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# Research Article
# Phytoremediation Potential of *Zea mays* L. and *Panicum coloratum* L. on Hydrocarbon Polluted Soils

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## Abstract
**Background and Objective:** Contamination of soils by heavy metals poses a big risk to humans and the ecosystem through direct ingestion or contact with contaminated soil and some plants can absorb, accumulate and immobilize environmental contaminants in a growth matrix. The ability of *Zea may* and *Panicum coloratum* to take up heavy metals from a hydrocarbon polluted soil was investigated. **Materials and Methods:** A Hydrocarbon polluted soil Sample was treated with OMF (Organo-mineral Fertilizer) for 10 weeks. *Zea may* and *Panicum coloratum* were planted on the soil and left to grow for another 10 weeks. The plants were then harvested and analyzed for selected heavy metals. **Results:** Results showed that spent engine oil caused a reduction in soil nutrients and increased heavy metals concentrations in the soil. The use of Organo-mineral Fertilizer amendment and planting of *Zea may* and *Panicum coloratum* for 10 weeks improved the soil nutrients with the plants accumulating between 7.86-93.32% heavy metals from the soil. **Conclusion:** This study demonstrated that *Zea may* and *Panicum coloratum* were able to grow in a hydrocarbon polluted soil, with nutrients support from the OMF used and were able to absorb heavy metals from the soil.

Key words: Phytoremediation, heavy metals, *Zea may*, *Panicum coloratum*, hydrocarbon, degradation, soil, treatment, pollution, organo-mineral

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

## INTRODUCTION

The soil essentially provides a suitable environment for plants to grow to their potential[1]. The nature of the soil is a critical factor in the plant's ability to extract water and nutrients. Pollution caused by crude oil and oil-related activities is among the most prevalent environmental problems in Nigeria. Over the years, various attempts have been made to solve the problem of soil contamination with hydrocarbons and heavy metals. Different measures have been tried involving physical and chemical remediation methods, mechanical soil removal and burial. Most of which are expensive and labor-intensive, impracticable on the large scale that is needed and environmentally destructive[2]. The quest to explore alternative means of addressing this problem led to the development of phytoremediation. The phytoremediation approach is considered cost-effective, environmentally friendly, long-term applicability and utilizes natural processes[3,4].

Abioye *et al.*[5] defined phytoremediation as the efficient use of green plants to remove, detoxify or immobilize environmental contaminants in a growth matrix (soil, water or sediments) through the natural biological, chemical and physical activities and processes of plants. Phytoremediation techniques are anchored on the fact that a living plant can be compared to a solar-driven pump, which can extract and concentrate particulate from the environment[6].

Phytoremediation is based on the natural abilities of plants to absorb, accumulate and possibly degrade constituents of soil and water environments. Vascular green plants have the marvelous ability of self-engineering or exerting limited control over the rhizosphere, local biogeochemistry, availability of water, nutrients and the local microclimate[7].

Contamination of soils by heavy metals has the potential of posing a big risk to human beings and the ecosystem through direct ingestion or contact with contaminated soil. This might find its way into the food chain through drinking contaminated groundwater, absorbed by plants which are eaten by animals and eventual reduction in food quality[8]. This could occur through the plants exhibiting some form of toxicity, a reduction in the agricultural value and productivity of the land, hence causing food security and land tenure problems. The World Health Organization (WHO) Target values specified to indicate desirable maximum levels of elements in unpolluted soil as shown in Table 1[9].

Plants and microbes utilize their natural capacity to degrade and detoxify hydrocarbons and heavy metals into less toxic substances and contain them in their tissues in the case of plants. Uhegbu *et al.*[10] reported that "given the difficulty of cleaning and restoring oil-polluted sites using conventional techniques, the need to explore a more cost-effective, adaptable and environmentally friendly approach has become very critical".

Table 1: Permissible levels of heavy metals in soil

| Elements | Target values in soil (mg kg$^{-1}$) | Permissible values in plants (mg kg$^{-1}$) |
|---|---|---|
| Cadmium (Cd) | 0.8 | 0.02 |
| Copper (Cu) | 36 | 10 |
| Lead (Pb) | 85 | 2 |
| Nickel (Ni) | 35 | 10 |

Source: WHO[9]

For a plant to qualify to be used for phytoremediation, it is expected to have the capacity to tolerate heavy metals, grow fast with a high biomass yield per hectare. Such plants should have the ability to accumulate heavy metals in their shoot system[11], develop a profuse root system and a positive bioaccumulation factor[12], grow easily on soils contaminated by metals, have high soil- shoot transfer factors, accommodate high shoot metal concentrations and produce high biomass quickly[13]. The success of phytoremediation technology in soils contaminated with heavy metals depends on the frequency at which plants extract or transform the contaminants into less toxic forms.

Phytoremediation can be used in both organic and inorganic pollutants present in the solid, liquid and gaseous substrates[14,15]. It can also be used to clean up metals, pesticides, solvents, explosives, crude oil and contaminants that may leak from landfills site. The following metals are easily bio-available for plant uptake: cadmium, nickel, zinc, arsenic, selenium and copper. Moderately bio-available metals are cobalt, manganese, iron, lead, chromium and uranium are not bio-available. Lead can be made much more bio-available by the addition of chelating agents to soils.

Heavy metals are components of the earth's crust and occur naturally in the ecosystem, with varying concentrations. Their presence affects all components of the ecosystem and ranges from physical and chemical contamination of soil, air, water to deleterious impacts on flora and fauna. Soil microbial populations are negatively affected by increased heavy metal concentration which also harms soil fertility[16].

Heavy metals in the soil at high concentrations have a direct and indirect effect on plant growth and development. One of the approaches to cleaning-up of heavy metal contaminated soil is through bioremediation, which is carried out *in situ* using microorganisms[2]. Microorganisms and plants employ different mechanisms for bioremediation of heavy metal polluted soils. A combination of microorganisms and plants ensures a more efficient clean-up of heavy metal polluted soils[17].

Organo-mineral fertilizer [Slurry from battery cage poultry farm plus ash from burnt palm fruit bunch and NPK (nitrogen, phosphorus and potassium) fertilizer] were used as a treatment for the polluted soil.

Though inorganic constituents can be used in phytoremediation activities, using organic constituents is ecologically friendly, enhances ecosystem nutrient cycles which are of great benefit to the environment. This is also beneficial to agriculture as it facilitates nutrients availability and uptake by plants.

This study investigates the potential of *Zea mays* L. and *Panicum coloratum* in the uptake of heavy metals from spent engine oil (hydrocarbons) polluted soils treated with organo-mineral fertilizers.

## MATERIALS AND METHODS

**Study location:** The experimental plot for this study was located in the farm area of the University of Calabar, Botanic Gardens, Calabar, Nigeria. This research project was conducted from March, 2014-September, 2015.

**Experimental laboratory:** The Physicochemical analysis of soil samples was carried out in the Soil Science Laboratory, Faculty of Agriculture, University of Calabar, Nigeria while analysis of heavy metals was undertaken at the BGI Resources Laboratory, Port Harcourt, Rivers State.

**Soil sampling:** Topsoil (0-20 cm depth) was collected from each of the four plots arranged in a complete randomized design using a spade. The collected soil was weighed in 20 kg parts and transferred into nylon bags after proper mixing. It was labeled accordingly.

**Soil pollution:** The soil sample was polluted to a 10% pollution level by adding 2 L of spent engine oil:

$$\text{Soil pollution (\%)} = \frac{\text{Quantity of spent engine oil}}{\text{Quantityof soil}} \times \frac{100}{1}$$

$$\text{10\% soil pollution} = \frac{2\text{ L}}{20\text{ kg}} \times \frac{100}{1}$$

**Treatment application:** To the Polluted soil, 200 g of Organo-mineral fertilizer was added to the soil as treatment, 2 weeks after pollution. The soil was allowed for eight more weeks before planting was done.

**Planting:** Planting boxes of Length 50 cm, Width 20 cm and Depth 20 cm containing 20 kg of the polluted of the treated soil sample were prepared to which maize seeds and cuttings of *Panicum coloratum* were planted into the various plots to a sowing depth of 12 mm.

### Analytical methodologies

**Physicochemical properties:** The physicochemical qualities of the soil samples were determined using the methods of the Association of Official Analytical Chemists (AOAC)[18]. The parameters determined were: pH, organic carbon, nitrogen, phosphorus, potassium, calcium, magnesium, hydrogen, aluminium, Effective Cation Exchange Capacity (ECEC) and base saturation.

**Determination of heavy metals in soil:** According to the American Public Health Association (APHA) 3111B[19]. Procedure: 10 g of the dried solid sample was weighed and transferred into an acid-washed 250 mL extraction bottle. About 100 mL of extraction reagent (reagent-grade disodium ethylenediaminetetraacetate-Na2 EDTA 0.1 M) was poured into the flask, sealed and was shaken for 30-45 min in an automatic Stuart SSL1 Orbital Shaker (Cole-Parmer, Staffordshire, ST15 OSA, UK). The suspension was filtered through a Whatman Grade 1 Qualitative Filter Paper (Cytiva, Marlborough, MA USA). The extracted solutions and blank were then run using Agilent 240 AA Atomic Absorption Spectrophotometer (Agilent, Santa Clara, Ca, USA).

**Calculation:**

$$\text{Concentration of element}\times(\text{mg L}^{-1}) = \text{A-B}$$

Where:

A = Concentration of element × (mg $L^{-1}$)
B = Concentration of blank (mg $L^{-1}$)

**Statistical analysis:** The collected data were subjected to a two-way analysis of variance (ANOVA) using a 2-factor (2×4) factorial in a Completely Randomized Design (CRD). Significant means were separated using Duncan Multiple Range Test (DMRT).

## RESULTS

The data of Table 2 shows the nutrient properties of the treatment used in this study. Organo-mineral Fertilizer (OMF) has significant concentrations of plant nutrients. Total Nitrogen, Phosphorus and Potassium concentrations are 47.30, 19.0 and 37.50 mg $kg^{-1}$. These appreciable concentrations could be related to its constituent, Slurry from a poultry farm and palm fruit bunch ash.

The physicochemical properties of the soil throughout the study period are revealed in Table 3. It gives the changes observed in the soil properties from when the soil was polluted, treatment and after planting. The Total Nitrogen and Phosphorus after pollution reduced from 0.18% and 8.7 mg $kg^{-1}$ to 0.08% and 6.75 mg $kg^{-1}$, respectively. The addition of the Organo-mineral fertilizer caused an increase in the soil Nitrogen and phosphorus concentration to 0.24% and 21.83 mg $kg^{-1}$, respectively. Further increase in the Nitrogen and phosphorus concentrations to 0.31% and 24.75 mg $kg^{-1}$, respectively were observed in the soil after planting. There was also an increase in the five selected heavy metals concentrations in the soil after pollution and a significant decrease after soil treatment and planting.

The data of Table 4 and 5 shows the physicochemical properties of the grown maize plant and *panicum coloratum*, respectively. Maize crop planted for 10 weeks in the pristine soil, the polluted control soil and the treated soil were uprooted, dried, ground and analyzed for their physicochemical properties. The crops planted in the treated soil was seen to have higher nutrients and accumulated more heavy metals compared to those planted in the pristine and controlled soil samples. The concentration of total Nitrogen, Phosphorus, potassium and calcium in the maize plant were 1.333%, 0.283, 0.597and 0.797 mg $kg^{-1}$ while in the *Panicum coloratum* they were 1.293%, 0.247, 0.567 and 1.133 mg $kg^{-1}$, respectively. The magnesium in the *P. coloratum* (0.617 mg $kg^{-1}$) was higher than that in *Zea mays* (0.397 mg $kg^{-1}$). The tables also showed that *Zea may* have higher concentrations of Zinc (Zn), Nickel (Ni), Cadmium (Cd) and Lead (Pb) while *Panicum coloratum* accumulated more concentrations of copper (Cu).

The percentage accumulation in both study plants was calculated and Table 6 revealed that *Zea mays* accumulated the target heavy metals in the order of Zn (93.32%), Ni (73.75%), Cu (37.32%), Cd (20.27%) and Pb (8.72%) whereas,

Table 2: Chemical properties of organo-mineral fertilizer used as amendments in this study

| Parameters | Organo-mineral fertilizer (mg $kg^{-1}$) |
|---|---|
| pH | 7.9±0.02 |
| Nitrogen | 47.30±0.03 |
| Phosphorus | 19.0±0.0 |
| potassium | 37.50±0.20 |
| Calcium | 9.00±0.00 |
| Magnesium | 57.50±0.15 |

Mean±SD

Table 3: Soil Physicochemical properties

| Parameters | Pristine soil | Polluted soil (week 2) | Treated with OMF (week 10) | After planting (week 20) |
|---|---|---|---|---|
| PH | 4.3±0.01 | 4.2±0.15 | 4.3±0.06 | 4.4±0.06 |
| Organic Carbon (%) | 2.3±1.20 | 1.07±0.08 | 3.1±0.42 | 3.67±0.19 |
| Total Nitrogen (%) | 0.18±0.10 | 0.08±0.01 | 0.24±0.06 | 0.31±0.01 |
| Phosphorus (mg $kg^{-1}$) | 8.70±1.89 | 6.75±1.11 | 21.83±2.08 | 24.75±0.87 |
| Potassium (mg $kg^{-1}$) | 0.08±0.01 | 0.08±0.02 | 0.08±0.01 | 0.09±0.01 |
| ECEC | 7.62±1.85 | 5.85±1.41 | 6.36±1.48 | 9.74±2.00 |
| Nickel (mg $kg^{-1}$) | 0.02±0.002 | 0.02±0.002 | 0.02±0.01 | 0.02±0.00 |
| Zinc (mg $kg^{-1}$) | 0.06±0.001 | 1.20±0.02 | 0.43±0.11 | 0.34±0.09 |
| Lead (mg $kg^{-1}$) | 0.06±0.002 | 0.19±0.001 | 0.06±0.02 | 0.04±0.01 |
| Cadmium (mg $kg^{-1}$) | 0.05±0.002 | 0.07±0.002 | 0.01±0.01 | 0.004±0.00 |
| Copper (mg $kg^{-1}$) | 0.17±0.002 | 0.42±0.001 | 0.26±0.12 | 0.17±0.06 |

OMF: Organo mineral fertilizer

Table 4: Physicochemical properties of *Zea mays* (maize)

| Parameters/Soil (mg $kg^{-1}$) | Pristine soil | Polluted (Not treated) | Polluted (OMF treated) |
|---|---|---|---|
| Total Nitrogen (%) | 0.733±0.058 | 0.593±0.058 | 1.333±0.058 |
| Phosphorus | 0.313±0.058 | 0.193±0.006 | 0.283±0.012 |
| Potassium | 0.587±0.012 | 0.497±0.006 | 0.597±0.006 |
| Calcium | 0.267±0.12 | 0.317±0.006 | 0.797±0.006 |
| Magnesium | 0.193±0.006 | 0.197±0.006 | 0.397±0.006 |
| Zn | 0.004±0.00 | 0.636±0.06 | 1.025±0.06 |
| Cu | 0.070±0.00 | 0.141±0.00 | 0.156±0.00 |
| Ni | 0.003±0.00 | 0.012±0.00 | 0.018±0.00 |
| Cd | 0.003±0.00 | 0.013±0.00 | 0.015±0.00 |
| Pb | 0.003±0.00 | 0.011±0.00 | 0.016±0.00 |

Mean±SD, OMF: Organo-mineral fertilizer

Table 5: Physicochemical properties of *Panicum coloratum*

| Parameters (mg kg$^{-1}$) | Pristine Soil | Polluted (Not treated) | Polluted (OMF treated) |
|---|---|---|---|
| Total nitrogen (%) | 0.697±0.001 | 1.123±0.000 | 1.293±0.000 |
| Phosphorus | 0.243±0.001 | 0.193±0.002 | 0.247±0.004 |
| Potassium | 0.557±0.001 | 0.483±0.003 | 0.567±0.003 |
| Calcium | 0.727±0.002 | 0.723±0.001 | 1.133±0.003 |
| Magnesium | 0.437±0.001 | 0.363±0.001 | 0.617±0.002 |
| Zn | 0.001±0.00 | 0.015±0.00 | 0.390±0.00 |
| Cu | 0.123±0.00 | 0.144±0.00 | 0.291±0.00 |
| Ni | 0.003±0.00 | 0.007±0.00 | 0.014±0.00 |
| Cd | 0.002±0.00 | 0.005±0.00 | 0.014±0.00 |
| Pb | 0.003±0.00 | 0.005±0.00 | 0.015±0.00 |

Mean±SD, OMF: Organo-mineral fertilizer

Table 6: Percentage accumulation of heavy metals in *Zea mays* and *Panicum coloratum*

| | Plant species | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | *Zea mays* L. | | | | | *Panicum coloratum* | | | | |
| Samples | Ni | Zn | Pb | Cd | Cu | Ni | Zn | Pb | Cd | Cu |
| Pristine | 11.25 | 6.17 | 5.23 | 7.02 | 40.94 | 12.50 | 2.167 | 4.29 | 4.89 | 72.11 |
| Polluted (Not treated) | 12.50 | 57.95 | 5.88 | 17.16 | 33.73 | 29.17 | 1.37 | 2.51 | 6.35 | 34.45 |
| Polluted (OMF treated) | 73.75 | 93.32 | 8.72 | 20.27 | 37.32 | 58.33 | 35.52 | 7.86 | 19.32 | 69.62 |

OMF: Organo-mineral fertilizer

*Panicum coloratum* accumulated the heavy metals in the order Cu (69.62%), Ni (58.33%), Zn (35.52%), Cd (19.32%) and Pb (7.86%).

## DISCUSSION

Phytoremediation studies with spent engine oil on the growth and yield of *Panicum coloratum* and *Zea mays* showed that hydrocarbon in the soil had significant effects on soil properties like nitrogen content, pH, carbon as well as the presence of heavy metals. Agbogidi *et al.*[20] reported that oil in soil has deleterious effects on the biological, chemical and physical properties of the soil depending on the dose, type of the soil and other environmental factors[2]. Okonokhua *et al.*[21] also reported that the physical property of oil imposes some stressful conditions which may interfere with water uptake and gaseous exchange. However, Zheljazkov and Warman[22] reported that the application of compost and vermin-compost to oil-contaminated soils improved soil fertility, physical properties and contribute to a successful approach to phytoremediation.

Soil pH is a major factor influencing the availability of elements in the soil for absorption by plants[23]. Also, McBraide[24] stated that many metal cations are more soluble and available in soil solution at lower pH (below 5.5) including Cd, Cu, Hg, Ni, Pb and Zn.

Baek *et al.*[25] reported that there were additions in the level of heavy metals (Validium and Lead) as the level of spent engine oil pollution increased. The reduction in the level of available soil nutrient (N, P and Mg) and rise in the level of heavy metals concentration agrees with the report that crude oil in the soil makes the soil condition unsatisfactory for plant growth, due to the reduction in the level of available plant nutrients in the soil or a rise in toxic levels of certain elements such as iron and zinc[26].

The addition of organic matter amendments such as compost, fertilizer and waste, is a common practice for immobilization of heavy metals and soils amelioration of contaminated soils[27]. Peat, compost and vermicomposting application led to effective immobilization of Pb, Cu, Zn and Cd photo accessible forms in soil. The effect of organic matter amendment on heavy metal bioavailability depends on the nature of the organic matter, their microbial degradability, salt content and effects on soil pH and redox potential as well as on the particular soil type and metals concerned[28].

Osaigbovo *et al.*[29] have also reported that heavy metal concentration increased with increasing concentration of the contaminant (spent engine oil) and amendment with organic fertilizer significantly remedied the polluted soil and decreased the heavy metal concentration. In this study, treatment fertilizers reduced the heavy metal concentration in the soil. Fertilizers and other soil amendments may also add small amounts of heavy metals to the soil, which build up over time with repeated applications[30]. The actual toxicity of heavy metals will be affected by soil texture, organic matter content and pH. Adding organic matter to the soil can help tie heavy metals chemically, reducing their availability for potential uptake. Similarly, limiting to a neutral pH and maintaining optimal soil phosphorus levels can reduce heavy metal availability to plants. There is little evidence to suggest that some heavy metals such as lead are accumulated within crops, the main health hazards being through indirect ingestion from the soil and inhalation[31].

In many plants, there is a direct relationship between the content of microelements in the soil solution and their uptake by plants. Kabata-Pendias and Pendias[32] reported that this relation is most evident with cadmium and less evident with zinc and lead. They reported that Pb, Zn, Cu and Cd uptake by potatoes depended on the soil amendments and treatment.

## CONCLUSION

Organo-mineral fertilizer (OMF) has a high potential to improve the properties of spent engine oil-polluted soil, enhance the uptake of heavy metals like Zinc, Iron and Copper by plants such as *Zea mays* and *Panicum coloratum*. Both species of plants used in this study have high phytoremediation potential. Given the high percentage reduction of heavy metals in the soil observed in this study, there is hope for the use of phytoremediation techniques.

## SIGNIFICANCE STATEMENT

This study discovers the potential of organo-mineral fertilizer and the plants *Zea mays* and *Panicum coloratum* that can be beneficial for the phytoremediation of heavy metals from spent engine-oil polluted oil. Amendment with fertilizers might act by stimulating microbial growth, thereby increasing the bioavailability of products for plant uptake.

This study will help the researcher show the differential sensitivity of plants to spent engine oil toxicity which reveals a gap in phytoremediation practice on the selection of appropriate plant species that are tolerant of the contaminant.

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