Assessment of Heavy Metal Contamination in Some Phosphate Fertilizers

Mahassan Hamad Rahim1 Mohammed Malik Hamid2
1,2Department Of Soil and Water Techniques- Al-Musayyab Technical College- Al-Furat Al-Awsat Technical University-Iraq.
1Email: mahassan.hamad.tcm44@student.atu.edu.iq 2Email: mohammed.hamid@atu.edu.iq

Abstract
We carried out this research at the University of Baghdad's College of Agriculture between 2024 and 2025, diving into the issue of heavy metal contamination in some everyday phosphate fertilizers Concentrated Superphosphate (CSP), NPK (15-15-15), Diammonium Phosphate (DAP), and Rock Phosphate (R.P.). Our focus was on tracking down levels of cadmium (Cd), chromium (Cr), nickel (Ni), and lead (Pb). Working in the Soil Science and Water Resources labs, we set up a straightforward experiment using a Completely Randomized Design (CRD), running three rounds for each fertilizer to get a solid set of 12 samples. We dug into the chemical makeup of these fertilizers and measured their heavy metal content, holding the numbers up against benchmarks from big names like the USEPA, FAO, and OECD. What we found was eye-opening: CSP and Rock Phosphate were loaded with Cd, Cr, and Ni, standing out as the heavy hitters in contamination, while NPK kept things clean, staying well within safe limits DAP seemed to land somewhere in the middle, though we didn't pin it down completely. These results echo what others have seen worldwide and drive home why we need to keep a close eye on fertilizer quality to protect our soils and environment, offering some practical takeaways for smarter farming.

Keywords: Contamination, Phosphate Fertilizers, Heavy Metals, Cadmium, Chromium, Nickel, Lead, Fertilizer Assessment .

Introduction

Phosphate fertilizers are a cornerstone of modern farming, giving crops the nutrients they need to thrive and boosting harvests. But there's catch research keeps showing that these fertilizers often come loaded with heavy metals like cadmium, lead, nickel, and chromium, all thanks to the phosphate rocks they're made from. Sometimes, those levels creep past what's considered safe by big players like the USEPA, FAO [8], and OECD [14,8], and that's where the trouble starts. These metals don't just sit there; they pile up in the soil over time, threatening the environment and sneaking into our food chain. Study after study shows how they move from dirt to plants and end up on our plates, with clear links between dirtier soil and more metals in our food, raising the odds of serious health issues down the line [13,21]. On top of that, how these metals shift and change in farmland can make it even easier for plants to soak up, speeding their trip through the food web. It's a real wake-up call we need to dig deeper into what's happening here and figure out solid ways to keep the risks in check.

The rising focus on this issue reflects a pressing demand for robust environmental policies to safeguard natural resources and ensure food security, especially given modern agriculture's growing dependence on both mineral and organic fertilizers. This study holds significance by offering evidence-based scientific and practical insights that could enhance agricultural production quality and

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refine regulatory standards to keep contamination within safe bounds, aligning with broader goals of sustainable development that prioritize environmental and public health considerations [15]. To this end, our research employs cutting-edge analytical techniques to measure heavy metal concentrations in fertilizer samples drawn from diverse sources, complemented by statistical analyses to explore the connections between contamination levels and the physical and chemical traits of the materials involved. Specifically, this investigation seeks to quantify the presence of cadmium, chromium, nickel, and lead in phosphate fertilizers, benchmark these levels against global standards such as those from the Association of American Plant Food Control Officials (AAPFCO), USEPA, and the California Department of Food and Agriculture (CDFA), and evaluate the fertilizers' suitability for agricultural use alongside their broader environmental implications.

Materials and Methods

Sample Collection and Preparation

For this study, we examined four kinds of phosphate fertilizers: Concentrated Superphosphate (CSP), Diammonium Phosphate (DAP), NPK 15-15-15, and Rock Phosphate (RP). We gathered samples from local suppliers, crushed them, and sifted them through a 1 mm mesh to keep the particle sizes consistent before diving into the analysis.

Some Properties and Heavy Metal Content in Phosphate Fertilizers (Cadmium, Chromium, Nickel, and Lead(

We picked four phosphate fertilizers that you can find around here Concentrated Superphosphate (CSP), NPK, DAP, and Rock Phosphate (RP) along with cow manure, to check out their starting characteristics and see how much heavy metal they're carrying for a contamination check. Here's what we did for the chemical tests:

pH

We took 20 grams of each ground fertilizer already sifted through a 1 mm mesh and popped it into a 100 mL plastic flask. Then, we added distilled water at a 2:1 ratio (fertilizer to water) and shook it for an hour. After that, we filtered the mix through Whatman No. 1 filter paper and checked the liquid's pH with a pH meter (the HANNA H 19811 model), following the steps in [16.[

Electrical Conductivity (EC(

To determine the salinity of these phosphate fertilizers, we measured the electrical conductivity (EC) of that same filtered liquid using an EC-Meter (a Conductivity Meter, C-501). This is a pretty straightforward way to see what's going on salt-wise.

Total Heavy Metal and Phosphorus Content

For this part, we broke down the fertilizer samples by digesting them in an acid mixHNO3 and HCl at a 1:4 ratio using the method from [11]. Once digested, we measured the total amounts of cadmium, chromium, nickel, and lead in the solution with an Atomic Absorption Spectrometer (A.A.S). For phosphorus, we switched to a Spectrophotometer, checking it at 470 nm, just like they do in [16.[

Dissolved Concentrations of Heavy Metals and Phosphorus

Here, we grabbed another 20 grams of each ground fertilizer sifted through that 1 mm mesh again and put it in a 100 mL plastic flask. We poured in distilled water at a 2:1 ratio (water to fertilizer this time), shook it for an hour, and filtered it. Then we tested the dissolved heavy metals cadmium, chromium, nickel, and lead using the Atomic Absorption Spectrometer (A.A.S), and measured phosphorus with the Spectrophotometer at 470 nm, sticking to the method in [16.[

Experimental Design

We carried out this study in the labs of the Department of Soil Science and Water Resources at the University of Baghdad’s College of Agriculture during the 2024-2025 academic year. Our goal was to figure out how much heavy metal is lurking in four common commercial fertilizers. We set things up using a Completely Randomized Design (CRD), running three replicates for each fertilizer type, which gave us 12 experimental units in total. The fertilizers we tested were four different kinds, gathered up for chemical analysis so we could compare their heavy metal levels specifically cadmium (Cd), chromium (Cr), nickel (Ni), and lead (Pb). To keep it fair, we handed out the samples randomly using a draw method, making sure no bias snuck in. We worked straight with the fertilizer samples themselves, no mixing with other stuff, and measured the heavy metals using trusted tools and standard techniques for fertilizer analysis. Everything was done under tight lab conditions to make ensure our results were spot-on and dependable.

Statistical Analysis

For the stats, we ran the data through an Analysis of Variance (ANOVA) based on the CRD setup to spot any big differences between the treatments. To dig deeper, we used the Least Significant Difference (LSD) test at a 5% probability level to check whether the differences in the averages really mattered. We crunched all the numbers with GenStat software, which helped us write accurate results and draw solid conclusions. This approach gave us a clear picture of how the different fertilizers stacked up regarding heavy metal content, phosphorus levels, and their chemical traits, all laid out with precision [3.[

Results and Discussion

Properties and Composition of the Phosphate Fertilizers Used in the Study

The data in Table (1) gave us a good look at the pH levels of the fertilizers we tested, measured at a 1:2 fertilizer-to-water ratio, and they ranging from 3.1 to 7.5. Concentrated Superphosphate (CSP) and NPK came in on the acidic side, with pH values of 3.1 and 5.2, respectively. That makes sense when you think about how they're made CSP comes from mixing phosphate rock with phosphoric acid, while NPK involves sulfuric acid reacting with the rock, as [18] points out. Conversely, Diammonium Phosphate (DAP) and Rock Phosphate (RP) leaned neutral to slightly basic, hitting 7.0 and 7.5. For DAP, that’s tied to its production from phosphoric acid and ammonia or calcium phosphate [19], and for RP, [17] backs up its mild alkaline vibe, which can be handy for acidic soils. Other studies, like [22], found close numbers CSP at 3.20, NPK at 5.75, and DAP at 7.62 so our results line up well. It really drives home how pH matters when picking the right fertilizer for the soil and conditions you’re working with.

When we checked electrical conductivity (EC), the differences jumped out. NPK topped the list at 10.5 dS/m, followed by DAP at 9.6, CSP at 7.5, and Rock Phosphate trailing with a low 3.5 dS/m. That spread comes down to the salt levels in each one, shaped by things like filler materials think clays or quartz tossed in during production, plus any added salts and even the water quality used, as [17] and [19] mention. Measuring this before spreading fertilizer is a big deal, especially if you're spraying it on leaves or mixing it into soil or irrigation water. High salinity can clog emitters or pile salt into the ground, so keeping an eye on it helps avoid trouble and keeps the soil in good shape.

As for phosphorus, CSP led the pack with a total of 20.5% and a hefty 7500 mg/L of soluble phosphorus. DAP wasn't far behind, with 18.5% total and 6600 mg/L soluble, while Rock Phosphate clocked in at 15.4% total but only 150 mg/L soluble. NPK brought up the rear with 8.8% total and 4500 mg/L soluble. Rock Phosphate's low soluble number isn't surprising it's mostly hydroxyapatite, which doesn't break down easily. That said, [4] found that mixing it with organic stuff like animal waste can boost its solubility and make it more plant-friendly. It’s clear from this that how well a phosphate fertilizer works isn’t just about how much phosphorus it’s got soil type, how you apply it, and how soluble phosphorus is all play a part

.

Table (1): pH, Electrical Conductivity, and Total and Soluble Phosphorus Content of the Phosphate Fertilizers Used

Fertilizer Type	*pH (1:2 ratio)*	*Electrical Conductivity (dS/m)*	*Total Phosphorus (%)*	*Soluble Phosphorus (mg/L)*
Concentrated Superphosphate (CSP)	3.1	7.5	20.5	7500
NPK (15-15-15)	5.2	10.5	8.8	4500
Diammonium Phosphate (DAP)	7.0	9.6	18.5	6600
Rock Phosphate (RP)	7.5	3.5	15.4	150

Total and Soluble Concentrations of Heavy Metals (Pb, Ni, Cr, Cd) in the Phosphate Fertilizers Used in the Study

The numbers in Table (2) lay out what we found about cadmium levels in the fertilizers we tested. For total cadmium, Concentrated Superphosphate (CSP, 47% P2O5) hit 17.5 mg/kg, NPK (15-15-15) came in at 7.5 mg/kg, Diammonium Phosphate (DAP, 0-46-18) was 8.5 mg/kg, and Rock Phosphate (R.P, 36% P2O5) topped the list at 25.05 mg/kg. When we looked at the soluble cadmium the stuff that dissolves and moves around more easily it was 0.35 mg/L for CSP, 0.25 mg/L for NPK, 0.17 mg/L for DAP, and just 0.03 mg/L for Rock Phosphate. These mineral fertilizers do wonders for soil fertility, but piling them on can leave behind nasty heavy metals like cadmium, which isn’t great for the environment or our health. Research from [13, 18, 5] backs this up, pointing out how overdoing it with phosphate fertilizers especially CSP can pile cadmium into the soil. Our findings match [13], who saw CSP loaded with more cadmium than Mono-Ammonium Phosphate (MAP) or DAP. Our data shows that CSP and Rock Phosphate are the cadmium heavyweights here.

We also checked out chromium levels. Total chromium came in at 50.47 mg/kg for CSP, 27.89 mg/kg for NPK, 39.46 mg/kg for DAP, and 33.57 mg/kg for Rock Phosphate. The soluble chromium numbers were 4.8 mg/L, 2.02 mg/L, 1.89 mg/L, and 0.37 mg/L, respectively. Chromium stood out as higher than the other heavy metals we tested (cadmium, nickel, and lead), which lines up with [7] saying CSP is a chromium hotspot. That said, our Rock Phosphate numbers didn't

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quite match [10], who found even higher chromium in samples from the USA and North Africa ours were a bit tamer.

Next up, nickel. Total nickel concentrations were 25.85 mg/kg in CSP, 15.7 mg/kg in NPK, 11.7 mg/kg in DAP, and 18.65 mg/kg in Rock Phosphate, with soluble levels at 0.56 mg/L, 0.11 mg/L, 0.58 mg/L, and 0.06 mg/L, respectively. CSP and Rock Phosphate led the pack here, echoing [13] 's finding that CSP beats out DAP for nickel content. But we saw something different from [10], who noted lower nickel in Rock Phosphate from the USA and North Africa our samples had more kick.

Finally, we looked at lead. Total lead concentrations were 75 mg/kg in CSP, 45.9 mg/kg in NPK, 63.32 mg/kg in DAP, and a whopping 95 mg/kg in Rock Phosphate. Soluble lead stayed close across the board0.22 mg/L for CSP, 0.25 mg/L for NPK and DAP, and 0.26 mg/L for Rock Phosphate. Rock Phosphate carried the most lead overall, though CSP still outdid the others in its group. This fits with [12], who flagged Rock Phosphate as a lead standout among phosphate fertilizers.

Table (2): Total (mg/kg) and Soluble (mg/L) Concentrations of Heavy Metals in the Phosphate Fertilizers Used in the Study

Fertilizer Type	***Total concentration***				***Dissolved concentration***			
	Cd	Cr	Ni	Pb	Cd	Cr	Ni	Pb
CPS (P2O5 47%)	17.5	50.47	25.85	75	0.35	4.8	0.56	0.22
NPK (15-15-15)	7.5	27.89	15.7	45.9	0.25	2.02	0.11	0.25
Dap (18-46-0)	8.5	39.46	11.7	63.32	0.17	1.89	0.58	25
R. P (P2O5 36%)	25.05	33.57	18.65	95	0.03	0.37	0.06	0.26

Evaluation of Heavy Metal Contamination in Phosphate Fertilizers

A bunch of studies have flagged how phosphate fertilizers often come with heavy metal baggage, pushing international groups to slap limits on how much of these elements should be in mineral fertilizers especially the phosphate kinds. Using those standards, we sized up the fertilizers in our study against what these global organizations say is okay.

Concentrated Superphosphate (CSP(

When we dug into Concentrated Superphosphate (CSP, 47% P2O5), the early tests showed it's packing some cadmium (Cd), chromium (Cr), and lead (Pb), based on classifications from [1, 6, 20], check Appendix (1) for the details. That said, cadmium didn't ring the contamination bell under [6]’s rules, since they bumped the limit way up to 340 mg/kg P2O5. In our case, cadmium clocked in at 17.5 mg/kg, well under some of those global caps. That’s close to what [2] saw, with their CSP hitting 22.5 mg/kg. The cadmium's coming from the phosphate rock it’s made from, as [18] points out. Speaking of which, our phosphate rock tested at 25.05 mg/kg for cadmium higher than CSP but still lower than what [10] found in other studies. Chromium, stole the show in CSP at 50.47 mg/kg, making it the heaviest hitter among the metals we checked. That tracks with [13], who saw chromium in Saudi CSP ranging from 39 to 41 mg/kg. Nickel (Ni), on the other hand? No worries there it didn't trip any contamination alarms.

Compound Fertilizer (NPK 15-15-15(

For the NPK (15-15-15), the heavy metal levels lead (Pb), nickel (Ni), chromium (Cr), and cadmium (Cd) were lower than CSP's, stacking up like this: Cd < Ni < Cr < Pb. It got dinged for cadmium contamination under [6]'s rules (Appendix 1), but other classifications like [1, 20] gave it a pass. Lead, though, was flagged as a problem by [20, 6] (Appendix 1), while some other standards didn't see it as an issue. All in all, NPK's keeping things pretty tame compared to CSP.

Diammonium Phosphate (DAP 0-46-18(

DAP (0-46-18) came out lighter on heavy metals than CSP, too. It got pegged for lead contamination by four of the classifications we used (Appendix 1), but nickel, chromium, and cadmium? Mostly clean, except [6] called out cadmium (Appendix 1). Earlier work, like [11], backs this up-DAP's cadmium levels are usually way below what you'd see in CSP.

Phosphate Rock (R.P(

Now, Phosphate Rock (R.P) was a different story. Table (2) shows it's loaded with cadmium 25.05 mg/kg enough to get flagged by pretty much every classification in Appendix (1) and our adopted standards. The only outlier was [6], which didn't call it contaminated. That high cadmium level screams that the rock itself is the main culprit for this stuff in phosphate fertilizers. [10] noted cadmium in Middle Eastern phosphate rock can hit 60 mg/kg, and [2] found 65.30 mg/kg in theirs both higher than what we saw here, but it still stands out compared to the other fertilizers we tested

.

Conclusion

All the fertilizers we tested had heavy metals cadmium, chromium, nickel, and lead but the amounts depended on the type of fertilizer.

Concentrated Superphosphate (CSP) had the highest heavy metal levels, especially cadmium, chromium, and nickel. It sometimes crossed environmental safety lines and earned a spot as a contamination source by global standards.

The phosphate rock used to make CSP was the main culprit behind its hefty heavy metal content.

NPK (15-15-15) kept things light, showing low heavy metal levels and no contamination from cadmium, chromium, or nickel, making it the most eco-friendly pick of the group.

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Appendix (1): Evaluation of Heavy Metal Contamination in Phosphatic Fertilizers According to Global Standards

Classification Number	***Classification System***	***Estimated Concentration and Permissible Limit (mg kg^{-1} P2O5)***	***Concentrated Superphosphate (CSP)***				***NPK***			
			Cd	Cr	Ni	Pb	Cd	Cr	Ni	Pb
1	AAPFCO (2001)	Estimated Concentration	17.5	50.47	25.85	75	7.5	27.89	15.7	45.9
		Permissible Limit	10	-	250	61	10	-	250	61
		Pollution Assessment	Polluted	-	Non-Polluted	Polluted	Non-Polluted	-	Non-Polluted	Non-Polluted
2	CDFA (2004)	Estimated Concentration	17.5	50.47	25.85	75	7.5	27.89	15.7	45.9
		Permissible Limit	4		-	20	4	-	-	20
		Pollution Assessment	Polluted	-	-	Polluted	Polluted	-	-	Polluted
3	CFIA (2005)	Estimated Concentration	17.5	-	25.85	75	7.5	27.89	15.7	45.9
		Permissible Limit	14	50.47	-	61	14	-	-	61
		Pollution Assessment	Polluted	-	-	Polluted	Polluted	-	-	Non-Polluted
4	OSDA (2005)	Estimated Concentration	17.5	-	25.85	75	7.5	27.89	15.7	45.9
		Permissible Limit	61	50.47	175	340	61			340
		Pollution Assessment	Non-Polluted	-	Non-Polluted	Non-Polluted	Non-Polluted	-	-	Non-Polluted
5	US EPA (2005)	Estimated Concentration	17.5	-	25.85	75	7.5	27.89	15.7	45.9
		Permissible Limit	14	50.47	-	28	14	-	-	28
		Pollution Assessment	Polluted	-	-	Polluted	Non-Polluted	-	-	Polluted

Continuation of Appendix (1(

Classification Number	***Classification System***	***Estimated Concentration and Permissible Limit (mg kg^{-1} P2O5)***	***DAP (0-46-18)***				***Phosphate Rock R.P (P2O5 36%)***			
			Cd	Cr	Ni	Pb	Cd	Cr	Ni	Pb
1	AAPFCO (2001)	Estimated Concentration	8.5	39.46	11.7	63.32	25.05	33.57	18.65	95
		Permissible Limit	10	-	250	61	10	-	250	61
		Pollution Assessment	Non-Polluted	-	Non-Polluted	Polluted	Polluted	-	Non-Polluted	Polluted
2	CDFA (2004)	Estimated Concentration	8.5	39.46	11.7	63.32	25.05	33.57	18.65	95
		Permissible Limit	4	-	-	20	4	-	-	20
		Pollution Assessment	Polluted	-	-	Polluted	Polluted	-	-	Polluted
3	CFIA (2005)	Estimated Concentration	8.5	39.46	11.7	63.32	25.05	33.57	18.65	95
		Permissible Limit	14	-	-	61	14	-	-	61
		Pollution Assessment	Non-Polluted	-	-	Polluted	Polluted	-	-	Polluted
4	OSDA (2005)	Estimated Concentration	8.5	39.46	11.7	63.32	25.05	33.57	18.65	95
		Permissible Limit	61	-	-	340	61	-	-	340
		Pollution Assessment	Non-Polluted	-	-	Non-Polluted	Non-Polluted	-	-	Non-Polluted
5	US EPA (2005)	Estimated Concentration	8.5	39.46	11.7	63.32	25.05	33.57	18.65	95
		Permissible Limit	14	-	-	2،8	14	-	-	2،8
		Pollution Assessment	Non-Polluted	-	-	Polluted	Polluted	-	-	Polluted

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