its concentration cauliflower samples was 3.81 mg/kg, and the highest concentration was 4.7 mg/kg in sample AQ10, the increase in the concentration of chromium in the plant is due to pollution in the soil, and the difference in these concentrations is due to the location of the sample and the properties of the soil. The plant absorbs it through the roots, then the stems, leaves,and fruits. Bioaccumulation factor value for chromium ranged with an average of 0.047 for all cauliflower samples. CF soil samples that the surface soil for this area is within a level (low pollution, CF <1) indicating the presence of pollution at a very low level, and the potential ecological risk index PRI found that all surface soil samples in the study area have (low risk level, PLI≤50), and Igeo indicates that there is no pollution (practically uncontaminated, Igeo ≤ 0). It was found that the value of THQnc for both groups of adults and children in the study area was greater than 1. The CRcancer values for both groups were greater than 1*10-4.

Keywords: Chromium; Size fraction; Bioaccumulation; Contamination index; Health risk assessment; Kirkuk

1. Introduction

Chromium is a toxic element for living organisms when it is present in high concentrations, while in low concentrations it is a micro-nutrient required for living organisms (Anderson, 1997). It is considered one of the most abundant elements in the earth's crust, which constitutes about 0.037% of it, and which occupies the twenty-first position of its rocks (Grath and Smith, 1990). Trivalent chromium Cr+3 is mostly found naturally, while hexavalent Cr+6 is mostly synthetic (Nath et al., 2009). The bioavailability of toxic elements, including chromium, is closely related to the nature of pollutants, the chemical forms in which they occur in the soil, and their physical and chemical properties, which control

DOI: 10.46717/igj.55.1E.14Ms-2022-05-30

the repartition of pollutants between the different geochemical regions of the soil (Adamo et al., 2014). The acidity is an important factor in the natural environment and can be a source of chromium release into soil (Komonweeraket et al., 2015). Soil organic matter is the main component of soil and is involved in reducing bioavailability and reducing its mobility in its solution (Wolińska et al., 2018). It is required for humans as it plays a vital role in the metabolism of protein, fat and glucose. As for hexavalent chromium, Cr(VI) is considered a danger to human health, especially through acute inhalation and chronic exposure, because it promotes respiratory problems, which is the main target for toxicity (Cabral-Pinto et al., 2020). It has toxic, mutagenic, and carcinogenic effects, as well as skin problems such as skin ulcers, skin perforation, perforation of the eardrum, low spermatogenesis and lung cancer (Bharagava and Mishra, 2018). Excessive use of chemical fertilizers in agricultural fields, municipal waste disposal, industrial development and sanitation among the most important sources of soil pollution in agricultural and urban areas all over the world (Ciarkowska, 2018). The mean daily exposure dose, non-carcinogenic risk assessment and it is calculated from target hazard quotient (THQ), and carcinogenic risk assessment (CR) have been used widely worldwide to determine (CR) and non-carcinogenic (NCR) substances for human health when ingesting food products, which developed by the US Environmental Protection Agency (USEPA, 2009). Chromium enters the human body via several ways, inhalation, mouth, and skin contact (Li et al., 2016). The current study goals to determine the concentration of chromium in surface soil samples and cauliflower, determine bioaccumulation (BCF) of cauliflower of chromium from soil to cauliflower plant, The process of evaluating the contamination of these samples with chromium from the surface soil, and through the consumption of cauliflower, and the consequent health risks resulting from this element to the local population of children and adults in this area located in Kirkuk governorate.

2. Materials and Methods

2.1. Study Area Location

Al-Abbasi town is located on the western side of Hawija town, southwest of Kirkuk city, and between longitude (43°35′37″- 43°44′36″ E) and latitude (35°16′21″- 35°26′50″ N). It is about 71 km away from the center of the governorate towards the southwest of Kirkuk governorate (Fig. 1). According to the description of (Buringh, 1960), Al-Abbasi town is completely covered by the sediments of the Quaternary sediment, and this type of sediments are sediments of Polygenetic deposit composed of gravel, sand and soil. It is characterized by the presence of river terrace deposits, which are aggregates of sedimentary materials consisting of gravel, sand and clay in layers, while the size of the gravel varies from large size to small size gradually towards the mouth. In addition to that, the presence of a sandy layer under the gravel layers and these deposits are located on both sides of the Lower Zab River mainly and consists of silica, igneous and mudstones (Jassim and Goff, 2006).

2.2. Sampling Collection

A total of 30 samples were collected from the topsoil in soil in the Al-Abbasi town on December 25th, 2020, They are symbolized by A at a depth of 0-20 cm using an auger tool and weight approximately 1 kg for each sample, this depth was chosen becauce it represents the surface soil. They were placed in polyethylene bags for the purpose of conducting laboratory analysis. They were also numbered and their coordinates were projected using the GPS in the laboratory, They were dried at 55 °C, and the samples were crushed and sieved through a 2 mm sieve. Eight samples of cauliflower were also collected on 25th, December, 2020 in the cultivated areas within Al-Abbasi town. They are by symbolized AQ (Table 1).

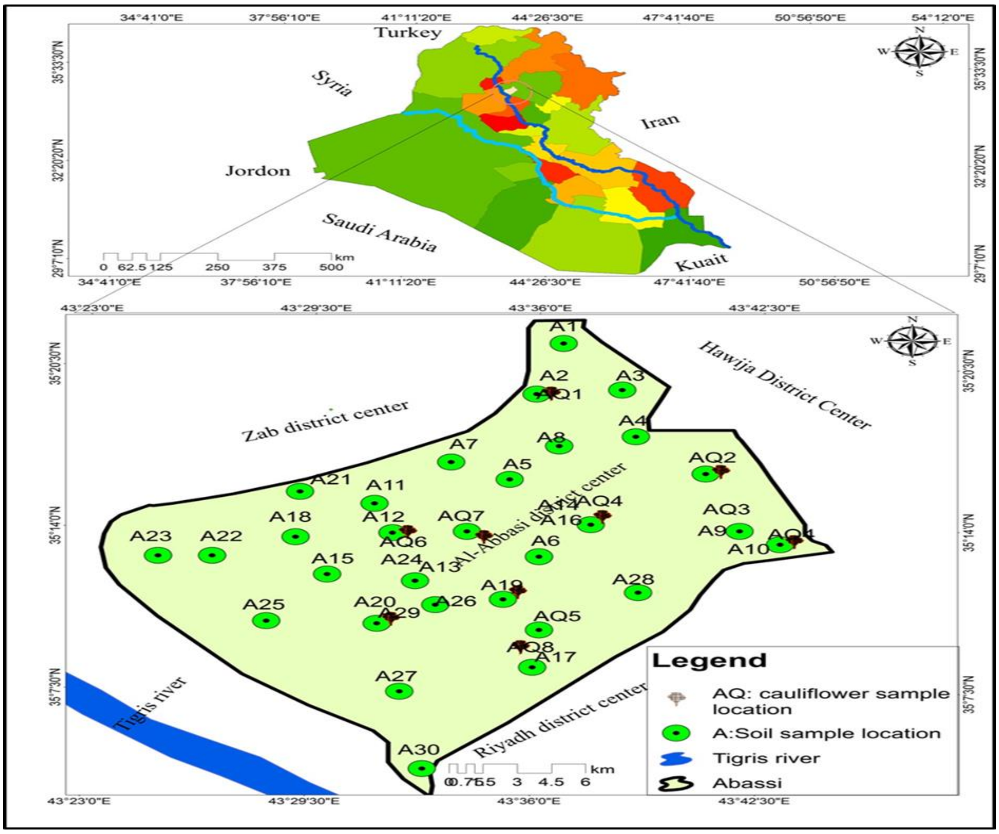

Fig. 1. The study area shows the locations of soil and cauliflower samples (Arc GIS)

They were dried in an oven at a temperature not exceeding 70°C, these procedures were carried out in accordance with the requirements of the laboratory to be analyzed. Thus, the required samples of soil and cauliflower are prepared according to the requirements of the laboratory and prepared for chemical analysis to determine the chromium concentration using ICP-MS technology in the laboratory of the Department of Geology, College of Engineering, Ankara University, Turkey.

Table 1. Coordinate′s and symbles for collected soil and cauliflower plant samples

Sample NO.	Latitude	Longitude	Sample NO.	Latitude	Longitude
A1	N35˚18′24″	E43°39′23″	A16	N35°16′34″	E43°35′47″
A2	N35°16′55″	E43°38′37″	A17	N35°16′46″	E43°35′48″
A[1]3 / AQ[2]3	N35°16′30″	E43°37′26″	A18	N35°17′19″	E43°35′41″
A4	N35°16′33″	E43°37′25″	A19 / AQ19	N35°18′14″	E43°35′37″
A5	N35°16′23″	E43°36′38″	A20	N35°18′42″	E43°35′38″
A6 / AQ6	N35°16′23″	E43°36′39″	A21	N35°18′58″	E43°35′53″
A7	N35°16′32″	E43°35′53″	A22	N35°18′59″	E43°35′54″
A8	N35°16′24″	E43°36′13″	A23	N35°20′35″	E43°37′26″
A9	N35°16′21″	E43°36′41″	A24	N35°21′19″	E43°38′10″
A10 / AQ10	N35°17′23″	E43°39′41″	A25	N35°20′23″	E43°37′20″
A11	N35°17′37″	E43°41′38″	A26 / AQ26	N35°19′43″	E43°37′55″
A12	N35°17′45″	E43°42′53″	A27	N35°19′18″	E43°37′56″
A13 / AQ13	N35°18′14″	E43°44′29″	A28 / AQ28	N35°19′37″	E43°38′10″
A14	N35°18′29″	E43°44′36″	A29	N35°19′39″	E43°38′51″
A15 / AQ15	N35°18′17″	E43°44′14″	A30	N35°18′34″	E43°39′25″

A[1]: Soil sample; AQ[2]: Plant sample

2.3. Size Fraction

For the purpose of studying chromium concentration and understanding its behavior in the size fraction part of the study area, nine soil samples for the purpose of covering this analysis within the study area (A1,A2,A8.A12.A16,A20,A22,A25,A28) were selected. They were separated volumetrically into sand, silt and clay using the pipet analysis method according to (Carver, 1971) and sent to the same laboratories for the purpose of analyzing chromium concentrations in them.

2.4. Bioaccumulation of Chromium in Cauliflower Plant (*Brassica oleracea*)

In general, the bioaccumulation factor is able to reverse the plant's ability to absorb elements including chromium (Jeelani et al., 2017). The ability of chromium to transfer from the soil to the cauliflower plant and it is referred to as the ratio of the concentration of chromium in the plant to its concentration in the soil (Abbasi et al., 2013). It is obtained by using the following equation:

$$BCF = C\ cauliflower / C\ topsoil \quad (1)$$

Where, C *cauliflower* Represent the concentration of Cr in the cauliflower plant (mg/kg). C *topsoil*: the concentration of Cr in the soil (mg/kg). According to Liu et al. (2007), if its value is BCF ≤ 1, this indicates that the cauliflower plant absorbs Cr without accumulating in it, but if it is BCF > 1, this indicates its accumulation in the plant.

2.5. Assessment of Soil Samples Contamination with Chromium

CF reflects human input into the pollution component and is widely used as an overall measure of soil pollution (Bhuiyan et al., 2010). It is obtained by dividing the concentration of chromium in the soil by its concentration in the earth's crust (Hakanson, 1980). As shown in the following equation:

$$CF = Ci / Bi \quad (2)$$

Where Ci: the concentration of Cr in the topsoil samples. Bi: The concentration of Cr in the earth's crust is (136 ppm) according to Widepool (1995). According to Hakanson, (1980); Loska et al. (2004) the CF is classified into five classes of pollution: low pollution (CF < 1); moderate contamination factor (1 ≤ CF < 3); Significant polluting factor (3 ≤ CF <6) and very high polluting factor (CF ≥6).

Potential Ecological Risk Index (PRI). The purpose of this assessment is to provide an empirical basis for understanding the environmental risks ranked for the concentrations of chromium or other heavy metals in soil samples. It is calculated by summing all the values derived from the environmental risk calculation ($E_r^i E_r^i$) and computed from this equation according to (Hakanson, 1980; Jiang et al., 2014):

$$PRI = \sum_{i=1}^{n} E_r^i \sum_{i=1}^{n} E_r^i, \quad (3)$$

$$E_r^i E_r^i = T_r^i T_r^i * (Ci/Bi), \quad (4)$$

Where, $E_r^i E_r^i$: is the potential environmental hazard of Cr, $T_r^i T_r^i$: the toxicity coefficient of Cr is equal to 2 according to Islam et al. (2014), Ci: the concentration of Cr, Bi: the concentration of Cr in the earth's crust, The levels of the potential environmental hazard index (PRI) for soils were classified according to (Guan et al., 2014): low risk (PLI ≤ 50), moderate risk (50 < PLI ≤ 100), considerable (100 < PLI ≤150), very high risk (150 < PLI ≤ 200), extreme risk (PLI > 200).

Geoaccumulation Index (Igeo) the purpose of using this tool is to determine the concentration of chromium in the topsoil within the study area according to (Muller, 1969; Lu and Bai, 2010) and as follows:

$$Igeo = Log2\ [C_{cr}/1.5*B_{cr}], \quad (5)$$

Where, C_{cr} is the concentration of chromium measured in the topsoil (mg/kg); 1.5 it is added due to the detection of minimal impacts resulting from anthropogenic and the variance of lithic impacts is reduced; Bn_{cr}: represents the concentration of chromium in the earth's crust, which is (136 ppm), according to (Wedepohl, 1995), According to Müller (1969), the Igeo index for each metal consists of seven grades (Table 2).

Table 2. Classification of Geoaccumulation Index According to Müller (1969).

Class	Value	Description
0	Igeo ≤≤ 0	Uncontaminated
1	0 << Igeo ≤≤ 1	Uncontaminated to moderately contaminated
2	1 << Igeo ≤≤ 2	Moderately contaminated
3	2 << Igeo ≤≤ 3	Moderately to heavily contaminated
4	3 << Igeo ≤≤ 4	Heavily contaminated
5	4 << Igeo ≤≤ 5	Heavily to extremely contaminated
6	Igeo >> 5	Extremely contaminated

2.6. Evaluation of the Health Risks of Chromium in the Cauliflower (Brassica oleracea)

The non-carcinogenic risks of chromium in cauliflower were assessed by calculating the target noncarcinogenic risk quotient (THQ) (Mičijević et al., 2019) and by using the following equation:

$$THQ = DIE_{ing} / RfD_{ing}, \quad (6)$$

$$DIE_{ing} = (C_{Cr} * DI_{grain} * EF * ED)/BW *AT \quad (7)$$

Where, DIE_{ing} is non-carcinogenic daily intake rate; C_{cr} represents the concentration of chromium in cauliflower; DI_{grain} is cauliflower plant ingestion rate; EF is exposure frequency; ED is exposure duration; BW represents the average body weight. Table 3 Shows the interpretation of the variables and their values that have been touched upon in Equations 6 and 7 according to Ge et al.(1996); Wang et al. (2005). If the value is less than one (THQ < 1), there are no non-carcinogenic health risks for the population of this area, and when its value is greater than one (THQ > 1), there is a high chance of no carcinogenic effects indicating a serious health risk to humans (Zheng et al., 2010).

Table 3. Interpretation of the variables and their values used to assess the health risks of Cr in cauliflower samples in the study area according to (Ge et al., 1996; Wang et al., 2005)

Symbol	Child	Adult	Unit	Definition
DIE_{ing}	-	-	mg/kg.day	Non-carcinogenic daily intake rate
C_{cr}	-	-	mg/kg	Chromium concentration in cauliflower
DI_{grain}	0.232	0.345	kg/person/day	Cauliflower ingestion rate
EF	365	365	days/year	Exposure frequency
ED	6	30	Year	Exposure duration
BW	32.7	63.9	Kg	Average body weight
AT	ED*365	ED*365	days	Average time non-carcinogenic
AT	70*365	70*365	days	Average time carcinogenic
RfD_{ing}^{*}	$3*10^{-3}$	$3*10^{-3}$	mg/kg/day	Oral reference dose

RfD^{*} Its value for chromium has been determined by (Li et al., 2013).

Carcinogenic risk is the risk of cancer with chromium in cauliflower which is calculated according to (Dehghani et al., 2017) from the following equation:

$$CR_{cancer} = DIE_{ing\text{-}cancer} * SF_{ing}, \quad (8)$$

Where, DIE_{cancer} represents the rate of daily carcinogenic consumption in (mg/kg.day) unit, the SF_{ing} represents the regression factor for chromium by ingestion pathway in (mg/kg.day) and its value for chromium (0.5 mg/kg.day) according to (Dehghani et al., 2017), note that at carcinogens average time (ED =70*365) both categories, If the value of the ingestion is greater than $CR>1*10^{-4}$, the risk of developing cancer is high, and it is less than $1*10^{-6}$, the risk of developing cancer is minimal and does not pose any obvious risk, while there is a probability of developing carcinogenic diseases if the THQ value is between ($1*10^{-6}$_ $1*10^{-4}$) as per (USEPA, 2009).

3. Results

3.1. Chromium Concentration in Soils and Cauliflower Plant

Determining the type of soil in the Al-Abbasi town using the triangle (Folk, 1974) to drop samples into it, as each head of the triangle represents 100% of the clay, silt and sand size fraction. Using this method, the surface soil samples were dropped for the study area, where the results showed that 28 samples of silty soil and two samples of silt loam soil type.The size fraction distribution in the Al-Abbasi town showed that the bulk of the surface soil samples were silty, with a percentage of about 89.24% and the clay samples amounted to 6.998%, while sand represents the least part of the samples with an average of (3.67%) (Table 4) (Fig .2). Using this method, the surface soil samples were dropped for the study area, where the results showed that 28 samples of silty soil and two samples of silt loam soil type the surface soil of the Al-Abbasi town is consistent with the study of (Al-Obeidi and Al-Jumaily, 2020), as it was shown that the soil of this area was mostly silty and a small part of it was of the silty loamy type. The Cr in the study area was concentrated in very fine granular sizes, this agrees with (Al-Jumaily and Al-Berzanje, 2020), as its concentration increased in the samples of the clay fraction followed by silt and sand. This indicates that the finer sizes have a high adsorption capacity for Cr because of their large surface area, as well as the availability of clay minerals and iron and manganese oxides (Bradl, 2004).

Table 4. Size fraction distribution of the surface soil samples of studied area

Sample	sand%	silt%	clay%	Sample	sand%	silt%	clay%
A1	2.5	92.5	5	A17	5.12	89.74	5.12
A2	1.31	88.16	10.53	A18	1.98	92.33	5.68
A3	2.01	90.45	7.53	A19	2.53	92.41	5.06
A4	1.51	93.43	5.05	A20	17.72	78.48	3.79
A5	7.59	86.08	6.32	A21	1.51	92.17	6.31
A6	6.45	74.19	19.35	A22	7.89	86.84	5.26
A7	3.79	91.14	5.06	A23	1.76	90.68	7.55
A8	2.28	92.64	5.07	A24	2.53	92.41	5.06
A9	2.53	89.87	7.59	A25	3.26	91.71	5.02
A10	2.03	91.6	6.36	A26	3.02	89.42	7.55
A11	7.69	87.18	5.12	A27	2.11	92.59	5.29
A12	5.3	89.65	5.05	A28	2.63	92.11	5.26
A13	2.11	92.59	5.29	A29	2.59	90.91	6.49
A14	5.47	89.04	5.47	A30	2.5	89.14	8.35
A15	2.5	91.92	5.57	Average	3.76	89.24	6.99
A16	5.03	87.41	7.55				

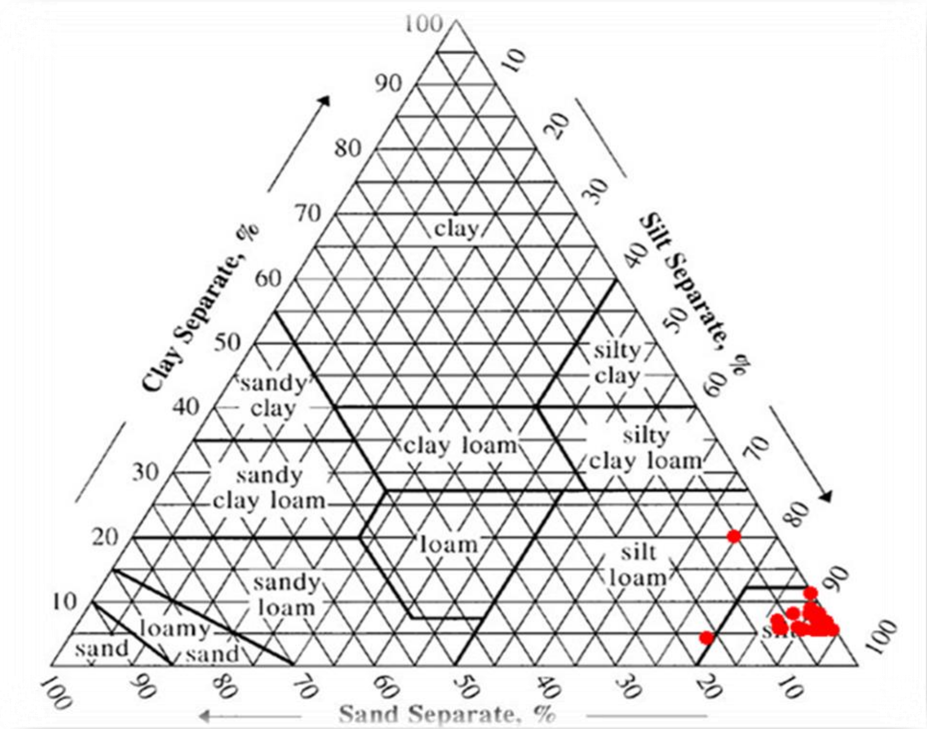

Fig. 2. The size fraction classification of the surface soil samples in the study area (Folk, 1974).

The range of chromium concentration of the surface soil samples within the study area was 72.6-93.4 mg/kg, that is, the average concentration in these samples was 78.59 mg/kg superior to its value recorded globally 59.5 mg/kg according to Kabata-Pendias (2011). Table 5 shows the concentrations of chromium in all soil samples within the study area. In the surface soil samples of the Al-Abbasi town, the highest concentration of chromium reached at the site (A12) with a concentration of 93.4 mg/kg. As commercial activities and traffic are a source of chromium in them. Therefore, the increase in chromium concentration in all these locations may be a result of human activities such as road traffic, vehicle exhaust and road surface erosion, all of these activities lead to an increase in chromium concentration in the soil and this is consistent with Suvarapu and Baek (2017). The sites (A16, A4, A28, A20) have high concentrations in these sites compared to what has been recorded globally and the aforementioned of it (88.8, 88.6, 87.6, 86.45) in mg/kg, respectively, as for the sites A10, A11, A5 concentrations of it (81.6, 79.4, 75.6) in mg/kg, respectively, as sites A16, A28, A10, A11, A5 are agricultural sites, and the increase in its concentration may be due to agricultural operations through the use of Pesticides and fertilizers and irrigation of the land with water containing waste water or polluted water sources. This is consistent with (Nziguheba and Smolders, 2008), Fertilizers may contain chromium as impurities, and that repeated fertilization processes may lead to its accumulation in the soil and this is consistent with Wuana and Okieimen (2011). It is close to the sewage stream, where liquid household waste flows into the sewer, which leads to the supply of pollutants to the sewer, and this water may seep into the agricultural land near it.. Therefore, these waste and household liquids may contain chromium, and this element is not degradable and remains in the soil. This result is in agreement with Venkatachalam et al. (2017). As for the A20 site, it is close to blacksmithing and paint workshops, as it releases solid waste into the environment and thus part of it settles in the environment. The analysis showed that this soil was rich in concentrations of this element as in the sites (A21, A14, A30, A1, A29, A23, A18, A9, A22, A24) concentrations (77.7, 77.3, 77.2, 75.7, 75.3, 75.1, 74.9, 72.6, 72.6) in mg/kg respectively, they are commercial markets and roadsides, as commercial activities and traffic are a source of chromium in them. Therefore, the increase in chromium concentration in all these sites may be a result of human activities, as well as agree with Li et al. (2013), that is, anthropogenic activities such as fossil fuel combustion, industrial activities, corrosion, and resuspension of natural particles through traffic. Construction, and surrounding agricultural activities are all factors that increase the concentration of chromium in the area, and sites (A6, A15, A26, A3, A13, A19) has high concentrations (78.5, 78.2, 77.3, 77.1, 75.9, 74.6) in mg/kg, respectively are agricultural sites, and the increase in its concentration may be due to agricultural operations through the use of irrigation with sewage and household waste water, this agrees with Mojiri and Jalalian (2011), as the sewage water leads to a change in the properties of the soil, a decrease in the acidity function, an increase in its salinity, and an increase in the concentration of chromium in it (Awasthi et al., 2016). However, A13 Agricultural land close to pasture and poultry fields, as animal manure and poultry droppings lead to an increase in chromium and some heavy elements in the soil, this is consistent with (Ramos and Martínez, 2006), as it was mentioned that livestock manure is a natural fertilizer that leads to an increase in the concentration of chromium. Some heavy metals in the soil, and the rest of the sites, represented by agricultural lands, near public sites, the public road and local markets (A2, A7, A8, A17, A25, A27), their concentrations were as follows (76.7, 77.6, 77.8, 76.3, 75.5, 76.8) in mg/kg, respectively, This pollution resulted from agricultural and commercial activities and the movement of vehicles.

Table 5. Chromium concentration values for the study area in the surface soil samples

Sample No.	**Soil Cr (mg/kg)**	**Sample No.**	**Soil Cr (mg/kg)**	**Sample No.**	**Soil Cr (mg/kg)**
A1	75.8	A12	93.4	A23	75.3
A2	76.7	A13	75.9	A24	72.6
A3	77.1	A14	77.3	A25	75.5
A4	88.6	A15	78.2	A26	77.3
A5	75.6	A16	88.8	A27	76.8
A6	78.4	A17	76.3	A28	87.6
A7	77.6	A18	75.1	A29	75.7
A8	77.8	A19	74.6	A30	77.2
A9	74.9	A20	86.45	Average	78.595
A10	81.6	A21	77.7	Range	72.6 - 93.4
A11	79.4	A22	72.6	W.A*	59.5

W.A* It is the world average for chromium according to Kabata and Pendias (2011).

Table 6 shows the chromium concentrations in cauliflower samples within the study area. The range of its concentration in cauliflower samples is 2.5 - 4.7 mg/kg at a rate of 3.81 mg/kg, and its lowest concentration was 2.5 mg/kg in sample AQ6 and the highest concentration reached 4.7 mg/kg in sample AQ10, This site represents a low agricultural land because low terrain in which water collects and a small water stream passes next to it that contains household waste that seeps from this stream into the cultivated land and is mostly carried on the chrome produced from domestic liquid waste. This is consistent with (Mojiri and Jalalian, 2011), as the sewage water leads to a change in the properties of the soil and a decrease in the acidity function, and an increase in its salinity, which inturn leads to an increase in the concentration of chromium in it. As for the sample AQ3, its concentration reached 4.2 mg/kg, which is the second highest concentration in this agricultural area, which is located near the public street, and this indicates that the waste resulting from traffic movement and erosion of road surfaces and brake erosion lead to an increase in chromium concentration in this area and this is consistent with (Adamiec et al., 2016). It was therefore concluded that erosion of road surfaces and brakes leads to enriching the soil nearby with chromium and some heavy metals. Sample AQ19 concentration reached 4 mg/kg and the agricultural area was close to the poultry fields, because while cleaning it, its waste is a mixture of dung and spoiled fodder, leading to its flow over time into the soil, and this may lead to an increase in the concentration of chromium in the soil, in accordance with (Ukpe and Chokor, 2018), as he mentioned poultry feed leads to soil contamination with chromium and some other heavy elements, and thus accumulates in agricultural crops grown with plants, including cauliflower, and samples (AQ13, AQ28, AQ26, AQ15) concentrations reached 3.7, 3.7, 3.8, 3.9 in mg/kg, respectively, it was found that its rate in cauliflower in the Al-Abbasi town is 3.81 mg/kg, which is higher than the average of the WHO/FAO (2007) 2.3 mg/kg.

Table 6. Chromium concentration in Cauliflower plant in the study area.

Sample No.	Cr (mg/kg)	Sample No.	Cr (mg/kg)
AQ3	4.2	AQ26	3.8
AQ6	2.5	AQ28	3.7
AQ10	4.7	Average	3.81
AQ13	3.7	Range	2.5-4.7
AQ15	3.9	(WHO,FAO, 2007)	2.3
AQ19	4		

The total BCF value for chromium ranged from 0.031-0.057 with a total average of 0.047 for all cauliflower samples, among values shown in Table 7. is that the fruits of cauliflower absorb the chromium, but it does not accumulate in it within the study area according to the results shown in the Table 7. because the values of bioaccumulation were less than 1 and although the concentration of chromium was high in the soil, it is difficult to move from the soil to the cauliflower fruit and this agrees with Liu et al. (2017), as it is difficult for some heavy elements, including chromium, to move from the soil to the other parts of the plant despite their high concentration in it, and the soil properties may have a limited effect on the absorption of chromium limited, this agrees with (Liu et al., 2016), When the main characteristics of the soil are not very changing, the chromium element accumulates in the fruits of plants in a very small concentration, and chromium accumulates in the plant, in the following form: roots > stems > leaves > seeds, as the roots work to prevent or reduce its transmission to other parts of the plant (Tiwari et al., 2009).

Table 7. Bioaccumulation (BCF) values of Cauliflower in the study area

Sample No.	BCF	Sample No.	BCF
AQ3	0.054	AQ19	0.053
AQ6	0.031	AQ26	0.049
AQ10	0.057	AQ28	0.042
AQ13	0.048	Average	0.047
AQ15	0.049	Range	0.031 - 0.057

3.2. Assessment of Soil Samples Contamination with Chromium

Indicators of pollution evaluation of Cr in soil samples in Al-Abbasi town are shown in Table 8. After calculating CF of soil samples for the Al-abbasi town, it was found that it ranges from 0.53 - 0.68 and at a rate of 0.58 meaning that the surface soil of this area is within the level of low contamination, CF<1. This indicates the presence of contamination at a very low level. The PRI was calculated for the soil samples and it was found that it ranges between 32-41.2 and a rate of 34.79 and it was compared with the values of the level of the global potential environmental hazard index. It was found that each surface soil samples that fall within the boundaries of the study area (low risk level, PLI≤50). After calculating the geo-accumulation index for the same samples and comparing them with the international values, it was found that they fall within the class 0 of the Al-abbasi soil with a range of -1.15 - -1.51 and a rate of 1.38, these values indicate that there is no contamination in these samples (Practically uncontaminated, Igeo ≤0).

Table 8. The environmental factors values of the surface soil of the study area

S. N*	CF	PRI	Igeo	S.N.	CF	PRI	Igeo	S.N.	CF	PRI	Igeo
1	0.557	33.441	-1.4	12	0.686	41.205	-1.15	23	0.553	33.22	-1.47
2	0.563	33.838	-1.43	13	0.558	33.485	-1.43	24	0.533	32.029	-1.4
3	0.566	34.014	-1.43	14	0.568	34.102	-1.43	25	0.555	33.308	-1.43
4	0.651	39.088	-1.22	15	0.575	34.5	-1.4	26	0.568	34.102	-1.43
5	0.555	33.352	-1.43	16	0.652	39.176	-1.22	27	0.564	33.882	-1.43
6	0.5764	34.588	-1.4	17	0.561	33.66	-1.43	28	0.644	38.647	-1.25
7	0.57	34.235	-1.4	18	0.552	33.132	-1.43	29	0.556	33.397	-1.43
8	0.572	34.323	-1.4	19	0.548	32.911	-1.43	30	0.567	34.058	-1.43
9	0.55	33.044	-1.47	20	0.635	38.139	-1.25	Min	0.533	32.029	-1.51
10	0.6	36	-1.32	21	0.571	34.279	-1.4	Max	0.686	41.205	-1.15
11	0.583	35.029	-1.4	22	0.533	32.029	-1.51	Average	0.579	34.795	-1.38

S.N*: Represents the sample number

3.3. Evaluation of the Health Risks of Chromium in the Cauliflower (*Brassica oleracea*)

As for the daily non-carcinogenic consumption of chromium in cauliflower in the Al-abbasi town for the adult group for the ingestion path, with a range ($1.3*10^{-2}$ - $2.5*10^{-2}$) and at a rate of $2*10^{-2}$ and for the children group, it reached a range at $1.7*10^{-2}$ - $3.33*10^{-2}$ and at a rate of $2.6*10^{-2}$ and the daily carcinogenic consumption of adults reached a range $5*10^{-3}$ - $1*10^{-2}$ and at a rate of $8.4*10^{-3}$ and for children its range $1.5*10^{-3}$ - $2.8*10^{-3}$ and an average of $2.2*10^{-3}$. It was found that the value of THQ_{nc} for both groups of adults and children in the study area is more than 1. This indicates the presence of a severe health risk to humans, especially in the category of children more than adults Table 9. The CR_{cancer} values are greater than $1*10^{-4}$ and indicate a high carcinogenic risk, (Table 10).

Table 9. Daily non-carcinogenic intake (DIE_{nc}) values, non-carcinogenic chromium values in cauliflower samples for the study area (THQ_{nc})

Sample NO.	$DIE_{non-cancer}$		$THQ_{non-cancer}$	
	Adult	Child	Adult	Child
AQ3	0.022	0.029	7.55	9.93
AQ6	0.013	0.017	4.5	5.91
AQ10	0.025	0.033	8.45	11.11
AQ13	0.02	0.026	6.65	8.75
AQ15	0.021	0.027	7	9.22
AQ19	0.021	0.028	7.2	9.45
AQ26	0.02	0.0267	6.83	9
AQ28	0.019	0.026	6.65	8.75
Average	0.02	0.026	6.85	9
Range	$(13-25)*10^{-3}$	$(17-33)*10^{-3}$	4.5 - 8.45	5.91 - 11.11

Table 10. Daily Intake of Carcinogens (DIE_{cancer}) values and carcinogenic (CR_{cancer}) values chromium in cauliflower samples for the study area

Sample NO.	DIE_{cancer}		CR_{cancer}	
	Adult	Child	Adult	Child
AQ3	0.009	0.0025	$4.8*10^{-3}$	$1.27*10^{-3}$
AQ6	0.005	0.0015	$2.8*10^{-3}$	$7.6*10^{-4}$
AQ10	0.01	0.0028	$5.4*10^{-3}$	$1.42*10^{-3}$
AQ13	0.008	0.0022	$4.2*10^{-3}$	$1.12*10^{-3}$
AQ15	0.009	0.0023	$4.5*10^{-3}$	$1.18*10^{-3}$
AQ19	0.0092	0.0024	$4.6*10^{-3}$	$1.21*10^{-3}$
AQ26	0.0087	0.0023	$4.3*10^{-3}$	$1.15*10^{-3}$
AQ28	0.0085	0.0022	$4.2*10^{-3}$	$1.12*10^{-3}$
Average	0.0084	0.0022	$4.35*10^{-3}$	$1.15*10^{-3}$
Range	0.005 - 0.01	$(15-28)*10^{-4}$	$(2.8-5.4)*10^{-3}$	$7.6*10^{-4}$- $1.42*10^{-3}$

4. Conclusions

It was concluded that the reason for the increase in chromium concentration in all soil samples in the study area is mainly caused by chemical fertilizers, sewage, commercial activities, traffic and industrial workshops. As a result of the pollution assessment, it was established that the topsoil of this area is within the level of low pollution, CF <1. This indicates the presence of contamination at a very low level. From the calculation of PRI for surface soil samples, it was found that all surface soil samples for the study area have low risk level, PLI$\leq$50. The calculation of the Igeo of the surface soil samples of the study indicates that the surface soil of the study area does not indicate any pollution (Practically uncontaminated, Igeo $\leq$0). The concentration of chromium in all samples of cauliflower exceeded the permissible limits recorded globally according to WHO/ FAO (2007). It is clear from BCF that the cauliflower absorbs the element chromium, but it does not accumulate in the samples within the study area because the values of bioaccumulation were less than 1.Although the concentration of chromium was high in the soil, it is difficult to transfer it from the soil to the cauliflower fruit. By assessing the health risks of chromium on the local population of both age groups through cauliflower samples, the results showed that the THQ values for both groups (THQ>1) indicate severe health risks to the local population, especially the children group, The results values of CR were greater than $1*10^{-4}$ indicating a high risk of cancer in both age groups. To sum up, we recommend from the obtained results, carrying out assessment and reform calculations on the soil and knowing heavy metals, including chromium before and after adding fertilizers and chemical pesticides. We also recommend not irrigating agricultural land with water contaminated with sewage, keeping agricultural areas away from main roads as well as from other sources of pollution, not setting up an industrial facility near agricultural, residential and commercial lands. Finally, it is recommended to make a periodical of all crops in the area in order to have better insight for the contamination records.

Acknowledgements

The authors would like to thank T.A Saudun M. Faraj for linguistic assistance in this paper. The authors are very grateful to the reviewers, Editor in Chief Prof. Dr. Salih M. Awadh, the Secretary of Journal Mr. Samir R. Hijab, and the Technical Editors for their great efforts and valuable comments

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