Kirkuk University Journal for Agricultural Sciences, Vol.17, No. 1, 2026 Online ISSN: 2958-6585

Kirkuk University Journal for Agricultural Sciences
ISSN:2958-6585
https://kujas.uokirkuk.edu.iq

RESEARCH ARTICLE
https://doi.org. 10.58928/ku26.17102

Accumulation of lead and cadmium in maize (Zea mays L.) plants growing in soil adjacent to the Northern Gas Company in Kirkuk.

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Received:09/07/2025 **Revised:05/ 09/2025** **Accepted: 02/01/2026** **Published: 04/03/2026**

ABSTRACT

The area surrounding the North Gas Company, was chosen to study the pollution resulting from the North Gas Company and its impact on plants in the surrounding area with (lead and cadmium), as well as to estimate the bioaccumulation of plants. Three sites were identified to estimate the bioaccumulation at a distance of (50, 1255 and 3150) meters. Soil samples were collected at a depth of (0-20) centimeters, September, 2024.regarding the plant , two samples were taken at the first station, one sample for each farm, while at the second and third stations Five samples per each station were taken, one sample per farm, The results showed that none of the sites had BCF values exceeding 1.

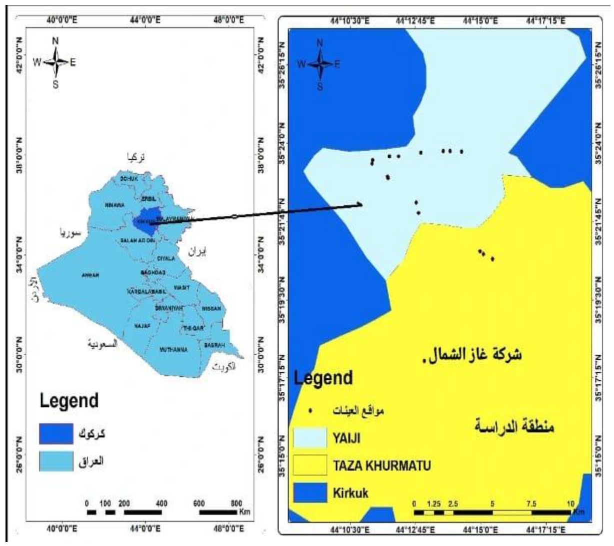
***Keywords*: Heavy Metals, Plants, bioconcentration factor, Kirkuk City.

INTRODUCTION

Plant pollution is the accumulation of pollutants within plant tissues, such as toxic elements and pesticides. The response of plants to various toxic elements present in the soil varies depending on the plant species, age, and growth stage of the plants. It is also affected by the physicochemical properties of the soil, root secretions, and the concentration and type of toxic elements in the soil, in addition to the difference in solubility, absorption, transport, and chemical effectiveness of toxic elements. All of this leads to differences in toxicity to plants[1] ،The increase in the concentrations of these elements in plants comes from the growth of the plant in soil contaminated with these elements [2]. The phenomenon of accumulation is a natural phenomenon in plants that accumulate toxic elements without showing symptoms of toxicity. There are approximately 400 plant species belonging to 45 families called accumulating plants, which are characterized by the ratio of the element's exacerbation in the vegetative system to the root system being greater than one, while for non-accumulating plants it is less than one [3]. There is a significant relationship between the concentration of heavy elements in the soil and the plants growing in it, and the difference in the concentration of any element in any type of plant is due to the difference in the active groups that are associated with the toxic elements for plants, which leads to differences in absorption efficiency and accumulation between plant species and varieties [4] that polluted soils have a negative impact on plants, but there are many plant species that have the ability to tolerate high concentrations of these elements without affecting their growth. Thus, these plants can be exploited in the process of reclamation and remediation of soils contaminated with toxic elements by absorbing and accumulating them within various plant tissues such as roots, stems, and leaves. This is known as bioremediation or phytoremediation. This technology is considered one of the promising solutions in treating soil pollution problems. It is called green technology through which the concentration of pollutants in the soil is reduced [5]. The bioaccumulation factor (BCF) is important in knowing the plants used in phytoremediation of soils contaminated with safe elements [6][7] The aim of this research is to study the effects of lead and cadmium on maize plants, and then estimate the bioconcentration factor (BCF) for the studied plants in the study area.

Materials And Methods

1- The study area and sample collection: The area surrounding the North Gas Company, which is about 24 kilometers from the city center of Kirkuk, was chosen. Three station were identified to estimate the concentration of plant biomass at a distance of (50, 1255 and 31255) meters. Soil samples were collected from the surface of the soil at a depth of (0-20) centimeters in,September,2024 and then transferred to the laboratory for the purpose of conducting physical and chemical analyses. while in regard to the plant, samples were collected from the same sites from which soil samples were collected , two samples were taken at the first location one sample for each farm. On the other hand, at the second and third location have Five samples per station were taken, and one sample per farm, as shown in Map (1).



Map (1) showing the location of the North Gas Company and sampling points.

2 . Soil Physical and Chemical Analysis

The study soil physical and chemical analyses were conducted in the soil laboratory at the College of Agriculture, University of Kirkuk.

2.1. Soil texture: Particle size distribution (PSD) estimated using the hydrometer method described by [8], as well as the texture triangle.

2.2. Soil moisture content was estimated using the gravimetric method as described by Jensen [9].

2.3. Bulk density was estimated using the paraffin wax method described by Black [10].

2.4. pH and Electrical conductivity (EC) estimated using a (Hanna model) pH-meter and EC-meter from a soil extract (1:2.5) according to the method described in Page [11]and EC expressed in units (ds m-1).

2.5.Organic matter (OM) ,measured using the wet oxidation method according to the Smith Weldon modification of the Walkey-Black method described in Black[10] Calcium carbonate ($CaCO_3$) was measured according to Piper (1950) as described in [12].

3. Total heavy metal estimation: The digestion process was carried out according to the method of [13] to estimate the total heavy metals.

4. Available heavy metals: extracted using a chelating compound of 0.005 mM (DTPA), 0.01 mM (calcium chloride), and 0.1 mM (triethanolamine (TEA) in a ratio of 2:1 (soil: extraction solution) according to the method described in [14].

5. Total and available heavy metal in the extracts were estimated using the Jena atomic absorption analyticaly (AAA).

6.Digestion of plant samples and determination of heavy elements in them The digestion process was carried out by taking 0.2 of the dry sample, then 4 ml of sulfuric acid was added and left overnight. After that, 2 ml of perchloric acid was added and exposed to heat as stated by [11].

7. Estimation of plant chlorophyll

Chlorophyll was estimated using 10 ml of ethyl alcohol and 0.50 g of the plant sample according to [15].

1.0 1.mg chlorophyll a/ml solution = (13.70)(A665nm) - (5.76)(A649nm)……..1

2.0 2.mg chlorophyll b/ml solution = (25.80)(A649nm) - (7.60)(A649nm)………2

8. Estimation of Bioconcentration Factor (BCF)

The accumulation of the element in cultivated plant species was estimated using the Bioconcentration Factor method according to [16] as shown in the following equation:

$$BCF=\frac{(Concentration\ of\ the\ element\ in\ the\ plant\ )}{(Concentration\ of\ the\ element\ in\ the\ soil\ )}\text{……….3}$$

9. Statistical Analysis

9.1. Analysis of Variance (ANOVA): - Significant differences in results between samples were determined based on station and seasonal differences and their overlap using the ANOVA method. Averages were compared using the LSD test at a significance level of 0.01 using SPSS Version 27.[17]

9.2. Pearson Correlation Coefficient - The correlation coefficient between the studied factors was calculated on a computer using the SPSS Special Program for Statistical Analysis (SPSS) software. This is a Pearson System Correlation Coefficient.[17].

Results And Discussion

1. Soil Physical and Chemical Analysis

1.1. Soil Texture: The soil texture of the study area was classified as medium to fine. It is well known that several factors are responsible for the soil formation and development, according to the equation [18].

1.2.Bulk density (Bd): Table (1) Shows non-significant influences of location on bulk density the highest value of 1.64 Mg m^{-3} was recorded at the second location and the lowest value of was 1.60 Mg m^{-3} at the third location , respectively. This is consistent with the findings of [19], where the Bd value before planting was 1.45 Mg m^{-3} in the soil of the College of Agriculture Research location - University of Kirkuk.

1.3.Soil Moisture Content% :Table (1) shows that the location did not have a significant effect at the level of significant 0.01 on the soil moisture content, as the highest percentage of 3.62% was recorded in the third location and the lowest percentage of 3.38% in the first location.

1.4.The ionic potential of hydrogen (pH) as shown in Table (1) that the location have a significant effect on the pH values, as the lowest value of 6.95 was recorded in the second location and the highest value of 7.44 in the third location, respectively. as the pH value before planting was 7.1 in the soil of the College of Agriculture Research Station - University of Kirkuk. It also partially agrees with what was reached by the researchers [20], The pH value was 7.72 before planting in the soil of the (Koldara) area, affiliated with the Alton Kopri district (Dibs district), Kirkuk Governorate.

1.5.Electrical conductivity (EC): It was found that had a significant effect, as the highest value of 1.58 dSm-1 was recorded at the third location and the lowest value of 1.18 dSm-1 at the first location , Table (1) “The results were in agreement with the researcher’s conclusion, indicating that the electrical conductivity was 0.38 dSm^{-1} in the soil of the Grdarasha Experimental Field Research Center, College of Agricultural Engineering Science[21].[22] where the EC Value before planting was 2.3 dSm-1 in the soil of the College of Agriculture Researchers location -University of Kirkuk. [23]The EC value was 2.17 before planting in the soil of the (Koldara) area, affiliated with the Alton Kopri district (Dibs district), Kirkuk Governorate.

1.6.Organic matter (OM) Table (1) shows that the location did not have a significant effect at the 0.01 level on the organic matter of the soil, as the highest rate was 1.10% at the first site and the lowest rate was 0.96% at the second and third location ,[24] The organic matter value was 0.97 before planting in the soil of the (Koldara) area, affiliated with the Alton Kopri district (Dibs district), Kirkuk Governorate.consistent .

1.7.Calcium carbonate (CaCO3) Table (1) shows that the location have a significant impact, with the highest percentage of 31.50% recorded at the second location and the lowest percentage of 25.86% at the first location.

2. Total and available lead concentration in the soil

2.1. Total lead concentration (Pb T): Table (1) shows significant differences between Pb concentration at the first and second location, where the highest concentration (98.15 ppm) appeared at the third stations and the lowest concentration (84.34 ppm) was recorded at the first location.

2.2. Available lead concentration (Pb A): Table (1) explains that there are significant differences between available concentration of Pb between the study location at the level of significant 0.01, where the highest concentration of 16.09 ppm was recorded at the third location and the lowest concentration of 12.97 ppm was observed at the first location.

3. Total and available cadmium concentration in the soil

Total cadmium concentration (Cd T): Table (1) shows that there are significant differences between Cd concentration between the study location , the highest concentrations was noted from the first and second location with the values of (22.36 and 21.30) ppm respectively, while the lowest concentration of 17.84 ppm was recorded at the first location On the other hand, the Available cadmium concentration (Cd A) was not detected.
and cadmium.

Table (1) Impact of location on the chemical and physical properties of the soil and concentration of total and available lead

parameters	location 1	location 2	location 3	L.S.D0.01
EC	1.18	1.36	1.58	0. 39
pH	7.29	6.95	7.44	0.33
$CaCO_3$	25.86	31.5	26.95	4.60
O.M%	1.10	0.96	0.96	0.71N.S
Bd $Mg.m^{-1}$	1.62	1.64	1.60	0.74 N.S
M%	3.38	3.60	3.62	0.21N.S
PbT ppm	84.34	86.12	98.15	13.81
Pb A ppm	12.97	14.66	16.09	1.42
Cd T ppm	17.84	22.36	21.30	3.80
Cd A ppm	N.D.= not detected			

4. Concentration of heavy elements in the plant

4.1. Plants lead concentration: Table (2) indicates to significant differences at level of significant of 0.01 between the stations. The highest average of 0.44 ppm was recorded at the second location and the lowest average of 0.04 ppm at the third location . It is clear that all concentrations and all location did not exceeded the limits permitted by the World Food and Health Organization, which is 5 ppm [25].

4.2. Concentration of cadmium element in the plant (Cd P) : Table (2) shows that there are significant differences at level of significance 0.01 between Cd concentration in the study location, where the highest average of 0.09 ppm was recorded at the third stations , and the lowest average of 0.6 ppm was observed at the first station. We note an increase in cadmium concentrations did not exceed the permissible limits of the World Food and Health Organization [25].

Table 2: Lead, cadmium and chlorophyll content in maize plants

Sequence	Location	Samples	Chlorophyll mg g^{-1}	Cd plant Ppm	Pb plant Ppm
1	First location	S_1R_1	4.60	0.03	0.41
2		S_1R_2	5.21	0.09	0.47
First Location average			4.90	0.06	0.44
3	second location	S2R1	5.22	0.09	0.49
4		S2R2	5.22	0.09	0.10
5		S2R3	5.22	0.10	0.05
6		S2R4	5.12	0.10	0.05
7		S2R5	5.16	0.10	0.06
second Location average			5.18	0.09	0.15
8	Third location	S3R1	5.22	0.10	0.05
9		S3R2	5.22	0.10	0.02
10		S3R3	4.88	0.09	0.06
11		S3R4	5.19	0.10	0.05
12		S3R5	5.22	0.09	0.05
Third Location average			5.14	0.09	0.04
L.S.D 0.01			0.4 N.S	0.2	0.10

5. Chlorophyll content (mg g^{-1}): Table (2) shows that there are no significant differences at the 0.01 level between the three location , as the highest rate of 5.18 mg g^{-1} was recorded at the second location and the lowest rate of 4.90 mg g^{-1} was recorded at the first location.

Table (5) Bioconcentration Factor (BCF) in maize plants in the study area

location	Lead	Cadmium
First location	0.00	0.00
second location	0.00	0.00
Third location	0.00	0.00

6.Bioconcentration Factor(BCF):

It is possible to estimate the amount of the element absorbed by the plant by estimating the bioconcentration factor as follow: The ratio between the concentration of an element in the plant and its concentration in the soil.. The results showed that the lowest bioconcentration factor (BCF) for lead absorption appeared in the maize plant, 0.00 all location , While the biological parameters of cadmium in maize plants were recorded at 0 for all sites. , which does not indicates the variation in the plant's ability to take the toxic element from the soil..

7. Pearson Correlation Coefficient:

Table (6) shows that the concentration of lead in plants has a significant negative relationship with the concentration of cadmium in plants, as the correlation coefficient value (r)reached 0.58 *. It also has a significant negative relationship, of r= -0.33 with the total concentration of cadmium in the soil, while the concentration of cadmium in plants has a highly significant relationship with chlorophyll, as the correlation coefficient (r) reached to 0.73**. It also has a significant positive (direct) relationship with the concentration of available lead, as the correlation coefficient0.60*.

Table (6) Pearson correlation relationships between soil lead and cadmium concentrations , plants lead and cadmium concentrations and chlorophyll content.

	Pb-p	Cd-p	Chll	Pb-T	Cd-T	Pb-A
Pb-p	1					
Cd-p	-0.58*	1				
Chll	-0.28	0.73**	1			
Pb-T	0.19	-.38	-0.47	1		
Cd-T	-0.33	0.47	0.16	0.17	1	
Pb-A	-0.763**	0.60*	0.29	0.21	0.55	1

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

Conclusion

The study showed that the concentration of lead in plants for all sites did not exceeded the permissible limits of the World Food and Health Organization which is 5 ppm [25]. The concentration of cadmium also did not exceeded the permissible limits of the World Food and Health Organization [25], which is 0.2 ppm . All location had BCF value did not exceeding 1.

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تراكم عنصري الرصاص والكادميوم في نباتات الذرة الصفراء (Zea mays L.) النامية في الترب المجاورة لشركة غاز الشمال /كركوك

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الخلاصة

تم اختيار المنطقة المحيطة بشركة غاز الشمال لدراسة تلوث الناتج من شركة غاز الشمال وتاثيرها على النباتات في المنطقة المحيطة بها ببعض العناصر الثقيلة (الرصاص والكادميوم) فضلا عن تقدير التراكم الحيوي للنبات ، تم تحديد ثلاث مواقع لتقدير التراكم الحيوي على بعد(50، 1255، 3150مترا)، موقع الاول نموذجين والمحطة الثانية والثالثة خمس نماذج ، تم اخذ عينات النبات والتربة الخاصة بة خلال الموسم الاول في حين جمعت عينات التربة فقط لموسمين من منطقة المحيطة وتم اجراء تحليل الكلورفيل وعنصري الرصاص والكادميوم للنبات و اجراء التحاليل الكيميائية والفيزيائية للتربة في موسمين) 2024) و(2025) اذ جمعت عينات التربة على عمق (0-20)سم ، ، وبينت النتائج وجود فروق معنوية لكل من تركيز عنصري الرصاص والكادميوم والكلوروفيل في النبات للمحطات الثلاثة المحددة في هذه الدراسة ،ان جميع المواقع قد لم تجاوز فيها قيم ***BCF*** عن 1 .

الكلمات المفتاحية: العناصر الثقيلة ، نباتات ، عامل التركيز الحيوي ، مدينة كركوك .