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Effectiveness of Bamboo (*Phyllostachys pubescens*) and Papyrus (*Papyrus cyperus*) in uptake of Heavy Metals from Soil Contaminated with Petroleum Sludge

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Abstract Petroleum sludge is a residue extracted mostly from petroleum storage. Contaminants from petroleum sludge may exist in the soil for long periods and be transmitted to plants and tissues of living organisms within the soil ecosystem. The aim of this study was to investigate sustainable technology for enhancing bioremediation of soil contaminated with petroleum sludge. The study involved planting of Bamboo (*Phyllostachys pubescens*) and Papyrus (*Papyrus cyperus*) plants in contaminated soil. Parts of the plant (roots, stem and leaves) were examined for their effectiveness of absorption and bioaccumulation of three heavy metals (lead, copper and chromium). The plants were harvested after every three months of growing for a period of one year. Presence of heavy metal in the soil and the harvested plant parts were analyzed by Atomic Absorption Spectrophotometry method. After growing the plants in the contaminated soil for 12 months, it was found that highest amounts of chromium (86.86%) were reduced by Bamboo plant while copper (83.33%) was the highest reduced metal by Papyrus plant. Heavy metal analysis on the plant parts depicted that Bamboo is an effective plant in accumulation of heavy metals in petroleum contaminated soil over a long period of time. Conversely, Papyrus accumulates heavy metals over a short period of time even in presences of extra amounts of water in the soil. It was further noted that both Bamboo and Papyrus accumulate copper and lead more in the roots than in leaves, however, chromium is most accumulated in leaves.

Keywords Absorption, Adsorption, Bioremediation, Phytoremediation, Petroleum Sludge

1. Introduction

Petroleum industries produce a great deal of effluent that contains various pollutants, such as heavy metals. Heavy metals pollutants are a great health concern in the environment. Depending on the components of petroleum sludge, they can be classified as soil, air or water contaminant. The contaminants are toxic, mutagenic and carcinogenic [1]. Particularly, contaminants generated from anthropogenic activities can harmfully affect both human and animals who depend on food chains affected by the contaminants. Even low levels of heavy metal contaminants in the food chains pose a health risk due to impending accumulation at higher trophic levels in the food chains through bio-magnification. The inorganic contaminants such as non-essential heavy metals are some of the common soil contaminants. They include lead (Pb), chromium (Cr), and Copper (Cu) in high concentrations.

Metal uptake by plants is generally aided by certain channel proteins or H^+ (transporters) coupled carrier proteins found at the cell membrane of the roots. Accidental uptake of heavy metals also takes place via other cell membrane transporters like phosphorus transporters which transports Arsenic (As) in form of Arsenic oxidearsenous trioxide (As_2O_3). It is therefore essential to find a sustainable solution to this potential threat with the ever-increasing demands of petroleum products. Among the most effective and additionally cost-effective suitable solution is phytoremediation. Phytoremediation bioremediation is much dependent on the physiological behavior of plants' roots to the soil contaminants and particularly heavy metals.

1.1. Phytoremediator Potentials of Bamboo and Papyrus

The use of plants as a technique for bioremediation technology has been embraced and found effective. Bamboo, which is a woody member of the grass family has been used as one of the bio remedies for soil pollution and erosion. About 18 species of Bamboo are reliably hyper accumulative of zinc (Zn) and other heavy metals [2]. In hydrophonic experiments, Bamboo has shown high Zn tolerance up to application of 400μM. Bamboo can grow on metalliferous

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soils and can accumulate extremely high concentration of heavy metal in both the shoot and root without suffering phytotoxic effects in hyperaccumulators [3,4,5].

Experimental results by Liu et al. [4] have indicated that at the highest lead (Pb) concentration (400 µmol/L), the growth of moso bamboo seedlings is repressed and Pb concentrations in roots, stems and leaves, can reach a maximum of 4282.8, 482.2, 148.8 mg/kg, respectively. In the same research, scanning electron microscopy showed that the too much Pb lessened rooting inclusions, stomatal opening, and just few stem inclusions. Even though ultrastructural analysis showed some internal physiological injuries, the plants subjected to 400 µmol/L Pb endured no physically observable Pb toxicity signs like chlorosis and necrosis. Liu et at. [4] noted that even at very high Pb treatment of the growth medium, no considerable variance was recorded for the biomass of stem as compared to controls. Bamboo is significantly tolerant to heavy metals and thus can tolerate high concentration of the heavy metals without any significant effect on its physiological behavior [6,7,8]. Bamboo has therefore been found to be a suitable phytoremediatory plant that is both sustainable and cost-effective.

Papyrus on the other hand has also been used in attempts to rehabilitate wetlands. *Cyperus papyrus*, a species of Papyrus, has been found by Lema et al [9] to have a greater tendency for removal of copper and iron with k values of 0.333 d-1 and 0.168 d-1 respectively. In their study, *Cyperus papyrus* was able to reduce an initial concertation of iron from 3.515 ppm to 0.077(±0.021) ppm in the soil. A study by Home and Muthigo [10] found that with a blend of *Cyperus papyrus* with Polygonum spp and Typha latifolia at the ratio of 2:1:1 while the plants grown in a wetland, had optimum removal of 89.8% of lead from raw sewage.

1.2. Bioaccumulation

Bioaccumulation is a type of biosorption in which living organisms gradually accumulate metals in their biomass through incorporation or assimilation [11]. The accumulation depends, in most cases, on active uptake, and partly on passive uptake [12]. Living organism incorporate metals within their biomass to protect themselves against metal toxicity. While in the body, the metals can be immobilized by complexation with intracellular proteins like sulfur-containing peptides [13]. Consequently, the success of bioaccumulation depends much on plant roots' affinity toward a given metal, and on the physicochemical conditions which affect metal toxicity like Eh, and pH.

1.3. Bioavailability

In phytoremediation, bioavailability is the presence of heavy metals in the form and quantities that can be absorbed and immobilized by the root system of a plant. It is thus a factor which define whether a heavy metal is available for uptake, and whether the form in which the metal occurs in the soil allows for its natural uptake. Bioavailability is defined by the transfer factor (TF) and bioaccumulation factor (BCF). In other words, to quantify bioavailability, one must determine the TF and the BCF. A TF of less than 1 and BCF of more than 10 implies that the bioavailability of a metal is very high and thus a lot of bioaccumulation occurs [6].

1.4. Phytoextraction

Phytoextraction is the removal of heavy metals from a contaminated medium such as soil or water through their uptake by plant roots. The process is advantageous over traditional techniques, because it is cost effective, can be used to treat pollution by more than one metal, can be conducted in situ and it is environmentally friendly [14]. However, Fawzy et al. [15] have found the following factors to influence the success of phytoextraction: dissolution of the metal in a medium that is absorbable by plant roots, bioavailability of the metal for the plant roots, chelation of the metal to protect itself and make the metal more mobile.

It is in this backdrop that the study sought to determine the effectiveness of Bamboo *(Phyllostachys pubescens)* and Papyrus (*Cyperus papyrus)* species in accumulating heavy metals in soil contaminated with petroleum sludge.

2. Methodology

The study followed an experimental design which included soil collection, cultivation of plants and analysis for heavy metals. Soil contaminated with petroleum sludge from a dump site in Makueni County, Kenya was analyzed through Atomic Absorption Spectrophotomentry (AAS) for lead, chromium and copper. Bamboo and papyrus plants were grown in the soil contaminated with petroleum sludge for a period of 1 year. The roots, stems and leaves of the plants were harvested and analyzed for the heavy metals. The plants were grown in a greenhouse to enhance monitoring under similar conditions. An investigation into the bioaccumulation of the heavy metals in the various parts of the plants was studied.

2.1. Sample Collection

Soil contaminated with petroleum sludge was sampled from a Kenya Pipeline Cooperation (KPC) sludge dumping site located at Sultan-Hamud in Makueni County. Soil auger was used to scoop contaminated soil from about 30-60 cm of depth from the site. The samples were then put in cooler boxes for transport and temporary storage at 4°C.

Red clay soil was sampled from Jomo Kenyatta University of Agriculture and Technology (JKUAT) soil stock used for horticultural studies. The soil was sampled following the same procedure as for the contaminated soil. Both soil samples were safely stored in a tightly sealed container to avoid any contamination. Since Bamboo seedlings were sourced from Kitil farm in Kajiado County and Papyrus rhizomes from JKUAT, the soil samples were divided into two and transported to the respective areas where the seedlings were to be sourced.

Bamboo seedlings (*Phyllostachys pubescens*) were sampled from Kitil Farm in Isinya – Kajiado County, and isolated into a greenhouse within the farm. Papyrus rhizomes (*Papyrus cyperus)* on the other hand were obtained from parts of the paddy farms within JKUAT. These rhizomes were used to grow and develop seedlings which were then used for the study.

2.2. Experimental set-up

The clean red clay soil was thoroughly mixed with the soil contaminated with petroleum sludge, compost manure and NPK fertilizer at a ratio of 3:3:1:0.1 by volume respectively. The blend was mixed until homogenous was achieved. Equal amounts of the blend were put in 32 plastic containers and water added just to make the blend moist.

Four bamboo plant seedlings (300 mm tall), were planted in each of the first 16 containers having the soil blend and papyrus seedlings of the same size were also planted in each of the remaining 16 containers. This ensured that for every specific treatment to be done for the plants, there were four sets (quadruplet). These containers were placed on benches within one of the green houses at Kitil farm for bamboo, and another green house in JKUAT for papyrus (Figure 1).

In addition to the normal agronomical water requirement (>2,000 mm per year) suggested by Kleinhenz and Midmore [16], varying amount of extra water were periodically added through drip method to the plant containers. For the Bamboo seedling containers, the extra water was added at alternate days while for papyrus seedlings water was added on daily basis. For every four pairs of containers with both bamboo and papyrus, 0ml, 500ml, 1000ml and 2000ml of water was added respectively for the containers through the growth period. As Cooper and Myers [17] confirms, both bamboo and papyrus grow well indoors where there is natural day light; implying that they grow well under laboratory setup. Ten number, 1 mm diameter holes were bored at the bottom of the containers to facilitate drainage.

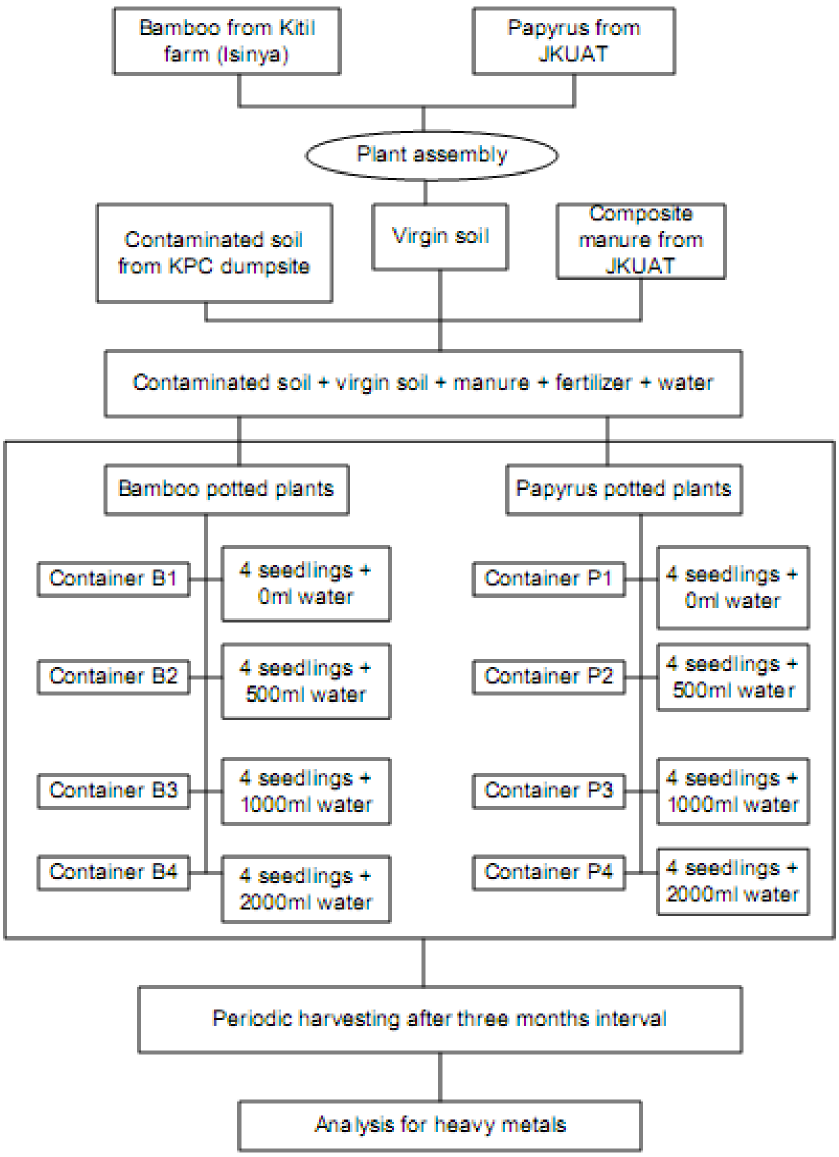

Figure 1. Schematic flow of the experimental set-up

2.3. Preparation for Analysis

The plants were harvested after every three months of growing for a period of one year. The plants, on harvesting, were divided into leaves, stems and roots. They were then dried under sun. The dry samples were chopped into small pieces that could easily fit into crucibles. Samples of between 1.5 gm and 2.0 gm were weighed and placed into labeled crucibles. The crucibles were placed on wire gauze on hot coils under a fume hood and the temperature was increased gradually until smoking ceased and sampled completely charred. The charred sample were transferred to a muffle furnace and temperature adjusted to 250°C where they were allowed to heat for 1 hour. The temperature was then re-adjusted to 5500°C and left to run for 6 hours. At the end of the six hours, the temperature was lowered to 3000°C as suggested by Skoog [18]. The processes were conducted in duplicates.

The ashes were quantitatively transferred to a 25ml beakers using 10ml of 1N HNO_3. The samples were heated at 90ºC on a hot plate for 5 minutes. The sample was then transferred to a 50ml volumetric flask and filled up to the mark with 1N HNO_3. It was shaken thoroughly to mix well. The mixture was filtered into clean dry polyethylene sample bottle and labelled according to the name of sample.

Three standard solutions of copper, lead and chromium were prepared from analytical stocks of 1000 ppm. The solutions were made into 2 ppm, 1.5 ppm, 1 ppm, 0.5 ppm, 0.2 ppm and 0.1 ppm as recommended by FAO and WHO [19]. These series were used to calibrate Atomic Absorption Spectrophotomentry (AAS) machine so that standard curves for all the three elements could be established.

2.4. Heavy Metal Analysis

All the samples were analyzed for three heavy metals elements: copper, lead and chromium. An Atomic Absorption Spectrophotomentry (AAS) machine was used in carrying out the analysis. The machine was turned on and the lamp allowed to warm up for 15 minutes. The machine was aligned and the monochromator positioned at the correct wavelength through selection of proper monochromator slit width. The hollow cathode current was placed according to the manufacturer's recommendation. The flame was lite and the flow of fuel and oxidant regulated. The burner and nebulizer flow rate were adjusted for maximum percent absorption and stability and balanced the photometer. A calibration curve was constructed by plotting the concentrations of the standards against the absorbance after running a series of standards of the standard solution. The samples were then aspirated and their concentrations determined from the calibration curve.

3. Results and Discussion

The raw unblended contaminated soil contained copper (0.204mg/g) as the highest concentration of the heavy metals (Table 1). However, the heavy metal concentration levels for pure sludge were within the range observed by Akpoveta et al [20]. On testing the blended soil where the plants had grown for 12 months it was found that highest amounts of chromium (86.86%) were reduced in presence of Bamboo seedlings while Papyrus highly reduced copper amounts by 83.33%. After 12 months, lead was reduced by 42.57% in presence of Bamboo compared to 39.60% in Papyrus seedlings.

It can be inferred from Table 1 that Bamboo seedlings are effective in reducing the amounts of chromium and lead in contaminated soils while Papyrus is effective in reducing copper.

3.1. Accumulation of Heavy Metals by Bamboo

The trend of uptake of the heavy metals by Bamboo after the 3rd, 6th, 9th and 12th month of planting are indicated in Table 2. The table present the amounts of the heavy metals accumulated by the various parts of the plant on adding varied extra amount of water in the four seasons of testing.

The Bamboo roots are the most effective in the accumulation of the three heavy metals (Table 3). According to Plants Rescue [21], the roots accumulation is accounted by both adsorption and absorption of the heavy metals, while the stem only accumulates in terms of assimilation in the biomass and cellular localization. Additionally, the roots also accumulate more of the contaminates because they are point of entry of the contaminates into the plants. The leaves accumulate the least of the three metals and this pattern can be attributed to phytovolatilization.

Table 1. Concentration of heavy metals

Mean Concentration of heavy metals in mg/g						
Metal	**Polluted soil (S_1)**	**Virgin soil (S_2)**	**Pure sludge**	**Blended soil at start of experiment ($S_3= S_1+S_2$)**	**Blended soil at end of experiment (Bamboo) (S_4)**	**Blended Soil at end of experiment (Papyrus) (S_5)**
Lead	0.107±0.042	0.002±0.000	0.121±0.002	0.101±0.022	0.058	0.061
Chromium	0.151±0.063	0.005±0.002	0.209±0.071	0.137±0.018	0.018	0.032
Copper	0.204±0.057	0.021±0.017	0.537±0.099	0.174±0.093	0.042	0.029

Table 2. Mean accumulation of Lead, Copper and Chromium in 12 months by Bamboo

Part of plant	Extra water added (ml)	Mean amount of metal accumulated by Bamboo in mg/g of sample											
		End of 3 Months			End of 6 Months			End 9 Months			End 12 Months		
		Cu	Pb	Cr	Cu	Pb	Cr	Cu	Pb	Cr	Cu	Pb	Cr
Root	0	0.006	0.003	0.003	0.002	0.001	0.006	0.013	0.004	0.010	0.034	0.024	0.015
	500	0.005	0.001	0.002	0.006	0.000	0.008	0.008	0.007	0.004	0.021	0.035	0.007
	1000	0.004	0.002	0.002	0.005	0.000	0.004	0.003	0.002	0.003	0.021	0.021	0.003
	2000	0.004	0.000	0.002	0.002	0.001	0.001	0.002	0.000	0.002	0.016	0.015	0.002
Stem	0	0.005	0.001	0.001	0.001	0.001	0.006	0.011	0.002	0.004	0.032	0.021	0.008
	500	0.004	0.001	0.002	0.008	0.000	0.006	0.004	0.000	0.003	0.017	0.016	0.004
	1000	0.004	0.000	0.002	0.004	0.000	0.004	0.004	0.001	0.002	0.019	0.016	0.003
	2000	0.003	0.000	0.001	0.003	0.001	0.003	0.001	0.001	0.005	0.013	0.009	0.001
Leaves	0	0.004	0.001	0.001	0003	0.000	0.008	0.005	0.000	0.005	0.027	0.010	0.006
	500	0.002	0.000	0.002	0.007	0.000	0.002	0.004	0.001	0.003	0.016	0.013	0.003
	1000	0.002	0.000	0.000	0.002	0.000	0.002	0.004	0.002	0.001	0.012	0.011	0.001
	2000	0.002	0.001	0.000	0.003	0.000	0.002	0.002	0.003	0.002	0.011	0.012	0.001

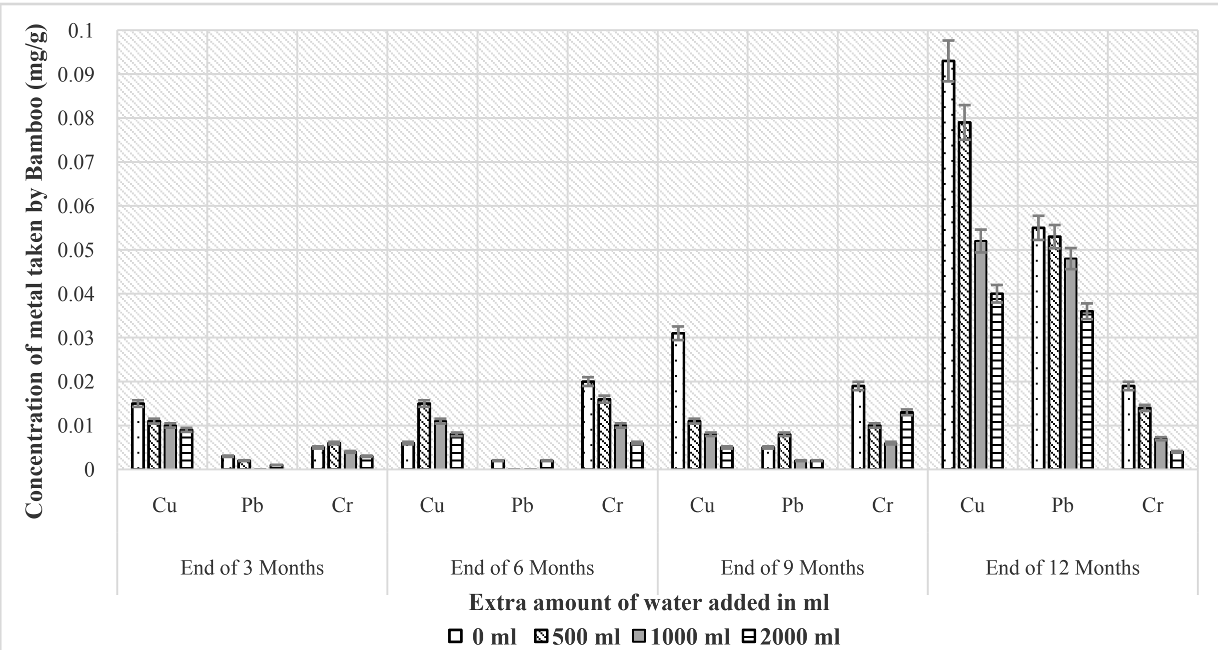

Figure 2. Heavy metals absorption by Bamboo as a plant

Figure. 2 presents the total mean accumulation of heavy metals at each harvesting time and treatment for the whole plant. It was observed that heavy metal accumulation in the Bamboo plant increased with time, however their concentration reduced on adding extra amount of water from 0ml to 2000ml. From the results, it is evident that accumulation of the heavy metals is highest with the least extra amount of water added (0ml), throughout the harvesting times. Copper was the most readily accumulated metal by Bamboo at the end of 3rd, 9th and 12th month of harvesting. This could be because it was the most abundant in the soil contaminated with petroleum sludge or because of plant physiology. More so, notably is the consistent reduction in accumulation of the metals with an exception of lead in second harvest time with more extra amount of water added. Additionally, throughout the experiment, lead is the least absorbed metal by Bamboo.

Figure. 2 also indicates that on adding more extra amount of water it minimized the amount of heavy metals taken up by Bamboo. This is consistent with the findings of Liu et al [2], who found that increased amount of water in soil, multiplies the rate of leaching. Leaching has been found to reduce the availability of materials that can be adsorbed and absorbed by plant roots.

The highest uptake of heavy metals by Bamboo occurred after 12 months. It can therefore be inferred that bioaccumulation requires time to be fully realized by Bamboo plants. According to Audet and Charest [22], the more Bamboo grows in contaminated soil, the more it takes up the contaminant until such a level when the concentration of the contaminant in that soil is too low to allow natural absorption. The total amount of heavy metal quantities accumulated by the different parts of the Bamboo plant are presented in Table 3.

Table 3. Sum accumulation of Lead, Copper and Chromium in Bamboo for 12 months

Part of the plant	Sum accumulation for 12 Months under 0ml extra additional water		
	Copper (Cu)	Lead (Pb)	Chromium (Cr)
Roots	0.055 (38.46%)	0.032 (50.0%)	0.034 (46.58%)
Stem	0.049 (34.26%)	0.025 (39.06%)	0.019 (26.03%)
Leaves	0.039 (27.27%)	0.007 (10.94%)	0.02 (27.4%)
Total	**0.143**	**0.064**	**0.073**

3.2. Accumulation of Metals by Papyrus

The trend of uptake of the heavy metals by Papyrus (*Papyrus cyperus*) after 3rd, 6th, 9th and 12th month of planting is as shown in Table 4. Compared to the metal accumulated by Bamboo over the first 3 months, it was observed that Papyrus accumulated more quantities of the heavy metals. There was 81.25% fall of total bio-accumulated copper on adding extra water from 0ml to 2000ml after 3 months. On the contrary, the mean accumulation of chromium was steady on the addition of water with a 40% accumulation noted.

There was no discernable trend of lead accumulation by Papyrus on the 3rd month. It was noted that there was accumulation of lead under 2000ml extra added water. This could have been contributed by the extremely insignificant uptake of metal when more water is present in the soil. This result augured well with the findings of Bentum et al [23].

Table 4. Trend of heavy metal uptake by Papyrus for the 12 months

Part of plant	Extra water added (ml)	Mean amount of metal accumulated by Papyrus in mg/g of sample											
		End of 3 Months			**End of 6 Months**			**End of 9 Months**			**End of 12 Months**		
		Cu	**Pb**	**Cr**	**Cu**	**Pb**	**Cr**	**Cu**	**Pb**	**Cr**	**Cu**	**Pb**	**Cr**
Root	0	0.011	0.002	0.001	0.015	0.009	0.007	0.007	0.004	0.003	0.007	0.003	0.005
	500	0.011	0.001	0.002	0.007	0.006	0.004	0.005	0.002	0.004	0.007	0.005	0.006
	1000	0.005	0.001	0.001	0.005	0.004	0.002	0.004	0.004	0.002	0.003	0.003	0.004
	2000	0.009	0.000	0.000	0.003	0.001	0.001	0.004	0.000	0.002	0.004	0.002	0.002
Stem	0	0.008	0.000	0.001	0.011	0.004	0.004	0.007	0.000	0.006	0.005	0.004	0.007
	500	0.007	0.002	0.002	0.005	0.003	0.003	0.006	0.003	0.002	0.004	0.000	0.002
	1000	0.003	0.000	0.001	0.005	0.002	0.003	0.002	0.001	0.002	0.004	0.002	0.003
	2000	0.008	0.000	0.001	0.004	0.002	0.002	0.001	0.002	0.001	0.003	0.001	0.003
Leaves	0	0.007	0.002	0.003	0.002	0.005	0.002	0.004	0.001	0.004	0.004	0.002	0.003
	500	0.006	0.001	0.002	0.003	0.005	0.002	0.003	0.001	0.003	0.005	0.001	0.005
	1000	0.003	0.001	0.002	0.003	0.003	0.002	0.001	0.001	0.002	0.003	0.003	0.002
	2000	0.001	0.000	0.002	0.003	0.000	0.001	0.001	0.001	0.001	0.002	0.0000	0.001

There was a high loss of accumulation of metal in roots and stems than in the leaves on adding extra amount of water (Table 4). This finding was consistent with results of Verbruggen et al [24] who found that due to the molecular nature of metal substances dissolved or suspended in water accelerates their flow with gravity rather than evapotranspiration. This therefore makes them to be carried away by water, further away from the plant roots, during the leaching process and may thus, go further away from the reach of the plant roots.

The highest bioaccumulation in Papyrus occurred in the roots, although there were a few exceptions in which the stems accumulated more heavy metals than the roots (Table 5). It is also evident that the highest uptake of the heavy metals occurred in containers in which the least amount of extra water was added. This demonstrated that absorption is a function of the level of leaching which is directly dependent on the amount of water added in every container. It was also observed that time influenced level of uptake of the heavy metals.

Table 5. Sum accumulation of Lead, Copper and Chromium in Papyrus in 12 Months

Part of the plant	Sum accumulation for 12 Months under 0ml extra additional water		
	Copper (Cu)	Lead (Pb)	Chromium (Cr)
Roots	0.040 (45.45%)	0.018 (47.37%)	0.016 (42.11%)
Stem	0.031 (35.23%)	0.011 (28.95%)	0.010 (26.32%)
Leaves	0.017 (19.32)	0.009 (23.68%)	0.012 (31.58%)
Totals	**0.088**	**0.038**	**0.038**

Figure. 3 shows the total amount of heavy metals absorbed by Papyrus as a plant over the four harvesting seasons. Copper is the highly absorbed metal with its absorbed quantity increasing with time. However, on increasing the amount of extra added water, the accumulated quantity reduced due to leaching process. The amount of extra amount of water added did not have a great influence on the amount of absorbed chromium and lead in the first 3 months of harvesting. However, there was no traces of lead absorbed on added 2000ml of extra water during the first harvesting session.

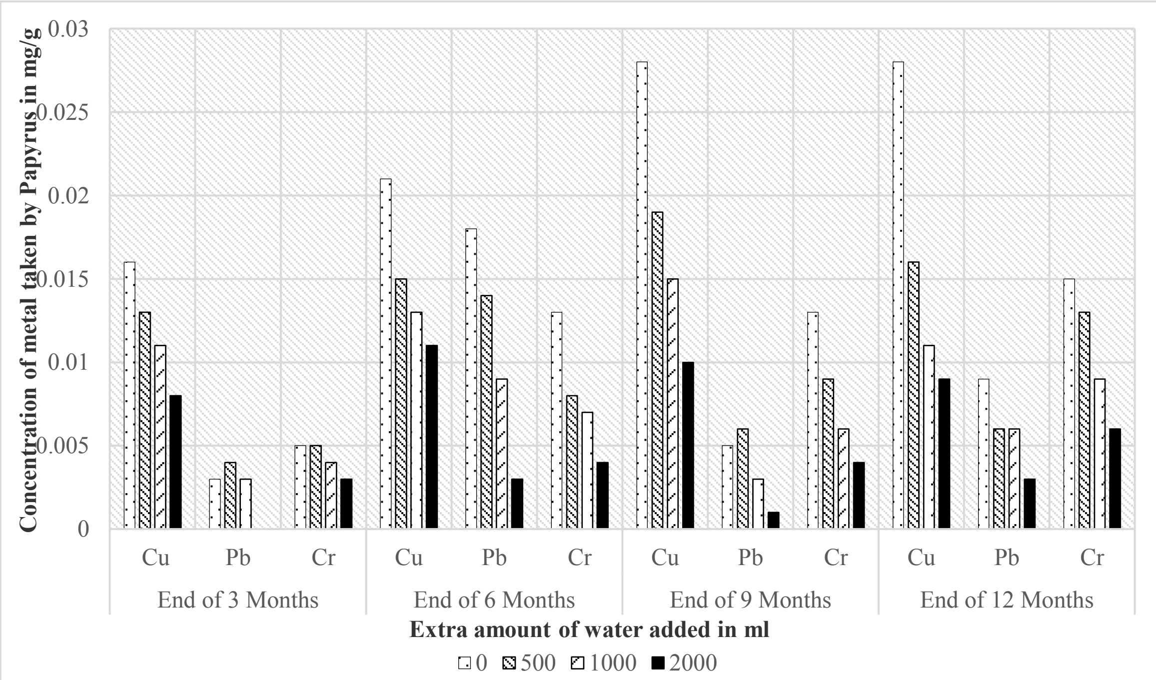

Figure 3. Accumulation of heavy metals by Papyrus plant

Table 6. Effectiveness of bamboo and papyrus on bioremediation of soil contaminated with petroleum sludge

	Concentration in mg/g				
	Ambient concentration in contaminated soil	**Highest accumulation by Bamboo**	**Highest accumulation by Papyrus**	**% accumulation by Bamboo**	**% accumulation by Papyrus**
Lead (Pb)	0.101	0.055	0.018	54.45	17.82
Copper (Cu)	0.174	0.093	0.028	53.45	16.09
Chromium (Cr)	0.137	0.02	0.015	14.60	10.95

The study results depict that Bamboo is an effective plant to accumulate heavy metals in petroleum contaminated soil over a long period of time while Papyrus accumulates heavy metals over a short period of time even in presences of extra amounts of water in the soil. This study augers well with the findings of Murányi and Ködöböcz [25], who recommended that bioaccumulation takes a long time and for practical establishment of effectiveness of bioaccumulation, Bamboo should grow in the contaminated media for at least five years. It is further noted that both Bamboo and Papyrus accumulate copper and lead more in the roots than in leaves, however, chromium is most accumulated in leaves. The trend of metal accumulation by the plants can be associated with the translocation and immobilization of the metals as they travel up to the leaves. However, Van et al [26] argue that, the accumulation can be facilitated using chelating agents such as Ethylene-Diamine-Tetra-Acetic acid (EDTA).

Table 6 shows a comparison of bioaccumulation of the heavy metals by the Bamboo and Papyrus plant species. The study recommends that in disposal of plants grown in petroleum contaminated soil, one should consider the part of the plant since they accumulate heavy metals at different levels.

4. Conclusions

This study sought to determine the effectiveness of Bamboo and Papyrus plant species in bioremediation of soils contaminated with petroleum sludge. The following conclusions were drawn;

i. Both Bamboo (*Phyllostachys pubescens*) and Papyrus (*Papyrus cyperus*) exhibited a definite trend of absorbing lead, copper and chromium from soil contaminated with petroleum sludge.
ii. The most accumulation of heavy metals taken up by Bamboo and Papyrus occurs in the roots with the least in the leaves. This accumulation is due to both absorption and adsorption of the plants.
iii. Longer time of growth of Bamboo and Papyrus in soil contaminated with petroleum sludge improves bioaccumulation. Bioaccumulation is directly

dependent on the ambient concentration of the heavy metals in soil and rate of leaching.

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