Research Article **AJAR (2017), 2:10**

American Journal of Agricultural Research (ISSN:2475-2002)

Influence of Contamination of Soil With Heavy Metal on the Growth of Three Herbaceous Plant Species

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ABSTRACT

Contemporary literatures are awash with Heavy metal contamination in soils as a source of global environmental concern. Cultivation of crops on these contaminated soils may result in accumulation of heavy metals resulting in possible risks on human health. For this reason, a pot experiment was conducted between May and August 2016 at the green house of the Department of Forestry and Environmental Management, Michael Okpara University of Agriculture, Umudike. The experiment was specifically aimed at evaluating the influence of kaoline mined soil samples on the growth of three herbaceous plant species (Chromolaena odorata, Ipomoea involucrata and Mariscus alternifolius) commonly found at abandoned kaolin mining site at Ohiya in Umuahia South East, Nigeria. The experiment was laid out in a Randomized Complete Block Design with Six (6) replicates. Data were collected on Plant height, Number of leaves, fresh and dry weight. Data were analyzed using Analysis of Variance (ANOVA). Mean separations were done using Fisher LSD at 0.05% probability. Two mean values were subjected to studentized-t-test using statistical analytical system (SAS) software, version 8.0. The result showed that the kaolin mined soil sample significantly affected all the growth parameters measured during the study.

Keywords: Soil, Heavy metals, herbaceous plants.

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How to cite this article:
Igwe et al.,. Influence of Contamination of Soil With Heavy Metal on the Growth of Three Herbaceous Plant Species. American Journal of Agricultural Research, 2017,2:10.

eSciencePublisher
eSciPub LLC, Houston, TX USA.
Website: http://escipub.com/

1. Introduction

Increasing environmental pollution occasioned by heavy metals released by industries and agricultural activities is a major source of public outcry in the world today (Nguyen, 2015). Implication of soil contamination by heavy metals is that these heavy metals are easily absorbed from the soil, and can accumulate along the food chain causing toxicity on plants and animals as well as adverse health effects on humans (Nelson and Sommers, 1982; Gasparatos and Haidouti, 2001). The toxicity of heavy metals is apparent in reducing growth and development of plants, and seriously harming the health of animals and humans (Kvesitadze *et al*. 2006). Heavy metal contamination of agricultural soils by atmospheric deposition or by disposal of sewage sludge has been reported to constitutes a risk of either leaching of these hazardous metals into the groundwater or excessive accumulation in the top soil (Adriano, 1992; Kabata-Pendias and Pendias, 1992). Industrial wastes are a major source of soil pollution that originate from mining industries, chemical industries, metal processing industries, and the like. These wastes include a variety of chemicals like heavy metals, phenolics etc. (Mueller et al., 1989; Babich & Stotzky, 1977). Use of industrial effluent and sewage sludge on agricultural land has become a common practice in the world as a result of which, these toxic metals can be transferred and concentrated into plant tissues from the soil (Abdul Ghani, 2010). Every heavy metal and plant tissue interacts in a specific way, which depends on several factors such as type of soil, growth conditions, and the presence of other ions. Soils rich in kaolin easily retain heavy metals and accumulate them above acceptable levels hence affecting the ecosystem (Gamiz et al., 1988). The present study therefore was specifically undertaken to evaluate the impact of some of these heavy metals on growth of three herbaceous plant species (*Chromolaena odorata*, *Ipomoea involucrata* and *Mariscus alternifolius*) commonly found growing on mining sites in the study location.

2.0 Materials and Methods

2.1 Study area

The experiment was located at the green house of the department of forestry and environmental science, Michael Okpara University of Agriculture, Umudike. One month old young seedlings of *Chromolaena odorata*, *Ipomoea involucrata* and *Mariscus alternifolius* were collected from a fallow field in Umudike for the experiment. The seedlings were first stabilized in a nursery for one month before being transplanted into experimental pots. Eighteen (18) pots were filled each with 5kg of soil collected from the overburden piled at the Ohiya kaolin mine site. Another set of Eighteen (18) pots were filled with 5kg of soil collected from an un-mined site (control). The three (3) species seedlings were differently transplanted into six (6) pots each containing the soil sample from overburden. The same was repeated for pots containing soils from the Un-mined site (Control). The treatment was carried out using six replicates.

All the thirty six (36) pots planted were labeled according to their treatments and transferred to the Nursery of the Department of Forestry and Environmental Management, Michael Okpara University of Agriculture, Umudike. The plants were watered every other day. The experimental pots were also perforated at the base to prevent water logging. The thirty six (36) potted plants were allowed to grow for a period of four (4) months (from May-August) (16WAP) during which growth parameters such the plant height and number of leaves were measured with tape in (cm) and counted on a monthly interval respectively. The experiment was laid out in a Randomized Complete Block Design with six (6) replicates of each plant species.

2.2 Preliminary soil studies for heavy metals concentration

Before the commencement of the studies, preliminary assessment of the Kaolin mine site was carried out to determine the levels of different heavy metals concentration in the area. Core soil samples were randomly collected from the overburden excavated by the miners at 0-15cm depth each on the Kaolin mine site. Also core soil samples were randomly collected on the opposite side of the kaolin mine site where a 20 year fallow is existing and it is undisturbed by miners. The un-mined site which is about 2kilometers away was used as the control. These core soil samples were differently homogenized in a clean plastic bucket and a composite sample was drawn from each. The composite samples were air dried and allowed to pass through a 2mm sieve which was then poured into polythene bags and labeled accordingly. The sieved soil samples were air dried and then taken to the laboratory for heavy metals analysis. The results showed that the soil at the kaolin mining site has higher concentration of heavy metals when compared with that from the fallow (control) site.

Fig. 1 One of the active mined pits at Ohiya kaolin mining site where samples were collected

3.0 Results

Heavy metals in soil samples from the kaolin mine site and the un-mined site

Table 1 shows the result of the preliminary studies on the comparative evaluation of heavy metals concentration in soil of the kaolin mining site (overburden) and the control site (fallow field). The concentration of lead (Pb) in the kaoline mined location was (2.4mg/kg) which was almost 60% higher than Pb concentration in the un-mined location (control) which recorded lead concentration of (1.53mg/kg). Nickel (Ni), Cadmium (Cd), Cobalt (Co) and Selenium (Se) contents of mined and un-mined soil samples were 0.77 and 0.49mg/kg, 0.16 and 0.10mg/kg, 9.84 and 8.14mg/kg, 1.06 and 0.99mg/kg respectively. There was significant differences ($P<0.05$) between the heavy metal contents observed in the mined soil than that of un-mined soil samples except in that of Cr (0.22 and 0.25mg/kg).

Table 1 Concentrations of some heavy metals in soil samples from kaolin mine site (Overburden) and un-mined site used as control

Sample	Pb	Cr	Ni	Cd	Co	Se
Mined Area (A) soil	2.40	0.22	0.77	0.16	9.84	1.06
Un-mined Area (B) soil	1.53	0.25	0.49	0.10	8.14	0.99
Probability	0.0014	0.1963	0.0000	0.001	0.0000	0.000
T¬- test (0.05%)	**	NS	***	**	***	**

KEY: NS= Not Significant, ** = Very Significant, *** = Highly Significant

3.1 Monthly measurement of growth in height of potted plants in unmined and mined site soil samples

The results of the measurement to determine the effect on plant growth in height by the un-mined and mined soil on samples of *C. odorata* (P1), *I. involucrata* (P2) and *M. alternifolius* (P3) measured in monthly interval is shown in table 2. From month 1 to month 4 growth periods on un-mined site soil sample, heights of P1 were (7.90cm, 12.00cm, 21.00cm and 24.80cm). Heights of P2 were (9.40cm, 15.00cm, 27.50cm, and 35.10cm) and heights of P3 were (4.80cm, 7.00cm, 11.30cm and 12.80cm), these heights were significantly higher than plants measured from mined site soil sample by almost 50% in each month except in P2, there were no significant difference between the un-mined site and mined site soil sample on the plant height of P2 at month 1 and month 2, and in P3 at month 3. But the percentage difference between the un-mined site and mined site soil on plants heights for both P1, and that of P2, P3 were (3.4%, 5.6%, and 2%) for month 1 and (5.53%, 0%,and 0.5%), (11%, 1.7% and 0%), (10.4%, 5.5% and 1.1%) for month 2, 3 and 4.

Table 2. Effect on plant height (cm)by un-mined site and mined site soil samples measured at monthly intervals

Sample	Month 1		Month 2		Month 3		Month 4	
	UMS	MS	UMS	MS	UMS	MS	UMS	MS
P1	7.90_b	4.46^b	12.00^b	6.47^b	21.00^b	10.00^c	24.80^b	14.40^b
P2	9.40	9.40^a	15.00^a	15.00^a	27.50^a	25.80a	35.10^a	29.60^a
P3	4.80^c	4.50^b	7.00^c	6.50^b	11.30^c	11.30^b	12.80^c	11.70^c
LSD(0.05%)	0.49	0.77	2.00	1.20	1.23	0.42	0.28	0.59

Mean values down the columns with the same superscript are not significantly different (P>0.05).
Key: P1 = *Chromolaena odorata,* P2= *Ipomoea involucrata* ,P3= *Mariscus alternifolius,* MS= mined site soil, UMS = un-mined site soil.

3.2 Effect of unmined site and mined site soil samples on number of plant leaves counted monthly

Table 3 shows the results of the effect of un-mined site and mined site soil on number of leaves of *C. odorata* (P1), *I. involucrata* (P2) and *M. aiternifolius* (P3) counted at different growth periods in monthly interval. At month 1 to month 4 growth periods on un-mined site soil sample, the numbers of leaves of P1 were (6.20, 10.20, 16.50 and 26.00). Numbers of leaves of P2 were (8.20, 12.00, 20.60, and 26.01) and numbers of leaves of P3 were (3.58, 4.30, 6.30 and 8.80), these leaves numbers were significantly higher than numbers of plant leaves counted from mined site soil samples by almost 30% in each month except in P3, which was about 10% . But the percentage difference between the un-mined and mined site soil on plants numbers of leaves for both P1, and that of P2, P3 were (2.2%, 2.7%, and 0.08%) for month 1 and (4.6%, 2.8%,and 0.5%), (7%, 5.3% and 0.1%), (10.7%, 6.41% and 1.8%) for month 2, 3 and 4.

Table 3. Effect of un-mined and mined sites soil samples on the number of leaves of P1, P2 and P3 samples counted at monthly interval.

Sample	Month 1		Month 2		Month 3		Month 4	
	UMS	MS	UMS	MS	UMS	MS	UMS	MS
P1	6.20^{a}	4.00^{b}	10.20^{a}	5.60^{b}	16.50^{a}	9.50^{b}	26.00^{a}	15.30^{b}
P2	8.20^{b}	5.50^{a}	12.00^{b}	9.20^{a}	20.60^{b}	15.30^{a}	26.01^{a}	19.60^{a}
P3	3.50^{c}	3.58^{b}	4.30^{c}	3.80^{c}	6.30^{c}	6.20^{c}	8.80^{c}	7.00^{c}
LSD(0.05%)	0.40	1.34	1.23	0.35	0.48	0.71	2.34	1.25

Mean values down the columns with the same superscript are not significantly different (P>0.05).
Key: P1 = *Chromolaena odorata* ,P2= *Ipomoea involucrata* ,P3= *Mariscus alternifolius,* MS = mined site soil, UMS = un-mined site soil.

3.3 Effect of unmined site and mined site soil samples on fresh and dry weights of plant samples

Table 4 shows the results of the effect of un-mined site (control) and mined site soil samples on fresh and dry weight of samples of *C. odorata (P1), I. involucrata (P2), and M. alternifolius* (P3) measured after harvesting. Fresh and dry weight of the plant samples from un-mined site soil sample were P1 (17.33g and 4.66g), P2 (50.00g and 8.00g) and P3 (7.33g and 2.66g) and these were significantly higher by almost 60% than fresh and dry weight of plant samples from mined site soil sample, but the fresh and dry weight of P2 from un-mined site soil sample were significantly higher by almost 75% than both P1 and P3 plant samples in un-mined soil sample. Fresh and dry weight of plant samples of P1, P2 and P3 from mined site soil sample were (6.66g and 1.66g), (20.00g and 4.00g) and (2.66g and 1.20g) and fresh and dry weight of P2 were significantly higher by almost 70% than both P1 and P3 plant samples from the same mined soil sample.

4.0 Discussion

Result from preliminary studies of the comparative evaluation of heavy metals concentration carried out on the study area showed high concentration of lead (Pb) (2.40mg/kg) and cobalt (Co) (9.82mg/kg)

Table 4. Effect of un-mined (control) and mined soil samples on fresh and dry weight of plant samples of P1, P2, and P3.

Plant sample	Fresh weight Mined Soil	Dry weight Mined Soil	Fresh weight Un-mined Soil	Dry weight Un-mined Soil
P1.	6.66g^{b}	1.66g^{b}	17.33g^{b}	4.66g^{b}
P2.	20.00g^{a}	4.00g^{a}	50.00g^{a}	8.00g^{a}
P3.	2.66g^{c}	1.20g^{b}	7.33g^{c}	2.66g^{c}
LSD(0.05%)	2.31	1.15	5.78	0.02

Mean values down the columns with the same superscript are not significantly different (P>0.05).
KEY: Key: P1 = *Chromolaena odorata,*P2= *Ipomoea involucrata ,*P3= *Mariscus alternifolius*

indicating that the area is contaminated especially when compared with EPA'S natural level of lead (Pb) occurrence (50ppm) which is equal to (0.05mg/kg), (Chaney *et al*., 1984, Reagan and Silbergeld, 1989). These could be as a result of kaolin mining activities at the area. Moreover, kaolin develops negative charge between its layers and attract positive charges minerals like heavy metals such as (Pb, Co, Cd, Cu, Cr etc.) resulting to contamination of the soil (Gamiz *et al*., 1988). From the evaluation, it was also observed that lead (Pb) and cadmium (Cd) from the mined site was significantly higher than that of the un-mined site by almost (60%) while cobalt (Co) was highly significant by (70%) when compared with the un-mined site. However, the problem of lead (Pb) and cadmium (Cd) poisoning in animals has widely been recognized requiring special attention for the environmentalist and health personnel's. They accumulate in different parts of the body especially the kidney, liver and brain (Mclaughlin *et al*., 1999; Swarup *et al*., 2005).

4.1 Effects of the mined site soil samples on plant growth parameters measured at monthly interval

From the present study, the heavy metal-contaminated mined soils appeared to limit soil fertility and inhibit all the plant growth parameters measured. Plant height and number of leaves observed at different growth periods were found to be significantly influenced (P<0.05) by the contaminated soil. At 1st , 2nd , 3rd and 4th months after planting period, *Ipomoea involucrata* had the highest height from (9.40cm- 29.60cm) while *Mariscus alternifolius* recorded the lowest height from (4.50cm-11.7cm). Number of leaves was also influenced by the soil, *I. involucrata* recorded highest number of leaves from (3.50-19.60) while *M. alternifolius* recorded the lowest number of leaves from (3.58-7.00). In addition to elevated metal concentrations in the study soil, other adverse factors including absence of topsoil, erosion, compaction, wide temperature fluctuations, and shortage of essential nutrients could also have contributed to the negative effects observed on plant growth. Degraded soils of mines usually have low concentrations of macro nutrients, like N, P and K (Huenneke *et al.*, 1990) essential for plant growth and development which was in agreement with the findings of the present study N ranges from (1.30- 3.00g), P (0.03- 0.09g.), K (0.49- 1.48g), Ca (0.27- 1.06g) and Mg (0.09- 0.27g) indicating low concentrations of macro nutrients on the plant species used for the study, while the corresponding values from the fallow plot (control) recorded N ranges from (1.82- 3.48g), P (0.02- 0.04g.), K (0.58- 1.38g), Ca (0.92- 1.44g) and Mg (0.11- 0.13g). Toxic metals can also adversely affect the number, diversity and activity of soil organisms, inhibiting soil organic matter decomposition and N mineralization processes. The chemical form of potential toxic metals and presence of other chemicals may aggravate or attenuate metal toxicity. The prevailing poor nutrient status of contaminated soil used in this study contributed to the poor growth performance of the plant species.

5.0 Conclusion and recommendations

Conclusion

The most common plant species in the mined sites were *Chromoleana odorata, Ipomoea involucrata and Mariscus alternifolius.* The growth pattern and biological characteristics favored their dominance of the mined site.

This native flora displayed varying ability to withstand high concentrations of heavy metals in the soil. They showed different accumulation patterns for metals at different soil Concentrations (Wong, 2003). The soils from the kaolin mined site was low in N P K but had elevated concentrations of some heavy metals namely Pb, Cr, Ni, Cd, Co etc. when compared to the un-mined area. This shows that soils rich in kaolin deposits may be deficient in soil macro-nutrients and are likely to be contaminated with heavy metals like Pb, Cr, Ni, Cd and Co etc.

In terms of growth parameters of the screened plant species*, Ipomoea involucrata* grew better as regards plant height and leaf number than the other 2 species examined when grown on the Pb and Co rich kaolin mined soil. The levels of Pb and Co in *Ipomoea involucrata* were higher than that of *Chromoneana odorata* and *Mariscus alternifolius* showing the capacity to accumulate and tolerate the potential toxicity of these heavy metals.

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