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THE EFFECT OF SOME PHOSPHATE FERTILIZERS ON THE CONTAMINATION OF SOME HEAVY ELEMENTS IN THE SOIL AND WHITE MAIZE PLANTS

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ABSTRACT

This research was carried out in the Soil Sciences and Water Resources Department labs at the College of Agriculture, University of Baghdad, over the 2024-2025 period. The goal was to investigate how certain phosphate fertilizers affect soil and white maize plants by contaminating them with heavy metals. We tested four widely used commercial fertilizers: Concentrated Superphosphate (CSP), NPK fertilizer (15-15-15), Diammonium Phosphate (DAP), and Rock Phosphate (R.P). The experiment followed a Completely Randomized Design (CRD) with three repeats per treatment, giving us 12 experimental units. Our findings showed clear differences in contamination levels depending on the fertilizer. Rock Phosphate (RP) stood out with the highest levels of cadmium (140.77 mg kg^{-1}) and lead (221.60 mg kg^{-1}), making it the main culprit behind soil and plant pollution. The other fertilizers also showed varying degrees of contamination; in some cases, heavy metal levels exceeded what's allowed under international guidelines (USEPA, FAO, OECD, AAPFCO). These results underline the pressing need for tighter controls on the quality of phosphate fertilizers in farming to cut down on pollutant buildup in soil and crops, and to lower the environmental and health risks that might follow.

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INTRODUCTION

Phosphate fertilizers are mainly used to ramp up crop yields by enriching the soil with key nutrients. But lately, a bunch of studies have pointed out a downside: these fertilizers can carry high levels of heavy metals like cadmium (Cd), lead (Pb), nickel (Ni), and chromium (Cr) (Kashmolaa *et al*., 2025; Jasim *et al*., 2015). The reason, the raw stuff they're made from specially phosphate rocks naturally has these elements in varying amounts, sometimes more than what's considered safe by big organizations like the U.S. Environmental Protection Agency (USEPA), the Food and Agriculture Organization (FAO, 2019), and the Organization for Economic Co-operation and Development (OECD, 2020; Saed and Hamid, 2023; Alkarawi, 2024; Al-Temimi and Al-Hilfy,2022).

When these heavy metals pile up in the soil over time, it's not just an environmental headache ;it hits the food chain and human health, too. The contamination moves from the soil into plants and then to whoever eats them. Research has shown a tight link between polluted soil and these metals building up in crops, raising the chances of health issues tied to long-term exposure to these toxic substances (World Health Organization, 2021; Hamid and Almaeakh,2024). On top of that, the chemical and biological changes these metals go through in farming settings can make them more available to plants and easier to pass along the food chain. That's why we need deep-dive studies to figure out how this works and come up with solid ways to cut the risks.

The rising focus on this topic comes from a real need to set up strong environmental policies that protect nature and keep our food safe ,especially since modern farming leans so heavily on minerals. This research matters because it could offer practical scientific and management ideas to improve farming output and tighten up monitoring rules, making sure pollution stays below dangerous levels. That's a step toward sustainable growth that keeps both the environment and people's health in mind (OECD, 2020; Hamid and Kadhim,2022; Hameed *et al*., 2025).

So, with all this in view, this study sets out to explore how certain phosphate fertilizers like R.P, DAP, NPK, and CSP affect soil and white maize plants by looking at contamination, checking how much heavy metals such as cadmium (Cd), chromium (Cr), nickel (Ni), and lead (Pb) build up in the soil and plants, and figuring out if these fertilizers are fit for farming and what they're doing to the environment.

MATERIALS AND METHODS

Getting the Soil and Plants Ready

We set up a pot experiment during the fall growing season, kicking off on July 15, 2024, in the Bad'aa area, part of the Musayyib Project in Babil Governorate. The spot sits at 32°47'29.6"N latitude and 44°26'21.3"E longitude. We picked out a decent patch to place our plastic pots and made sure we had everything we needed to pull off the experiment without a hitch.

For the soil, we started by letting it dry out in the open air, then ground it up and sifted it through a 4 mm sieve. We filled plastic pots 50 cm wide and 30 cm tall with 25 kg of soil each, packing it down a few times to get a density close to what you'd find in a real field. Table (1) lays out some of the soil's physical and chemical traits we worked with. We planted white maize seeds (*Sorghum bicolor L.*), dropping five into each pot. Once they sprouted, we thinned them down to three plants per pot to keep their growth even. After they'd grown for a while, we gathered up soil and plant samples from each treatment and ran lab tests to check the heavy metal levels in both, trying to figure out how the phosphate fertilizers were affecting contamination in the soil and plants.

Laboratory Procedures

Preparation and Analysis of Soil Samples

Once the experiment wrapped up, we air-dried the soil samples and stored them in plastic containers, getting them ready to analyze both the available and total heavy metals, including nickel (Ni), chromium (Cr), lead (Pb), and cadmium (Cd), for each treatment.

Preparation and Analysis of Plant Samples

We collected plant samples (both the shoots and roots) from each experimental unit, washing them first with running water and then with distilled water. The samples were air-dried before being placed in an electric oven at 65°C for 48 hours until their weight stabilized. After that, we ground them with a wooden hammer, mixed them thoroughly, sifted them through a 0.5 mm sieve, and kept them in plastic containers for heavy metal analysis (Ni, Cr, Pb, Cd) for each treatment.

Table (1): Some Chemical and Physical Features of the Soil We Used

<table>
<tr><td colspan="3">Property</td><td colspan="2">Value</td><td colspan="3">Unit</td></tr>
<tr><td colspan="3">Soil Ph</td><td colspan="2">7.80</td><td colspan="3"></td></tr>
<tr><td colspan="3">Electrical Conductivity (EC)</td><td colspan="2">4.50</td><td colspan="3">dS m^{-1}</td></tr>
<tr><td colspan="3">Total Solid Carbonates</td><td colspan="2">225.00</td><td colspan="3">g kg^{-1}</td></tr>
<tr><td colspan="3">Cation Exchange Capacity (CEC)</td><td colspan="2">20.60</td><td colspan="3">cmol kg^{-1}</td></tr>
<tr><td colspan="3">Organic Matter</td><td colspan="2">7.99</td><td colspan="3">g kg^{-1}</td></tr>
<tr><td colspan="3">Available Phosphorus</td><td colspan="2">31.36</td><td colspan="3">mg kg^{-1}</td></tr>
<tr><td colspan="3">Soluble Phosphorus</td><td colspan="2">10.28</td><td colspan="3">mg L^{-1}</td></tr>
<tr><td colspan="4">Dissolved Ions</td><td colspan="4">mmol L^{-1}</td></tr>
<tr><td colspan="4">Cations</td><td colspan="4">Anions</td></tr>
<tr><td>Mg-2</td><td>Ca+2</td><td>K+</td><td>Na+</td><td>SO4-2</td><td>Cl-</td><td>CO3-2</td><td>HCO3-</td></tr>
<tr><td>5.63</td><td>7.88</td><td>1.06</td><td>18.90</td><td>4.50</td><td>29.25</td><td>Nill</td><td>5.50</td></tr>
<tr><td rowspan="3">Texture</td><td>Sand</td><td></td><td colspan="2">g kg^{-1}</td><td colspan="3">396.00</td></tr>
<tr><td>Silt</td><td></td><td colspan="2">g kg^{-1}</td><td colspan="3">362.00</td></tr>
<tr><td>Clay</td><td></td><td colspan="2">g kg^{-1}</td><td colspan="3">242.00</td></tr>
<tr><td colspan="3">Soil Texture Type</td><td colspan="2"></td><td colspan="3">Loam</td></tr>
</table>

Extraction and Estimation of Heavy Metals (Pb, Ni, Cr, Cd)

Soil Analyses

We measured the available, total, and dissolved heavy metals in the soil using an Atomic Absorption Spectrophotometer (AAS) following different analytical methods. The available heavy metal content was extracted using a mix of 0.005 M DTPA, 0.01 M calcium chloride, and 0.1 M TEA, with a pH of 7.3 and a 1:2 soil-to-solution ratio, as outlined by Lindsay and Norvell (1978). The total heavy metal content was determined after digesting the samples, while the dissolved concentration was assessed by preparing a 1:1 soil-to-water suspension and analyzing the filtrate with the AAS.

Plant Analyses

We estimated the heavy metals in the shoots and roots after digesting the plant samples with a mixture of acids ($HClO_4$ + H_2SO_4) following Jones (2001). We took 0.5 g of the dried, sifted (2 mm) sample, placed it in a 250 ml Pyrex flask, added 5 ml of concentrated sulfuric acid (H_2SO_4), and let it sit for 24 hours. Then, we heated it on a hot plate at 80°C for an hour, added 3 ml of perchloric acid ($HClO_4$), and cranked the heat up to 180°C for 2-3 hours until the solution turned clear and colorless. The sample was filtered using Whatman No. 42 filter paper, brought to a volume of 50 ml with distilled water, and the heavy metal concentrations were measured using the AAS.

Biological Experiment

We ran a farming experiment with white maize (*Sorghum bicolor L.*) during the 2024/2025 growing season in a field in Babil Governorate, Musayyib District, at a depth of 0-30 cm. We collected a composite soil sample from the field, air-dried it, and passed it through a 4 mm sieve. We put 25 kg of soil into plastic pots, added phosphorus at a single rate of 60 kg P ha^{-1} at planting time, and mixed it into the topsoil. The plants were watered until they reached field capacity, and we harvested them 1.5 cm above the soil surface to avoid contaminating the shoots. The roots were carefully pulled out, and the plants were washed with regular water first, then distilled water, to get rid of any stuck-on dirt. Afterward, we dried them in an oven at 65°C for 72 hours until the dry weight settled, recording the dry weight for both shoots and roots. The samples were cut, ground, sifted through a 1 mm sieve, and stored in clean plastic containers in the fridge until we could do the necessary chemical analyses.

Experimental Design

The experiment included 12 experimental units arranged in a Completely Randomized Design (CRD) with three replicates per unit, as follows:

- First factor: Concentrated Superphosphate fertilizer (47% P_2O_5) at 60 kg ha^{-1}.
- Second factor: Rock Phosphate fertilizer (15% P) at 60 kg ha^{-1}.
- Third factor: NPK fertilizer at 60 kg ha^{-1}.
- Fourth factor: Diammonium Phosphate (DAP) fertilizer at 60 kg ha^{-1}.

Statistical Analysis

We analyzed the experiment's data using Analysis of Variance (ANOVA) based on the Completely Randomized Design to check for significant differences between the fertilizer treatments. We tested the significance of differences between means using the Least Significant Difference (LSD) test at a 5% probability level, relying on the GenStat software to crunch the numbers accurately and draw reliable, scientific conclusions. This analysis helped us evaluate how different fertilizer types affected heavy metal and phosphorus concentrations and their chemical properties with precision and clarity (Gomez and Gomez, 1984).

RESULTS AND DISCUSSION

Total, Available, and Dissolved Concentrations of Heavy Metals in the Study Soil

The results shown in Tables (2 and 3) illustrate the distribution of heavy metal concentrations in the study soil based on different analytical methods. The total cadmium concentration reached 0.187 mg kg^{-1}, falling within the natural range for soils (0.01–0.70 mg kg^{-1}) and closely matching the concentration found in the Earth's crust (0.20 mg kg^{-1}). The available cadmium recorded 0.010 mg kg^{-1} (representing 5.35% of the total), which is lower than findings by Vishnu *et al*. (2007) in clay soils. This low availability of cadmium is likely due to its binding with oxides and carbonates, coupled with high soil pH and the role of organic matter in forming stable complexes with it (Al-Mayah and Al-Maliky, 2023; McBride, 1980). The dissolved cadmium was 0.002 mg L^{-1}, equivalent to 1.07% of the total and 20% of the available fraction, showing relatively low levels compared to Al-Rubai and Al-Taei (2023). studies.

For chromium, the total concentration was 25.44 mg kg^{-1}, fitting within the range found in sedimentary rocks (5–120 mg kg^{-1}) as noted by Al-Saad and Al-Imarah (2022). The available chromium stood at 0.210 mg kg^{-1} (0.83% of the total), while the dissolved chromium was 0.015 mg L^{-1} (0.06% of the total and 7.14% of the available), reflecting chromium's association with water-insoluble forms like calcium or lead chromates (Al-Saad and Al-Imarah, 2022). Nickel's total concentration reached 7.55 mg kg^{-1}, with available nickel at 0.200 mg kg^{-1} (2.65% of the total) and dissolved nickel at 0.030 mg L^{-1} (0.39% of the total and 15% of the available). This highlights how soil properties, such as carbonate and organic matter content, influence nickel's availability to plants (Cempel, 2006; Sparks *et al*., 2001).

As for lead, the total concentration was 8.850 mg kg^{-1}, lower than the Earth's crust value of 16.0 mg kg^{-1}. The available lead was 0.150 mg kg^{-1} (1.69% of the total), and the dissolved lead was 0.040 mg L^{-1} (0.45% of the total and 26.67% of the available). This suggests that most lead is bound in insoluble forms such as oxides, hydroxides, or lead carbonates, aligning with findings from Monday and Michael (2004), Al-Rubai and Al-Taei (2023), and Hamid and Naser (2020).

Table (2): Total and Available Concentrations (mg kg^{-1}) and Dissolved Concentrations (mg L^{-1}) of Heavy Metals (Cd, Cr, Pb, Ni) in the Study Soil

Element	Total Concentration	Available Concentration	Soluble Concentration
Cadmium (Cd)	0.187	0.010	0.002
Chromium (Cr)	25.440	0.210	0.015
Nickel (Ni)	7.550	0.200	0.030
Lead (Pb)	8.850	0.150	0.040

Table (3): Percentages of Available and Dissolved Heavy Metals Relative to the Total Concentration in the Study Soil

%Soluble from Total Concentration				%Available from Total Concentration			
Pb	Ni	Cr	Cd	Pb	Ni	Cr	Cd
0.45	0.39	0.06	1.07	1.69	2.65	0.83	5.35

Heavy Metal Concentrations in the Shoots and Roots of White Maize

The results in Table (4) show that the concentrations of heavy metals in the shoots and roots of white maize are clearly influenced by phosphate fertilizers, and their combined use. For cadmium, the average concentration in the shoots and roots of the control treatment was 0.025 and 0.048 µg Cd/g dry matter, respectively, with a 92% higher level in the roots. This is likely because cadmium binds to proteins in the roots, limiting its movement to the upper parts of the plant (Genchi *et al*., 2020; Ajeel and Al-Hakeim, 2024), and adding phosphate fertilizers (CSP, NPK, DAP, R.P) significantly increased cadmium levels in both shoots and roots, reaching 0.17 and 0.21 µg Cd/g dry matter—a jump of 540% and 375.5% compared to the control. The fertilizers' impact on cadmium increase followed this order: R.P < NPK < DAP < CSP. The lower cadmium concentration with rock phosphate (R.P) is explained by its lower solubility compared to the others (Al-Hilfy and Al-Temimi, 2017; Al-Temimi and Al-Hilfy, 2022).

For chromium, the results showed varying effects from the phosphate fertilizers (R.P, DAP, NPK, CSP). The impact on chromium levels in the shoots was not significant except in the mixed treatment, but it was significant in the roots. Chromium concentrations in the shoots for the control, phosphate fertilizer, organic fertilizer, and mixed treatments were 2.99, 8.15, 6.89, and 9.53 µg/g dry matter, respectively, while in the roots, they were 3.68, 10.08, 8.56, and 13.02 µg/g dry matter. This points to chromium pooling in the roots, with the fertilizers' effect ranked as: R.P < NPK < DAP < CSP. Chromium levels far exceeded those of cadmium by varying multiples.

Nickel showed a significant response to phosphate fertilizers and their combination. Nickel concentrations in the shoots for the control, phosphate fertilizer, and mixed treatments were 0.323, 0.425, 0.400, and 0.933 µg/g dry matter, respectively, and in the roots, they were 2.99, 4.56, 3.23, and 6.57 µg/g dry matter. The increase in the roots outpaced the shoots by 604.18% to 972.94%. These findings align with previous studies showing that potassium and NPK fertilizers enhance maize growth and yield (Rasul, 2010). The fertilizers' effect on nickel in the shoots followed this order: R.P < DAP < CSP < NPK, while in the roots it was: DAP < R.P < NPK < CSP. Using cow manure alone or mixed with fertilizers further boosted nickel concentrations. This aligns with previous research showing that biofertilizers, organic fertilizers, and foliar boron application can enhance maize yield (Ajeel *et al.*, 2025).

For lead, the results recorded concentrations in the shoots for the control, phosphate fertilizer, mixed treatments as 4.29, 6.47, 5.88, and 7.98 µg/g dry matter, respectively, and in the roots as 9.06, 13.13, 12.56, and 15.03 µg/g dry matter. The increase in the roots surpassed the shoots by 88.35% to 113.61%. The fertilizers' impact on lead followed this sequence in both shoots and roots: R.P < CSP < DAP < NPK. The significant differences between treatments stemmed from varying lead content and solubility in the fertilizers. Cow manure increased lead availability in the soil, which raised its concentration in the plant. Mixing phosphate fertilizers with cow manure bumped up lead levels in the shoots and roots by 37.06% and 38.63%, respectively. This highlights the need for pretreating organic fertilizers to cut down on heavy metal pollution risks.

Table (4): Heavy Metal Content (Cd, Cr, Ni, Pb) in the Shoots and Roots of White Maize (µg g^{-1} dry matter)

Fertilization Treatment	Root System				Shoot System			
	Pb	Ni	Cr	Cd	Pb	Ni	Cr	Cd
Control (No Fertilization)	9.06	2.99	3.68	0.048	4.29	0.323	2.99	0.025
Fertilized with CSP	10.77	5.65	12.73	0.256	6.31	0.245	10.65	0.256
Fertilized with NPK	16.45	4.76	9.96	0.222	7.85	0.648	6.87	0.154
Fertilized with DAP	12.76	3.83	10.46	0.232	6.33	0.436	9.68	0.165
Fertilized with R. P	12.54	3.99	7.16	0.126	5.37	0.370	5.39	0.124
L.S.D (0.05)	1.36	2.01	2.55	0.068	1.02	0.341	0.85	0.017

Assessment of Heavy Metal Contamination in the Shoots and Roots of White Maize

Several international agencies and scientific institutions have set standard limits for heavy metal concentrations in plants based on numerous studies and experiments. The results presented in Tables (5-a) and (5-b) show the concentrations of heavy metals (Pb, Ni, Cr, Cd) in the shoots and roots of white maize when using phosphate fertilizers and cow manure, compared to permissible limits according to various classifications such as (Awashthi, 2000; Vishnu *et al.*, 2007; FAO, 2007).

Cadmium (Cd)

The shoots and roots of white maize in the control treatment (unfertilized) were not contaminated with cadmium according to the different classifications. However, the use of phosphate led to cadmium contamination in the plants according to the FAO (2007) classification, though levels remained within acceptable limits based on Awashthi (2000) and Vishnu *et al.* (2007). Cadmium concentrations in plants can become toxic to humans if they exceed 3.0 μg g^{-1} dry matter.

Chromium (Cr)

Chromium levels in the shoots and roots across most treatments exceeded the permissible limit according to Vishnu *et al*. (2007). The threshold was surpassed in the concentrated superphosphate (CSP) treatment, as well as in CSP combined with DAP. However, according to Awashthi (2000), which raises the critical limit to 20.0 μg g^{-1} dry matter, some treatments were still considered contaminated with chromium.

Nickel (Ni)

The shoots in the control treatment were not contaminated with nickel, but the concentration in the roots exceeded permissible limits according to Awashthi (2001) and Vishnu *et al*. (2007). Toxicity was observed in some plants when nickel levels went beyond one μg g^{-1} dry matter, with high nickel concentrations causing toxicity in oats and potatoes.

Lead (Pb)

The results indicated that the shoots of white maize were contaminated with lead according to Awashthi (2000) and FAO (2007), with the NPK treatment exceeding permissible limits in the roots. Lead contamination was higher in the roots compared to the shoots.

Checking How Much Heavy Metals Pollute the Soil Before and After Adding Fertilizers and Growing Crops

To figure out how phosphate fertilizers (R.P, DAP, NPK, CSP) and cow manure affected soil pollution with heavy metals like lead (Pb), nickel (Ni), chromium (Cr), and cadmium (Cd), we used a method called the Geoaccumulation Index (I-geo), which was first suggested by Müller back in 1979. It looks at the total amount of heavy metals in the soil. The numbers we got, shown in Table (5), tell us what the soil was like after growing white maize. The total heavy metal levels ranged from: cadmium (Cd) at 0.05 to 1.44 mg per kg of soil, chromium (Cr) at 20.69 to 25.00 mg per kg, nickel (Ni) at 8.05 to 9.26 mg per kg, and lead (Pb) at 5.00 to 7.66 mg per kg. On average, across everything, it came out to 0.27, 22.69, 8.64, and 6.83 mg per kg of soil for Cd, Cr, Ni, and Pb, respectively. For the control plot with no fertilizers, the levels were 0.15, 23.41, 9.33, and 7.98 mg per kg. After we harvested the maize, we noticed the heavy metal levels dropped in all the fertilized soils—cadmium went down by 80%, chromium by 3.07%, nickel by 7.39%, and lead by 14.41%. We think this happened because the maize plants sucked up some of these metals. According to Müller's scale, the I-geo numbers for all the metals in all the treatments showed the soil was "unpolluted," except for cadmium in the rock phosphate (R.P) treatment, where it hit "moderately polluted." That tells us rock phosphate might be adding more cadmium to the soil than the others, so we'd need to keep a closer eye on it for environmental reasons.

Table (5-a): Assessment of Heavy Metal Contamination in the Shoots of White Maize

Fertilization Treatment	Lead (Pb)		Nickel (Ni)		Chromium (Cr)		Cadmium (Cd)	
	Permissible Limit	Estimated	Permissible Limit	Estimated	Permissible Limit	Estimated	Permissible Limit	Estimated
	Micrograms per gram of dry matter		Micrograms per gram of dry matter		Micrograms per gram of dry matter		Micrograms per gram of dry matter	
Control (No Fertilization)	2.5a 30-1b 0.5c	4.29	1.5 a 4-0b --	0.323	20.0a 5-1b --	2.99	1.5a 1.2-0.05b 0.2c	0.025
Fertilized with CSP		6.31		0.245		10.65		0.256
Fertilized with NPK		7.85		0.648		6.87		0.154
Fertilized with DAP		6.33		0.436		9.68		0.165
Fertilized with R. P		5.37		0.370		5.39		0.124

Source: A - Indian Standard (Awashthi, 2000), B - Vishnu *et al.* (2007), C - WHO/FAO (2007)

Table (5-b): Assessment of Heavy Metal Contamination in the Roots of White Maize

Fertilization Treatment	Lead (Pb)		Nickel (Ni)		Chromium (Cr)		Cadmium (Cd)	
	Permissible Limit	Estimated	Permissible Limit	Estimated	Permissible Limit	Estimated	Permissible Limit	Estimated
	Micrograms per gram of dry matter		Micrograms per gram of dry matter		Micrograms per gram of dry matter		Micrograms per gram of dry matter	
Control (No Fertilization)	2.5 a 30-1 b 0.5 c	9.06	1.5 a 4-0 b --	2.99	0.02 a 5-1 b	3.68	1.5 a 1.2-0.05 b 0.2 c	0.048
Fertilized with CSP		10.77		5.65		12.73		0.256
Fertilized with NPK		16.45		4.76		9.96		0.222
Fertilized with DAP		12.76		3.83		10.46		0.232
Fertilized with R. P		12.54		3.99		7.16		0.126

Source: A - Indian Standard (Awashthi, 2000), B - Al-Zu'bi *et al.* (2006), C - WHO/FAO (2007)

CONCLUSIONS

Using phosphate fertilizers leads to the buildup of heavy metals in both soil and plants, with rock phosphate (RP) standing out as the biggest polluter, especially when it comes to cadmium and lead. The CSP fertilizer showed high cadmium levels, while NPK had a lot of lead, pointing to how different fertilizers affect pollution in their own ways. Some heavy metal concentrations went beyond what's allowed by global standards, calling for strict oversight of fertilizer quality in farming to cut down on environmental and health risks. The study recommends putting in place tougher monitoring policies and steps to improve the quality of agricultural materials, aiming to reduce the spread of pollutants into the food chain and protect both the environment and public health.

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CONFLICT OF INTEREST

There are no conflicts to declare.

تأثير بعض الأسمدة الفوسفاتية في تلوث بعض العناصر الثقيلة في التربة ونبات الذرة البيضاء

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الخلاصة

نُفذ هذا البحث في مختبرات قسم علوم التربة والموارد المائية، كلية الزراعة، جامعة بغداد، خلال الفترة 2024–2025، بهدف دراسة تأثير بعض الأسمدة الفوسفاتية في تلوث التربة ونباتات الذرة البيضاء بالعناصر الثقيلة. شملت الدراسة أربعة أنواع من الأسمدة التجارية الشائعة الاستخدام: السوبر فوسفات المركز (CSP) ، السماد المركب(15-15-15) NPK ، فوسفات ثنائي الأمونيوم(DAP) ، والفوسفات الصخري .(R.P) اعتمدت التجربة تصميمًا عشوائيًا تامًا (CRD) بثلاث مكررات لكل معاملة، ليبلغ عدد الوحدات التجريبية 12 وحدة. أظهرت النتائج اختلافًا واضحًا في مستويات التلوث تبعًا لنوع السماد المستخدم، إذ تميز الفوسفات الصخري (R.P) بأعلى تركيز من الكادميوم (140.77 ملغم. كغم$^{-1}$) والرصاص (221.60 ملغم. كغم$^{-1}$)، مما يجعله المصدر الرئيس للتلوث في التربة والنبات. أما الأسمدة الأخرى فقد سجلت مستويات متفاوتة من التلوث، وتجاوزت في بعض الحالات الحدود المسموح بها دوليًا حسب معايير (USEPA، FAO، OECD، AAPFCO). تؤكد هذه النتائج ضرورة فرض رقابة صارمة على جودة الأسمدة الفوسفاتية المستخدمة في الزراعة، للحد من تراكم الملوثات في التربة والمحاصيل، وتقليل المخاطر البيئية والصحية المحتملة.

الكلمات المفتاحية: الأسمدة الفوسفاتية، تلوث العناصر الثقيلة، الذرة البيضاء، التلوث البيئي، تراكم المعادن الثقيلة.

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