



**ORGANOMINERAL FERTILIZER (OMF) AS SUPPLEMENT FOR
MAIZE (*Zea mays*) ACTUATED PHYTOREMEDIATION**

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ABSTRACT

The effectiveness of organo-mineral fertilizer (OMF) in enhancing maize (*Zea mays*) activated phytoremediation of cadmium (Cd) contaminated soil was investigated around Askar Paints Factory, Eleyele, Ibadan. The experimental site was divided into six plots where maize was cultivated with and without OMF application for 110 days. Pre- and post-harvest soil samples and maize plant tissues were analyzed for Cd levels using Atomic Absorption Spectrophotometry (AAS). Initial cadmium concentrations in the topsoil and subsoil were 31.48 ± 7.82 mg/kg and 31.35 ± 3.72 mg/kg, respectively in OMF-treated plots, compared to 26.96 ± 7.81 mg/kg and 33.50 ± 3.72 mg/kg in the control plots. Post-harvest, Cd levels in the OMF-treated topsoil decreased by 39.17% (to 19.15 ± 9.14 mg/kg) and in the subsoil by 15.18% (to 26.59 ± 3.28 mg/kg). In contrast, control plots showed reductions of 27% and 16.24% in topsoil and subsoil, respectively. These results indicated that OMF significantly improves maize's ability to remove Cd, particularly from the topsoil. The trend of Cd accumulation in the Control and OMF treated maize was Root > Shoot > Leaf > Seed. Analysis of maize plant parts revealed that, OMF treatment increased Cd concentrations in roots (6.30 ± 1.24 mg/kg vs. 4.70 ± 1.73 mg/kg), shoots (4.72 ± 1.53 mg/kg vs. 3.50 ± 1.39 mg/kg), and leaves (2.88 ± 1.96 mg/kg vs. 1.92 ± 1.52 mg/kg), compared to control plants. However, Cd concentrations in seeds were lower in OMF-treated plants (0.61 ± 0.56 mg/kg) compared to control (0.82 ± 0.60 mg/kg). OMF application also positively affected the fresh and dry weights of maize plant parts, with significant increases in root, shoot, leaf, and seed weights in treated plots. This study demonstrated that OMF enhances the phytoremediation efficiency of maize by increasing Cd uptake and translocation to vegetative parts, while potentially reducing Cd accumulation in seeds. Thus, OMF presents a promising approach for improving the phytoremediation of contaminated soils.

Keywords: Maize, Soil, Phytoremediation, Cadmium, Organo-mineral, Fertilizer.

INTRODUCTION

When heavy metals accumulate in soil over a period of time, it can result in health risks as some could find their ways into ground water while others get absorbed into food crops and ultimately linked into the food consumption matrix (Khan and Ghouri, 2011). Toxic heavy metal contamination is a severe threat to human health and the environment, prompting commitments to remediation approaches. For example, pollution from industrial effluents and automobiles are at alarming proportions (Campanale *et al.*, 2020) while untreated or improperly treated wastes pollute rivers, reservoirs, soil and dependent substrates causing ill health and loss of crop productivity (Khan and Ghouri, 2011). When sewage and wastes are deposited in the environment, heavy metal toxicity is to be expected. Although these metals could be considered as natural constituents of the earth's crust, ever increasing anthropogenic activities have introduced higher quantities of these metals to the surrounding air, water,



soil and tissues of living organisms (Suman *et al.* 2018; Akhtar *et al.*, 2021). ‘Heavy metal’ is generically used to describe a range of elements in the class of pollutants (Briffa *et al.*, 2020). They are notably stable, high density metals including Cadmium (Cd), lead (Pb), Zinc (Zn) and Mercury (Hg). They are often non-degraded by biological or physical means and remain in the soil for extended period of time, thus posing a long-term environmental concern (Suman *et al.*, 2018). Majority of the heavy metals and their compounds are toxicants (Akhtar *et al.*, 2021). According to Popoola *et al.*, (2018), heavy metals enter the environment through three primary channels: (i) atmospheric particulate matter deposition, (ii) disposal of metal-enriched sewage sludge and sewage effluents, and (iii) byproducts of metal-mining operations.

Toxic metal pollution of water and soil is environmentally harmful, and known remediation approaches, including physical and chemical remediation, do not provide acceptable solutions. Consequently, improved technology to clean up the environment, which should be simple to use, cost effective, and practicable is required. In other words, prevention of heavy metal pollution is inescapable because clearing of already contaminated soils is expensive and difficult. Recent environmental concerns have led to the development of technologies to determine the presence and mobility of metals in soil, water, and wastewater (Yan *et al.*, 2020). Phyto-remediation happens to be a set of ecological strategies that uses metal-accumulating plants to promote the breakdown and removal of pollutants from the environment (Murphy and Coats, 2011; Shrestha *et al.*, 2019; Nedjimi 2021). Such plants with exceptional metal-accumulating capacities are said to be hyper-accumulators (Balafrej *et al.*, 2020) and the choice of a phytoremediation material is based on its hyper -accumulating ability (Yan *et al.*, 2020). Maize has the tendency to accumulate heavy metals through the fibrous root system, which predominantly occupy the topsoil. As an annual crop, it is susceptible for use to remove heavy metals on the topsoil for about three consecutive planting seasons per year. Its propensity to mature quickly is a plus to its phytoremediation efficacy. The maize plant is of particular interest because it is a vast primary source of food. It also is an industrial raw material and the possibility exists that it could serve as a remediation agent on polluted lands. Adding organic and/or inorganic amendments to mine wasters has long been a popular strategy for creating a favorable environment for plant development (Acosta *et al.*, 2018; Al-lami *et al.*, 2019; Saleem *et al.*, 2020) These additions limit metal availability while also dispensing nutrients for plant growth and improving soil microbial activity (Lwin *et al.*, 2018). The organic component of the organo-mineral fertilizer improves the physical, biological, and chemical qualities of the soil while also giving plant nutrients and ensuring its long-term use. Organo -mineral fertilizers are made up of organic and mineral fractions and come in a variety of N, P, and K ratios that are optimal for crop productivity (Shrestha *et al.*, 2019). The final product might be granulated, pelleted, or powdered, and is usually derived from regional organic sources. However, in highly contaminated areas, large volumes of organic matter may be required to aid plant development, raising remediation costs significantly (Singh *et. al.*, 2018). Hence this study evaluated the effect of organo-mineral fertilizer on maize plant activated phytoremediation. The study also assessed the distribution of cadmium in various parts of maize plants (*viz.* roots, stem, leaves and seeds) grown on contaminated soil.

MATERIALS AND METHODS

Study Area

The study area was Askar Paints Factory premises located at Eleyele in Ibadan Metropolis (Figure 1). The company is a major manufacturer of paint products for over four decades. It is located on latitude 7° 24' 47.99" and longitude 3° 51' 46.75". Askar Paints produces decorative paints texcote, industrial paints and wood finishing. A section of the premises was chosen as the experimental field. Record has it that effluents from the factory were discharged onto the experimental site in the premises and thus are contaminated *in situ*.

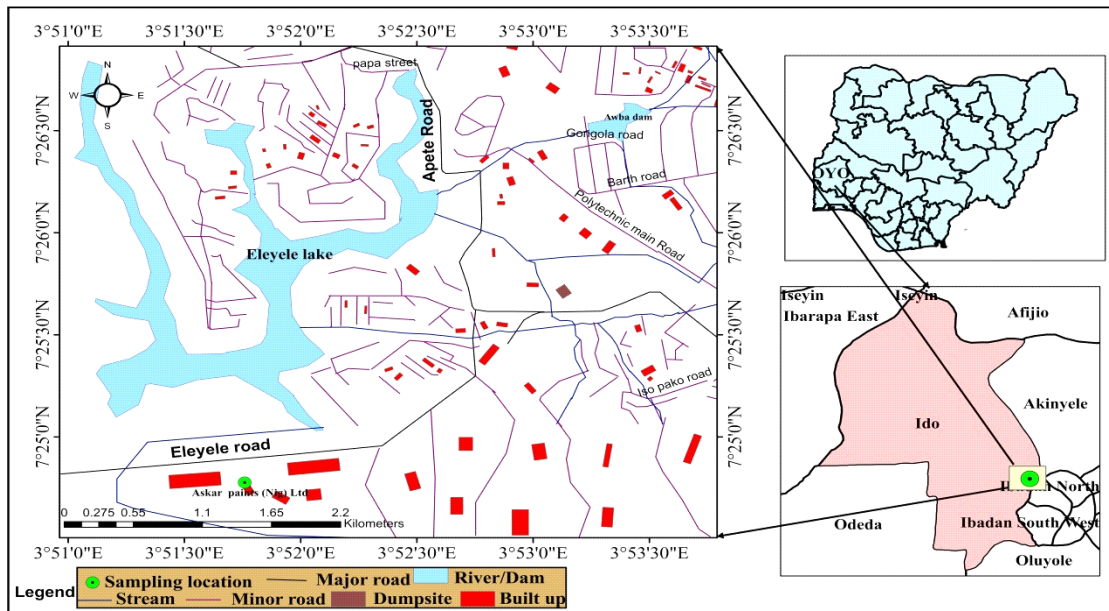


Figure 1: Askar Paints premises, Eleyele, Ibadan

Sourcing for Maize Seeds

Viable maize seeds (*Zea mays*) designated as original test materials were obtained from the Institute of Agricultural Research and Training (IAR & T), Ibadan.

Plots Preparation:

The study site was 7.5 x 2.5 m in dimension from which six plots (A – F) measuring 2 x 2m each were carved out for the experiments. About 0.5 m distance was provided as space between each blocks and boundary. Organo-mineral fertilizer (OMF) was added to three plots, while the remaining three plots did not receive OMF.

Soil Sampling and Preparation before Planting

Soil samples were collected before planting the maize to determine background levels of cadmium *in-situ*. The soil samples were collected from the topsoil (0 - 15cm) and subsoil (15 - 30cm) with the use of soil auger. Portions of soil samples from the same site were collected twice, and thoroughly mixed together to form a composite sample. Thus, a total of four composite samples of topsoil and subsoil were obtained and, from these, base levels of cadmium were determined with the use of Atomic Absorption Spectrophotometer (AAS). (Akran *et al.* 2015).

Planting

The experimental field comprised of six plots used to cultivate maize. Maize seeds were planted manually at a spacing of 0.5m x 0.7m. Four seeds of maize per hole and depth of 3.4cm were adopted. Thinning was carried out after 12 days of planting.

Application of Organo-mineral Fertilizer (OMF)

Organo-mineral fertilizer was applied two weeks before planting for it to start decomposing and release nutrients to the soil. A quantity of 10 tons of OMF per hectare using conventional ring method (Adewole, 2005) was applied.

Digestion of Soil and Plant Samples for Determination of Cd

The maize plants were harvested after 110 days of planting. The fresh and dry weights of the maize were recorded after 48 hours of oven drying at 70°C. Samples from the same plot were bulked together according to their parts viz: - roots, shoots, leaves and seeds. Samples from each plot were blended thoroughly and subjected to wet digestion method (Hansen *et al* 2009). The filtrates obtained were analyzed for the presence of Cd in the plant tissues using Atomic Absorption Spectrophotometer (AAS).



Post-Harvest Soil Samples for Cd Determination

Soil samples at depths of 0-15cm and 15-30cm were collected after harvest from areas where the representative plants samples were collected. Soils obtained from the same distance and from the same plot were bulked together to represent the plot. The samples were air-dried, grounded in mortar and sieved with 0.5 mm sieve. Wet digestion method was employed and digests of the soil samples were analyzed for lead and cadmium using Atomic Absorption Spectrophotometer (AAS) according to Ogunlela *et al.*, (2018).

Statistical Analyses

The mean values of cadmium removed from the soil by maize and their percentage distribution in the component parts in the test and control plots were determined; using One-way analysis of variance (ANOVA) on SPSS IBM 20.0.

RESULTS

The study evaluated the effectiveness of organo-mineral fertilizer (OMF) in enhancing maize plant activated phytoremediation by measuring cadmium (Cd) levels in soil before and after remediation. The results as presented in Table 1 revealed that, the initial concentration of cadmium in the OMF treated top soil was 31.48 ± 7.82 mg/kg, which decreased to 19.15 ± 9.14 mg/kg post-harvest, reflecting a 39.17% reduction. Similarly, the initial concentration of Cd in the control topsoil was 26.96 ± 7.81 mg/kg, reducing to 19.68 ± 7.70 mg/kg post-harvest, which was a 27% reduction. The initial cadmium concentration in the OMF treated subsoil was 31.35 ± 3.72 mg/kg, and it decreased to 26.59 ± 3.28 mg/kg after remediation, indicating a 15.18% reduction while the initial concentration of Cd in the control subsoil was 33.50 ± 3.72 mg/kg, decreasing to 28.06 ± 2.20 mg/kg post-harvest, resulting in a 16.24% reduction (Table 1).

Specifically, in topsoil, OMF-treated plots removed 39.17% of Cd, compared to 27% in control plots. In subsoil, OMF treatment led to a 15.18% Cd removal, whereas control plots achieved 16.24%. This indicates that OMF significantly enhances the ability of maize to remediate contaminated soil, particularly in the topsoil layer. Summarily, OMF significantly improves the phytoremediation efficiency of maize by increasing the uptake and removal of Cd from the soil, particularly in the topsoil.

Table 1: Percentage of Cd Removed through Phytoremediation

Treatment and Sample Cultivated plots	Soil type	Mean Cadmium levels and standard deviation		% Removed
		Initial Concentration in mg/kg (Before Remediation)	Post-Harvest Concentration in mg/kg (After Remediation)	
OMF treated	Top	31.48 ± 7.82	19.15 ± 9.14	39.17
Control	Top	26.96 ± 7.81	19.68 ± 7.70	27.00
OMF treated	Sub	31.35 ± 3.72	26.59 ± 3.28	15.18
Control	Sub	33.50 ± 3.72	28.06 ± 2.20	16.24

The distribution of cadmium (Cd) in different parts of maize plants—roots, shoots, leaves, and seeds with organo-mineral fertilizer (OMF) treatment and in the control group is presented in Figure 2. The figure also revealed that the trend of Cd accumulation in the Control and OMF treated maize was Root > Shoot > Leave > Seed. The highest concentration of Cd was observed in the roots of OMF-treated maize plants (6.30 ± 1.24 mg/kg). This indicates that the application of organo-mineral fertilizer enhances Cd uptake into the root system. The control plants had a lower root Cd concentration (4.70 ± 1.73 mg/kg), suggesting that without OMF, Cd uptake by roots is less efficient. Cd concentration in the shoots of OMF-treated plants was 4.72 ± 1.53 mg/kg. This is higher compared to the control, reflecting increased translocation of Cd from roots to shoots facilitated by the OMF treatment. The control plants had a lower shoot Cd concentration (3.50 ± 1.39 mg/kg), indicating less effective metal transport from roots to shoots.

The figure also revealed that the leaves of OMF-treated plants had a Cd concentration of 2.88 ± 1.96 mg/kg. This was higher than the control, suggesting that OMF treatment enhances Cd accumulation in the leaves as well. Control plants had lower leaf Cd levels (1.92 ± 1.52 mg/kg), consistent with reduced uptake and translocation of Cd to the leaves. The Cd concentration in seeds of OMF-treated plants was 0.61 ± 0.56 mg/kg, which is lower compared to the control (Figure 2). The control plants had a higher Cd concentration in seeds (0.82 ± 0.60 mg/kg). This indicates that although OMF treatment increases Cd accumulation in the vegetative parts of the plant, it may reduce Cd accumulation in the seeds.

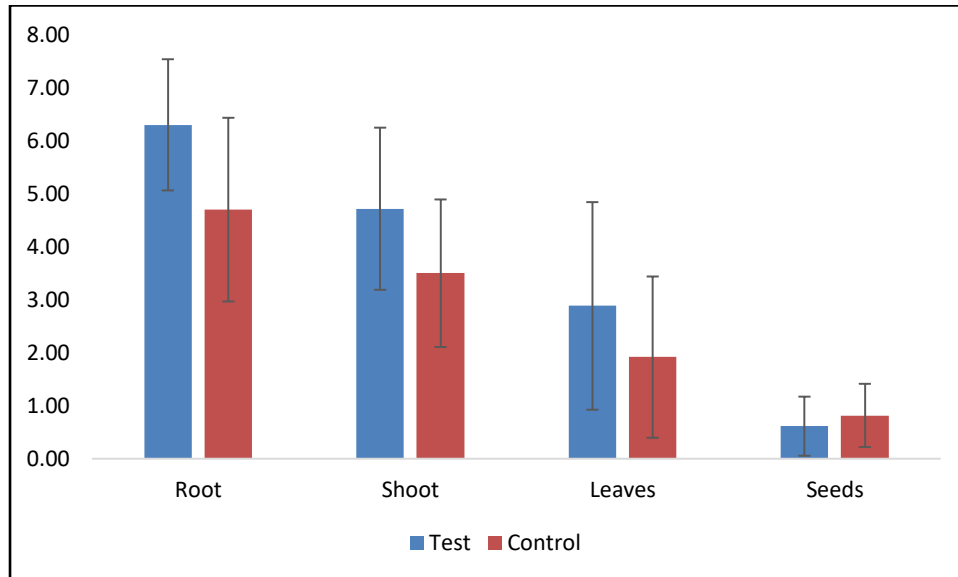


Figure 2: Distribution of Cd in Maize Plants

The application of organo-mineral fertilizer (OMF) resulted in higher Cd concentrations in the roots, shoots, and leaves compared to control plants, indicating that OMF enhances the uptake and translocation of Cd within the plant. In contrast to the increased metal concentrations observed in vegetative parts (roots, shoots, and leaves), the seeds of OMF-treated plants contained lower Cd levels compared to the control. This suggests that while OMF treatment improves Cd accumulation in non-reproductive plant parts, it may limit Cd transfer to the seeds.

The impact of organo-mineral fertilizer (OMF) on the fresh and dry weights of maize (*Zea mays*) after 110 days of planting is presented in Table 2 which revealed that the fresh weight of roots was significantly higher in the OMF-treated maize (44.81 ± 17.96 g) compared to the control (31.44 ± 12.39 g). The dry weight of roots was also slightly higher in OMF-treated plants (22.62 ± 13.72 g) than in control plants (21.02 ± 13.24 g). The table also revealed that OMF-treated maize showed a notable increase in fresh weight of shoots (156.20 ± 77.39 g) compared to the control (118.49 ± 55.81 g). The dry weight of shoots was significantly greater in OMF-treated plants (42.56 ± 21.42 g) compared to control plants (35.33 ± 20.71 g). The fresh weight of leaves in OMF-treated maize (194.34 ± 101.61 g) was substantially higher than that in the control (111.72 ± 46.90 g). The dry weight of leaves was markedly increased in OMF-treated plants (109.34 ± 68.51 g) compared to the control (53.85 ± 21.21 g). OMF treatment led to a higher fresh weight of seeds (131.53 ± 84.37 g) compared to the control (68.51 ± 36.15 g). Similarly, the dry weight of seeds was greater in OMF-treated plants (38.60 ± 33.73 g) than in control plants (22.49 ± 8.85 g). Overall, the application of OMF resulted in significant increases in both fresh and dry weights across all maize plant parts, indicating enhanced growth and development of maize under OMF treatment (Table 2).

Table 2: Fresh and Dry Weight of Maize Plant (after planting for 110 Days)

Part	Fresh weight (Control)	Fresh weight (OMF -treated)	Dry weight (Control)	Dry weight (OMF -treated)
Root	31.44±12.39 ^a	44.81±17.96 ^a	21.02±13.24 ^a	22.62±13.72 ^a
Shoot	118.49±55.81 ^{ab}	156.20±77.39 ^b	35.33±20.71 ^a	42.56±21.42 ^a
Leaves	111.72±46.90 ^{ab}	194.34±101.61 ^b	53.85±21.21 ^a	109.34±68.51 ^{ab}
Seeds	68.51±36.15 ^{ab}	131.53±84.37 ^b	22.49±8.85 ^a	38.60±33.73 ^{ab}

DISCUSSION

The high concentration of the cadmium in the subsoil than in top soil can be attributed to the leaching capability of the topsoil. This may be due to high porosity of the top soil. Heavy metals such as Cd and Cr are more kept in smaller amount in topsoil and are leached towards the subsoil (Yan *et al.* 2020). This study demonstrates that the use of organo-mineral fertilizer (OMF) significantly impacts cadmium removal from contaminated soils, particularly in topsoil. The higher percentage of cadmium removal in the topsoil (39.17%) compared to the control (27%) suggests that OMF enhances the phytoremediation capacity of maize plants in these conditions. In the subsoil, the effectiveness of OMF is less pronounced but still notable. The reduction in cadmium levels with OMF (15.18%) was slightly less compared to the control (16.24%), indicating that while OMF has some beneficial effect in deeper soil layers, it is more effective in topsoil. This could be due to better nutrient availability and plant growth promotion in the topsoil where OMF is more effective (Chen *et al.*, 2017).

The higher reduction of cadmium in the topsoil where OMF is applied may be attributed to improved maize growth and increased biomass production due to the nutrient enhancements provided by OMF. Enhanced maize growth likely leads to greater uptake of cadmium from the soil, thereby improving the phytoremediation process (Zhang *et al.*, 2019). The results of this study on the effect of organo-mineral fertilizer (OMF) on maize plant activated phytoremediation provide valuable insights that align with and extend findings from previous research. The findings of this study confirm that OMF treatment in topsoil resulted in a higher percentage of cadmium removal compared to the control, consistent with the improved remediation efficiencies reported by Chen *et al.* (2017) and Zhang *et al.* (2019). The enhanced reduction in cadmium levels with OMF treatment supports the notion that the fertilizer's nutritional benefits boost maize's ability to uptake and accumulate heavy metals.

Kumar *et al.* (2015) noted that while nutrient amendments can improve plant growth in topsoil, their effectiveness in deeper soil layers can be limited due to lower root penetration and reduced nutrient availability. Singh *et al.* (2018) also observed that while topsoil responded well to nutrient amendments, subsoil remediation was less effective. This study reflects similar trends, with OMF showing a more significant impact on cadmium reduction in topsoil compared to subsoil. This supports the hypothesis that while OMF improves remediation in topsoil where plant roots are more active, its effects are diminished in deeper soil layers where nutrient and root activity may be less effective (Singh *et al.*, 2018). Gonzalez *et al.* (2020) observed that control treatments, which do not receive additional nutrients or amendments, typically exhibit lower efficiencies in removing contaminants compared to amended treatments. This is due to the lack of enhanced plant growth and metal uptake. The reduction in cadmium levels in control plots (27% in topsoil and 16.24% in subsoil) aligns with these findings, highlighting the limitation of relying solely on natural soil processes without any amendments. The increased efficiency observed with OMF treatment accentuates the value of integrating nutrient amendments to enhance phytoremediation outcomes.

The results from the fresh and dry weights of maize after harvest showed that the various weights from the various parts of maize plants (root, shoot, leaves and seeds) were higher in the OMF treated than the control experimental plot. Similarly, the dry weights of the different parts of maize plant in the test experiment were higher than in the control. The increase in weight of the different parts of the maize plant for the fresh and dry parts could be as a result of the organo- mineral fertilizer that was used in the test plots. The organo-mineral fertilizer enhanced the uptake of nutrient and growth, which resulted in the increase of the yield. Ayeni *et al.* (2017) also obtained similar result in their study. The application of OMF resulted in the high number of leaves and grain yield.



Ming *et al.* (2021) discovered that OMF application led to increased maize biomass and root development, which are critical for effective phytoremediation. The improved plant growth can enhance the uptake and translocation of heavy metals from the soil to the plant tissues. Ojo *et al.* (2017) found that organo-mineral fertilizers significantly improved soil fertility and increased the capacity of maize to uptake heavy metals, including cadmium, from contaminated soils. Similarly, Ogunlela *et al.* (2018) reported that the application of organo-mineral fertilizers led to a notable reduction in cadmium levels in soil and increased maize biomass, which aligns with our findings.

Ojo *et al.* (2017) found that control plots with no added fertilizers exhibited lower levels of heavy metal removal compared to plots with nutrient amendments, confirming the necessity of enhancing soil conditions for effective remediation. This study's control plots, which showed a lower reduction in cadmium levels (27% in topsoil and 16.24% in subsoil), align with these findings. The increased efficiency observed with OMF-treated plots highlights the importance of using soil amendments to improve phytoremediation outcomes. Ogunbayo *et al.* (2021) reported that OMF application significantly enhanced maize growth and increased the uptake of heavy metals, including cadmium, from contaminated soils. This is supported by Adeoye *et al.* (2020), who observed improved plant biomass and heavy metal accumulation in maize with the use of organo-mineral fertilizers. The results of this study, showing improved maize growth and cadmium removal with OMF treatment, corroborate these findings. The enhanced growth and increased biomass observed with OMF application likely contribute to the higher cadmium removal efficiencies reported in our study.

The OMF-treated maize plants accumulated a higher concentration of Cd in their roots (6.30 mg/kg) compared to the control (4.70 mg/kg). This indicates that OMF treatment enhances the plant's ability to uptake and retain Cd in the root system. This finding aligns with Adebisi *et al.* (2019) that reported increased heavy metal uptake in roots due to improved plant growth and nutrient availability with organo-mineral fertilizers. The Cd concentration in the shoots of OMF-treated plants (4.72 mg/kg) was also higher than that in control plants (3.50 mg/kg). This suggests that OMF treatment not only increases the uptake of Cd into the roots but also facilitates its translocation to the shoots, enhancing overall metal accumulation in the plant. The Cd levels in the leaves of OMF-treated plants (2.88 mg/kg) were higher than in control plants (1.92 mg/kg). This can be attributed to the increased metal uptake and translocation resulting from OMF application. Enhanced leaf Cd concentration supports the findings of Ogunbayo *et al.* (2021), who observed increased metal accumulation in plant tissues with improved nutrient conditions.

Interestingly, the Cd concentration in seeds from OMF-treated maize (0.61 mg/kg) was lower compared to the control (0.82 mg/kg). This might indicate a selective mechanism where Cd is less translocated to the seeds or that OMF treatment influences the distribution of Cd differently, potentially reducing Cd accumulation in reproductive parts (Ogunlela *et al.*, 2018). The observed higher Cd concentrations in the roots, shoots, and leaves with OMF treatment but lower concentrations in seeds compared to the control suggest that while OMF enhances overall metal uptake and translocation, it might also influence the distribution of metals within different plant parts (Ogunbayo *et al.*, 2021). OMF enhances the effectiveness of maize in remediating Cd-contaminated soils by increasing Cd uptake and accumulation in non-reproductive plant parts while potentially reducing Cd levels in seeds. This dual effect suggests that OMF not only aids in soil decontamination but also helps in managing the risk of Cd contamination in edible parts of the plant. This pattern indicates that OMF enhances the efficiency of Cd uptake and accumulation in the roots, shoots, and leaves but may have a mitigating effect on Cd accumulation in seeds, potentially reducing the risk of Cd transfer through the food chain.

CONCLUSION AND RECOMMENDATION

The study confirmed the ability of maize to accumulate cadmium into their tissues. When maize is planted using organo-mineral fertilizer, the rate of uptake was remarkably enhanced with higher concentration of cadmium recorded in maize roots, followed by shoots, leaves and then seeds. The application of organo-mineral fertilizer (OMF) enhances the efficiency of maize plant activated phytoremediation, particularly in topsoil. The results indicate that OMF-treated plots achieved a greater reduction in cadmium levels compared to control plots. However, the effect of OMF on cadmium



removal in subsoil is less pronounced, though still beneficial. The application of organo-mineral fertilizer (OMF) significantly affects the distribution of cadmium in maize plants. OMF treatment increased Cd concentrations in the roots, shoots, and leaves compared to the control, indicating improved metal uptake and translocation. However, OMF treatment resulted in a lower Cd concentration in the seeds compared to the control. This suggests that while OMF enhances Cd accumulation in the vegetative parts of the maize plant, it may reduce Cd accumulation in seeds, potentially affecting the overall risk of Cd transfer through the food chain. Evidently, OMF improved the phytoremediation potential and general growth of the maize plant and it is of value when industrial pollutants like cadmium are to be removed from contaminated soils. The findings of this study emphasize the potential of organo-mineral fertilizers as a valuable tool in phytoremediation strategies, especially for topsoil. Further research is needed to optimize application methods and explore the benefits of combined remediation techniques for deeper soil layers.

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