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## PHYTOREMEDIATION POTENTIAL AND EFFECT OF ORGANO-MINERAL FERTILIZER ON LEAD (Pb) UPTAKE BY MAIZE (*Zea mays* L.) AND SUNFLOWER (*Helianthus annuus* L.) FROM CONTAMINATED SOIL

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### ABSTRACT

The role of organo-mineral fertilizer in enhancing the phytoremediation efficiency of plants like maize and sunflower has not been adequately addressed. Thus, this study investigates the phytoremediation potential of maize (*Zea mays*) and sunflower (*Helianthus annuus*) for the removal of lead (Pb) from contaminated soils, with the effects of Organo-Mineral Fertilizer (OMF) treatment. The study also evaluated the concentration of Pb in both topsoil and subsoil before and after treatment with OMF, as well as the distribution of Pb across different plant tissues parts. The samples were assayed for their Pb content utilizing Flame Atomic Absorption Spectrophotometer. Descriptive and inferential statistics were used for data interpretations. The results revealed that sunflower exhibited a significantly higher Pb removal efficiency compared to maize, with control sunflowers removing 75.58% of Pb from the topsoil and 83.58% from the subsoil, while maize removed only 18.83% and 14.21%, respectively. Despite these increases in biomass, OMF treatment did not significantly improve Pb translocation or enhance the phytoremediation efficiency of either plant. These findings suggest that while OMF treatment promotes plant growth, it may not be the most effective strategy for enhancing Pb removal in phytoremediation efforts. The study recommends further optimization of OMF formulations and the exploration of other soil amendments to improve both maize and sunflower growth and metal uptake, as well as long-term field trials to assess the sustainability and practicality of phytoremediation in real-world conditions.

**Keywords:** Lead contamination soil; Phytoremediation; Sunflower (*Helianthus annuus*); Organo-mineral fertilizer (OMF); Pollution, Ibadan

### INTRODUCTION

Phytoremediation, the use of plants to clean up or detoxify polluted environments, has emerged as an environmentally sustainable and cost-effective approach for the remediation of heavy metal-contaminated soils. Lead, a persistent and toxic heavy metal, is a significant environmental contaminant due to its widespread use in industries and its potential to accumulate in air, plant, soil, water, and living organisms. Lead contamination of soils occurs primarily through industrial processes, mining activities, agricultural practices (such as the use of lead-based pesticides), and vehicular emissions (Ali *et al.*, 2013). Lead poses serious health risks to humans and wildlife, including neurological damage, developmental issues in children, and bioaccumulation in the food chain (Afolayan *et al.*, 2021). As such, the need for effective methods to remove Pb from contaminated environments has become critical. Phytoremediation offers an eco-friendly alternative to conventional remediation techniques like soil excavation

and chemical treatments, which are often expensive and disruptive to the environment (Collin *et al.*, 2022).

Plants, particularly those with high metal uptake capabilities, can absorb, accumulate, and sometimes detoxify heavy metals from contaminated soils, making them valuable tools for soil remediation. Sunflower (*Helianthus annuus*) and maize (*Zea mays*) are among the plants commonly studied for their phytoremediation potential due to their fast growth rates and ability to accumulate metals in their tissues (Acuna *et al.*, 2020)

### METHODOLOGY

#### Study Area

The study was conducted on a fallow land (Latitude 7°24'47.99"N and Longitude 3°51'46.75"E) located near a well-established paint manufacturing company in Eleyele, Ibadan, Oyo State. Paint production typically involves the use of various additives to enhance properties such as

biocidal effectiveness, viscosity, and flow characteristics. However, some of these additives may contain heavy metals, including lead (Afolayan *et al.*, 2021; Ranjbar *et al.*, 2023). The factory discharges its effluent into the surrounding land around it; this land was selected for the experiment.

### Sample Collection/Preparation

Viable seeds of sunflower (*Helianthus annuus*) (Funtua variety), and maize (*Zea mays*) were obtained from the Institute of Agricultural Research and Training (IAR&T), Ibadan, Nigeria while Organo-mineral fertilizer (OMF) was prepared by IAR&T and applied according to Adewale (2005).

### Agronomic Practices

An area of 7.5 m x 12.0 m was used as the study site; divided into twelve plots of 2 m x 2 m (4m<sup>2</sup>) each with a spacing of 0.5 m in between and within sub-plots labelled. Sub-plots were used for maize cultivation, while another sub-plots were used for sunflower cultivation. Land preparation was done manually with cutlass, the experimental design followed a randomized complete block arrangement and was established in triplicates. Maize seeds were planted at a spacing of 0.5 m x 0.75 m. Four maize seeds were sown per hole at a depth of 3.4 cm. Likewise, sunflower seeds were planted at a spacing of 1 m x 0.7 m, with four seeds per hole at a depth of 3–4 cm. Thinning was carried out twelve days after sowing to maintain four healthy stands, while the organic mineral fertilizer (OMF) was applied two weeks after sowing. OMF was applied on the test sub-plots for both crops; while OMF was not applied on the control sub-plots for both crops. Data on growth parameters of maize and sunflower (leaves, root, shoot, and seeds) were collected from the third week, and fortnightly for 15 weeks.

### Harvest of Plant Samples

The maize plants were harvested after 110 days of planting while sunflower plants were harvested after maturity (105 days); bulked for each sub-plot. The fresh weights of each of maize and sunflower plants were recorded on the field; and dry weights were recorded after 48 hours of oven drying at 70°C. All samples were divided into roots, shoots, leaves and seeds, and blended thoroughly to get homogenized samples (Adewale, 2005).

### Determination of Pb in Maize and Sunflower Plants

Lead concentration in maize and sunflower tissues were subjected to wet digestion method (Voshii *et al.*, 2020). The filtrates obtained were analyzed for the presence of Pb in

the plant parts using Flame Atomic Absorption Spectrophotometer (FAAS).

### Determination of Pb in Soil

Lead concentrations in the soil regions (0 – 30 cm) were determined at the beginning and end of the planting experiments. Soil samples were digested using wet digestion method, and the digests were analyzed for Pb concentration in the plant parts using FAAS (Afolayan *et al.*, 2021).

### Quality Control/Quality Assurance

Quality assurance/control (QA/QC) protocol for Pb analysis described by Afolayan *et al.* (2021) was followed. Analytical precision was ensured by using certified standard reference materials (NRC-CNRC SOIL-5 for soil analysis and NIST SRM 1573a for plant tissue analysis) from the National Research Council of Canada and by performing replicate analyses (National Research Council of Canada, 2015; National Institute of Standards and Technology, 1991).

### Data Analysis

Data were analyzed using both descriptive and inferential statistical methods with the aid of the Statistical Package for the Social Sciences (SPSS) version 20.0. Means were separated by Duncan's multiple range test using IBM SPSS (20.0). The results were compared with the Food and Agricultural Organization/World Health Organization Codex Alimentarius General Standard for Contaminants and Toxins in Food and Feed (FAO/WHO, 2021).

### Reagents Adopted and their Sources

All the reagents employed, namely nitric acid (HNO<sub>3</sub>), (Riedel-deHaen, Germany), hydrochloric acid, (HCl), (Sigma-Aldrich, Germany), hydrofluoric acid (HF), (British Drug House, BDH, Chemical Ltd, Poole, England), sulphuric acid (H<sub>2</sub>SO<sub>4</sub>), (Sigma-Aldrich, Germany), perchloric acid (HClO<sub>4</sub>), (Sigma-Aldrich, Germany), acetic acid (HOAc), (Sigma-Aldrich, Germany) and doubly distilled water, were of analytical grade. These were applied to formulate standard solutions.

## RESULTS

The concentrations of Pb in the topsoil before and after the remediation process using maize and sunflower plants are presented in Table 1. For sunflower, the control group had a Pb concentration of 651.83±17.03 mg/kg in the soil before remediation, which decreased to 159.17±54.83 mg/kg after remediation, resulting in a Pb removal of 75.58%. In contrast, the OMF-treated group showed a slightly higher Pb concentration before remediation (661.67±17.03 mg/kg)

but after remediation, the Pb concentration decreased to 231.00±10.04 mg/kg, reflecting a lower Pb removal of 65.09%. This suggests that sunflower effectively removes Pb from topsoil, particularly under the control condition. For maize, the control group started with a Pb concentration of 761.00±35.51 mg/kg before and after remediation, this reduced to 617.67±41.79 mg/kg, showing a modest Pb

removal of 18.83%. The OMF-treated maize group had a pre-remediation Pb concentration of 740.50±35.51 mg/kg, which decreased slightly to 616.67±7.22 mg/kg post-remediation, resulting in a minimal Pb removal of 16.72%. These results indicate that maize is less effective in Pb removal compared to sunflower, with both the control and treated conditions showing low percentage removals.

Table 1: Mean Concentrations of Pb (mgkg<sup>-1</sup>) removed by Maize and Sunflower from Topsoil

Plant	Experiment	Lead in soil Before Remediation	Lead in soil After Remediation	% removal
Sunflower	Control	651.83±17.03	159.17±54.83	75.58
	Treated	661.67±17.03	231.00±10.04	65.09
Maize	Control	761.00±35.51	617.67±41.79	18.83
	Treated	740.50±35.51	616.67±7.22	16.72

The data in Table 2 displays the concentrations of Pb in the subsoil before and after remediation using maize and sunflower plants. For sunflower, the control group had a Pb concentration of 973.33±132.79 mg/kg in the subsoil before remediation, which decreased significantly to 159.83±44.16 mg/kg after remediation, reflecting a Pb removal of 83.58%. The OMF treated sunflower group started with a slightly lower Pb concentration of 896.67±132.79 mg/kg before remediation and after treatment, the Pb concentration dropped to 169.17±54.21 mg/kg, resulting in a removal of 81.13%. These results suggest that sunflower is highly effective at removing Pb from subsoil, with a higher percentage of removal in the

control group compared to the OMF treated one, although both showed notable reductions. For maize, the control group showed a Pb concentration of 518.33±4.62 mg/kg in the subsoil before remediation, which was reduced to 444.67±7.23 mg/kg after remediation, resulting in a Pb removal of 14.21%. Similarly, the OMF treated maize group started with a Pb concentration of 515.67±4.62 mg/kg, which decreased to 436.90±49.39 mg/kg post-remediation, showing a slightly higher Pb removal of 15.27%. These figures indicate that maize is much less effective in removing Pb from the subsoil when compared to sunflower, with relatively low percentages of Pb removal in both control and OMF treated conditions.

Table 2: Mean Concentrations of Pb (mgkg<sup>-1</sup>) Removed by Maize and Sunflower from Subsoil

Plant	Experiment	Pb in soil Before Remediation	Pb in soil After Remediation	% removal
Sunflower	Control	973.33±132.79	159.83±44.16	83.58
	Treated	896.67±132.79	169.17±54.21	81.13
Maize	Control	518.33±4.62	444.67±7.23	14.21
	Treated	515.67±4.62	436.90±49.39	15.27

The distribution of Pb in the various parts (leaves, roots, seeds, and shoots) of maize and sunflower plants under both control and OMF treated conditions was presented in Table 3. In the control group of sunflower, the root (145.87±8.58 mg/kg) was the primary site for Pb accumulation, followed by shoots (74.87±4.12 mg/kg), the leaves (38.50±4.77 mg/kg) and the seeds (6.03±1.20 mg/kg). The OMF treated sunflower showed a decrease in Pb concentrations across all parts. The leaves contained

27.70±3.76 mg/kg, roots had 128.70±5.48 mg/kg, seeds had 4.37±2.40 mg/kg, and shoots had 63.40±5.24 mg/kg. Despite the treatment, the pattern of Pb accumulation remained similar, with roots being the main site of Pb storage, although the overall Pb concentrations were lower compared to the control group.

For maize, the control group showed a lower Pb concentration in all parts compared to sunflower: the

leaves contained 10.17±2.36 mg/kg, roots had 75.87±5.64 mg/kg, seeds contained 2.40±1.30 mg/kg, and the shoots had 19.67±5.13 mg/kg. Similar to sunflower, maize showed the highest Pb concentration in the roots, followed by shoots, with the seeds again having the lowest Pb content. After treatment, maize exhibited a slight decrease in Pb concentrations across all parts. The

leaves contained 7.83±0.76 mg/kg, roots had 71.50±4.44 mg/kg, seeds contained 1.80±0.95 mg/kg, and shoots had 18.50±1.80 mg/kg. While the reduction in Pb concentrations was noticeable in all parts of maize, the distribution pattern remained similar to that of the control, with the roots still accumulating the most Pb.

Table 3: Mean Distribution of Pb (mgkg<sup>-1</sup>) in some Parts of Maize and Sunflower

Plant	Experiment	Leaves	Root	Seeds	Shoot
Sunflower	Control	38.50±4.77 <sup>b</sup>	145.87±8.58 <sup>d</sup>	6.03±1.20 <sup>a</sup>	74.87±4.12 <sup>c</sup>
	Treated	27.70±3.76 <sup>b</sup>	128.70±5.48 <sup>d</sup>	4.37±2.40 <sup>a</sup>	63.40±5.24 <sup>c</sup>
Maize	Control	10.17±2.36 <sup>b</sup>	75.87±5.64 <sup>d</sup>	2.40±1.30 <sup>a</sup>	19.67±5.13 <sup>c</sup>
	Treated	7.83±0.76 <sup>b</sup>	71.50±4.44 <sup>d</sup>	1.80±0.95 <sup>a</sup>	18.50±1.80 <sup>c</sup>

Means±SD along the same row with heterogeneous superscript are significantly different (p<0.05).

Table 4 presents the fresh and dry weights of different parts of maize under both control and OMF treated experimental conditions. In the treated group, the dry weight was slightly higher than the control in all parts. Similarly, the treated group had higher fresh weight across all parts compared to the control, with the roots having 44.81±17.96 mg/kg, shoots having 156.20±77.39

mg/kg, leaves having 194.34 ± 101.61 mg/kg, and seeds having 131.53 ± 84.37 mg/kg. The increase in weights of the treated plants, especially in the leaves and seeds, suggests that the treatment led to increased biomass accumulation, which may reflect enhanced plant growth and health, potentially due to improved conditions or nutrients for growth.

Table 4: Mean Fresh and Dry weight of Maize in (mgkg<sup>-1</sup>)

Maize Part	Dry weight (Control)	Dry weight (Treated)	Fresh weight (Control)	Fresh weight (Treated)
Root	21.02±13.24 <sup>a</sup>	22.62±13.72 <sup>a</sup>	31.44±12.39 <sup>a</sup>	44.81±17.96 <sup>a</sup>
Shoot	35.33±20.71 <sup>a</sup>	42.56±21.42 <sup>a</sup>	118.49±55.81 <sup>ab</sup>	156.20±77.39 <sup>ab</sup>
Leaves	53.85±21.21 <sup>a</sup>	109.34±68.51 <sup>ab</sup>	111.72±46.90 <sup>ab</sup>	194.34±101.61 <sup>b</sup>
Seeds	22.49±8.85 <sup>a</sup>	38.60±33.73 <sup>ab</sup>	68.51±36.15 <sup>ab</sup>	131.53±84.37 <sup>b</sup>

Means±SD along the same row with heterogeneous superscript are significantly different (p<0.05).

The fresh and dry weights of different parts of sunflower plants under both control and treated experimental conditions were presented in Table 5. While the dry weight of the roots and seeds increased slightly in the treated group compared to the control, the shoot and leaf dry weights remained relatively unchanged. The OMF treated group showed significant increases in fresh weight across all parts, particularly in the shoots and leaves. The substantial increase in fresh weight of the treated sunflower, especially in the shoots (852.15±253.80 mg/kg) and leaves

(313.06±164.33 mg/kg), suggests that the treatment had a positive effect on overall plant growth, leading to enhanced biomass production. The increase in root fresh weight, from 120.44±82.63 mg/kg in the control group to 158.97±67.83 mg/kg in the treated group, also indicates better root development. Although the fresh weight of seeds showed a slight decrease in the treated group compared to the control, the overall trend indicates a growth response to the treatment, particularly in the above-ground parts.

Table 5: Mean Fresh and Dry weight of Sunflower in (mgkg<sup>-1</sup>)

Sunflower Part	Dry weight (Control)	Dry weight (Treated)	Fresh weight (Control)	Fresh weight (Treated)
Root	30.58±19.10 <sup>a</sup>	40.31±10.15 <sup>a</sup>	120.44±82.63 <sup>ab</sup>	158.97±67.83 <sup>b</sup>
Shoot	169.82±73.46 <sup>a</sup>	139.19±115.13 <sup>a</sup>	706.51±226.65 <sup>b</sup>	852.15±253.80 <sup>b</sup>
Leaves	81.33±32.08 <sup>a</sup>	94.12±37.06 <sup>a</sup>	290.28±132.46 <sup>ab</sup>	313.06±164.33 <sup>b</sup>
Seeds	38.93±21.76 <sup>a</sup>	36.13±20.28 <sup>a</sup>	130.75±28.14 <sup>b</sup>	122.47±45.14 <sup>b</sup>

## DISCUSSION

The results of this study suggest that both maize and sunflower are capable of removing Pb from the soil, with sunflower exhibiting superior Pb removal compared to maize. Sunflower, especially in the control group, demonstrated a high percentage of Pb removal (75.58% in the topsoil and 83.58% in the subsoil), indicating that sunflower has significant potential for Pb remediation. This is consistent with previous studies that show sunflowers as highly efficient phytoextractors of metals like Pb (Kumar *et al.*, 2015). In contrast, maize showed lower Pb removal percentages, particularly in the subsoil (14.21% in the control and 15.27% in the treated), which suggests that maize may not be as effective as sunflower in extracting Pb from soil.

Organo-mineral fertilizer treatment generally reduced the Pb removal efficiency in both plants. For sunflowers, OMF treatment led to a decrease in Pb removal from 75.58% to 65.09% in the topsoil and from 83.58% to 81.13% in the subsoil. Similarly, maize showed slightly reduced Pb removal with OMF treatment in both topsoil (18.83% to 16.72%) and subsoil (14.21% to 15.27%). These reductions suggest that while OMF might stimulate plant growth, it may not significantly enhance Pb uptake, and could potentially interfere with the plants' metal extraction capacities (Goyal *et al.*, 2018).

The reduced Pb removal in maize and sunflower treated with OMF could be due to altered soil conditions, such as changes in nutrient availability, which could affect the plants' ability to absorb and translocate Pb (Farooq *et al.*, 2015). Organo-mineral fertilizer treatment may enhance plant growth but does not necessarily improve the phytoextraction efficiency, as the increase in biomass might lead to a dilution effect, reducing the concentration of Pb per unit of plant tissue.

The overall impact of OMF on the phytoremediation potentials of maize and sunflower is somewhat mixed. On the one hand, OMF treatment led to increased biomass accumulation in both plants, as evidenced by the fresh and dry weight data. However, this increase in biomass did not translate into significantly higher Pb removal efficiency. While the OMF treatment promoted plant

growth and overall biomass, it did not enhance the phytoremediation potential of either maize or sunflower to a large extent. These results align with studies suggesting that while fertilizers like OMF can stimulate plant growth, they do not always enhance the plants' ability to remove some heavy metals from the soil (González-Mendoza *et al.*, 2016).

The distribution of Pb in different plant parts, as shown in this study, is an important indicator of the plant's ability to translocate Pb from the soil to various parts for storage. Both maize and sunflower predominantly accumulate Pb in their roots, as expected, since roots are the first point of contact with contaminants in the soil. In sunflower, the highest Pb concentration was in the roots, followed by shoots, leaves, and seeds. The same trend was observed in maize, although the overall Pb concentrations were lower in maize compared to sunflower. Organo-mineral fertilizer treatment had a noticeable effect on Pb distribution, particularly in sunflower. The OMF-treated sunflowers showed lower concentrations of Pb in the roots (128.70±5.48 mg/kg) compared to the control group (145.87±8.58 mg/kg), suggesting that the OMF treatment might have influenced the root uptake capacity. However, the reduction in Pb concentration in the roots did not seem to affect its accumulation in the shoots or leaves significantly. This distribution pattern is consistent with other studies where roots serve as the primary site for Pb accumulation, with lower translocation to above-ground parts (Zhao *et al.*, 2006). In maize, the distribution of Pb was similar, with roots accumulating the highest concentration, followed by shoots, leaves, and seeds. The OMF treatment appeared to slightly reduce Pb accumulation in all parts of maize. This suggests that maize is less effective than sunflower in translocating Pb, and the OMF treatment did not significantly enhance its Pb uptake or translocation abilities.

## CONCLUSION

This study highlights the potential of maize and sunflower for phytoremediation of Pb-contaminated soils, both in topsoil and subsoil, with an emphasis on the effects of OMF treatment. Sunflower demonstrated superior Pb removal capabilities compared to maize, with the highest

concentrations of Pb found in the roots, followed by shoots and leaves. Despite the higher efficiency of sunflower, both plants exhibited a reduction in Pb removal efficiency following OMF treatment. This suggests that while OMF can enhance plant growth, it may not significantly improve the phytoextraction of Pb, potentially due to complex interactions between soil nutrients and metal uptake processes. Additionally, OMF treatment led to an increase in biomass, particularly in the above-ground parts, without directly enhancing Pb translocation from roots to shoots or leaves. Organo-mineral fertilizer treatment had a mixed impact on the phytoremediation potential of both maize and sunflower, indicating that further optimization of fertilization strategies is needed to enhance both plant growth and Pb extraction capacity. The effectiveness of OMF in boosting phytoremediation is dependent on a balance between promoting plant growth and improving metal uptake efficiency. Further research is needed to optimize OMF use for phytoremediation, as it may have complex interactions with the plant's ability to absorb and translocate contaminants.

#### Ethical Statement

The authors confirm that all experiments were carried out following the approval of the appropriate ethical review committee of the Central Research Laboratory, University of Ibadan, Nigeria (reference number not applicable) and were following both the national and international safety regulations and ethical principles for animal welfare. The authors also confirm that they have followed EU standards for scientific purposes.

#### Conflict of Interests

The authors declare that they have no financial or non-financial competing interests that are directly or indirectly related to this work.

#### Data availability statements

All data generated or analysed during this study are included in this published article

#### Authors' Contributions

All of the authors worked together to complete this project. POO, AEE and TOO1 conceptualized, designed and participated in the work. The protocol was written by POO, AOA, AEE, and TOO2. The statistical analysis was carried out by AOA and POO. The study's analyses and literature searches were handled by POO, AOA and BAB. The original draft of the manuscript was written by AOA. The final manuscript was read, corrected and approved by all the authors.

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