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Original Research Article

Comparative Analysis Of Tomato Plant (*Lycopersiconesculentum*) And Stubborn Grass (*Eleusineindica*)In The Phyto-Remediation Of Soils Polluted With Heavy Metals

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There is a continuous waste discharge and pollution of the environment due to the increase in establishment of industries and factories in Nigeria. Waste treatment facilities are less considered, due to their high cost and maintenance, but phytoremediation offers an option towards solving this problem. Investigations were carried out to compare the remediating capacity of tomato plant and stubborn grass in reducing the pollution caused by heavy metals, namely Lead (Pb), Zinc (Zn) and Copper (Cu).Soil samples were taken from 6 different points at an industrial estate in Ibadan, South-western Nigeria and these were analyzed to determine the level of contamination of the afore mentioned pollutants. 7 wooden seed boxes were constructed for the experiment. All were filled to a depth 15cm with polluted soil after which tomato and stubborn grass were planted inside the three seed boxes, each with a varied population of 10, 20and 30 stands of plants while the last seed box was used as a control. Phyto-remediation was then carried out using the two plant species for a period of 8 weeks, after which soil analysis was performed to evaluate the changes in the contamination level of the soil.Both plants were found to be capable of remediating contaminated soil. In comparison with tomato, stubborn grass which removedabout 155.5 ppm of Pb was found to be a little less effective than tomato which removed 159.9 ppm. However, stubborn grass performed better in the uptake of Zn and Cu, removing323.0 and 152.3 ppm of Zn and Cu respectively, compared with tomato which removed 283.4 and 131.6 ppm of Znand Cu respectively. Moreover, total pollutant removed from the soil was found to be directly correlated with the number of plants used for remediation. It was concluded that stubborn grass is generally more efficient than a tomato plant in soil remediation and more efforts should be directed towards using phytoremediation as a cost-effective method of soil treatment.

Keywords Phyto-remediation, Heavy metals, Pollution, Waste management, Soil.

INTRODUCTION

Phytoremediation, a procedure in which plants are used to remove, transfer, stabilize or destroy contaminants in polluted soils, sediment, surface water and ground water has been suggested in some climes as a cost effective alternative (Alkorta et al., 2004; Terrie *et. al.,* 2009, Vangronsveld et al., 2009; Ziarati and Alaedini, 2014). Different plants possess different remediatingcapacities and a crop which can remediate a certain pollutant may not be the most suitable for another.Phytoremediating features are found in plant families such as *Brassicaceae, Lamiaceae, Scrophulariaceae, Cyperaceae, Poaceae, Apocynaceae, Cunoniaceae, Proteaceae, Euphorbiaceae, Flacourtiaceae, Violaceae*and *Fabaceae*(SUMATECS, 2008).

Phytoremediation is a good optional method to solve this problem due to its environmental friendliness, cost effectiveness, low initial cost, less manpower consumption and it does not require gathering of the polluted environmental material/medium before treating. Phytoremediation is less disruptive to the environment. It is suitable for most regions and climates and is driven by solar energy. It is aesthetically pleasing due to its plant use and reduces cost compared to traditional methods. This method of remediation does not require expensive equipment or highly specialized personnel. Phytoremediation can be applied in situ to remediate shallow soil and groundwater. It can also be used in surface water bodies and also controls erosion (Ghosh and Singh, 2005; Amin, 2011).Contaminated soils and waters pose a major

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environmental and health problem, which may be partially solved by phytoremediation technology (Schwitzguébel, 2001). A good example is its application after the nuclear accident at Chernobyl, Ukraine, in 1986, when phytotechnologists began using plants to decontaminate soil and water. The removal of heavy metals is governed by the processes of ion transport and hyper-accumulation in tolerant plants, after mobilizing the metals in the rhizosphere, phytodegradation and phytovolatilisation of organic xenobiotics have both to rely on the metabolism of foreign compounds in the plant (Schwitzguébel, 2001).

Four different phytoremediation systems are known and these are: Phytoextraction; also called phytoaccumulation which is the use of metal accumulating plants that translocate, remove or concentrate inorganic contaminants mostly metals from the soil into their roots, shoots or leaves (Annelies, 2010). Phytostabilization on the other hand is the use of plants to reduce the mobility of pollutants such as heavy metals and some organic contaminants at the root/soil interface of the soil (Terrie *et al.*, 2009). Phytovolatisationinvolves the use of plant in extracting contaminants from the soil, converting them into volatile form and transpiring them into the atmosphere (Mueller *et. al*, 1999) while phytodegradation; is the use of plants and associates to degrade organic contaminants to less toxic or non-toxic compounds or to breakdown complex organic molecules into simple molecules (Russell, 2005).

Uncontrolled waste disposal and its consequent negative environmental effects on soil and which has been attributed to increased industrialization has been of major concern in the developing world (Adejoh, 2011; Cherniwchan, 2012; Kaur-Dhami et al., 2013). However, setting up of the waste treatment facilities is less considered due to high cost of procurement and maintenance (Eapen and D'Souza, 2005). Moreover, seepage and infiltration of untreated waste that may contain heavy metals, dangerous to the ecosystem has been noticed in many industrialized areas (Ghanam, 2005). The remediation of such soils is of utmost importance. Availability of local plants to achieve phytoremediation would be a welcome development. This study was therefore carried out to evaluate the remediating capability of tomato plant and stubborn grass to reduce pollution from lead, zinc and copper.

MATERIALS AND METHODS

Sampling Site and Sampling Methodology

The Oluyole Industrial Estate in Ibadan Oyo State, Nigeria was used as the source of experimental samples because of the presence of many industries at this location and pollution of the surrounding soils have been reported (Ogedengbe and Akinbile, 2010; Osibanjo et al., 2011; Agaja *et al.* 2013). It was observed that subsistence farming is being carried out around these afore mentioned companies without prior analysis of the soil. Soil sampleswere taken from 6 different points in the industrial estate and analyzed to detect the level of contamination of Lead, Zinc and Copper as shown in Figure 1. The contaminated soil was collected at a depth ranging between 10cm to 15cm so as to obtain soil samples within the root zone of the plants to be tested. The soil was mixed thoroughly and 17 kg was weighed and poured into each of the wooden seed box. Soil wetting, in preparation for planting was the concluding part of the soil preparation for the experimental setup. Wooden seedbeds of dimension 0.61 x 0.31 x 0.23 m (Figure 2) were constructed and filled to a depth of 15cm with contaminated soil. Filling depth of 15cm was used because tomato and stubborn grass have rooting depth of 5 cm.

Tomato seedlings were first propagated on humus soil in a nursery for three weeks before transplanting. An average height of 15cm was achieved before transplanting, so as to ensure a high survival rate of the tomato plants.Stubborn grass was transplanted from the same source as the tomato plants. The grass is mostly propagated through vegetative means by transplanting its suckers. A single indivisible unit of the sucker from the parent grass was used for the experimentation. Sixty (60) tomato seedlings were taken from the nursery and transplanted into three seed boxes. 10, 20 and 30 tomato seedlings were planted in seed boxes A, B and C respectively as shown in Figure 3.

Stubborn grass on the other hand was separated into the smallest indivisible and viable sucker. Sixty suckers were used for the experiment, 10, 20 and 30 suckers planted in the seed boxes D, E and F respectively as shown in Figure 4. A seed box containing the same soil in the other seed boxes was used as a control for the experiment, no crop was planted in it and it was placed under the same condition with the other boxes. The seed box was labeled 'O'. The seed boxes were protected from rainfall.

Laboratory Analysis of soils

Soil analysis was performed to evaluate the changes in the contamination level of the soil with samples taken on a weekly basis. An improvised soil auger made of PVC pipe of 2cm internal diameter was used. The pipe is placed on the soil and driven down to take the soil along its profile. The pipe was washed after sampling from each of the seed box, to reduce the alteration of the concentration of contaminant in each seed box. Soil samples were kept in glass bottles and sent to laboratory for heavy metal analysis within 2-3 hours of sampling. A total of 56 soil samples was collected over a period of 8 weeks.

RESULTS AND DISCUSSIONS

Initial Pollutant Concentration in Soil

Laboratory analysis showed that of the 6sampling points, mean contamination levels were higher than the permissible levels when compared with the Federal Environmental Protection Agency regulations (FEPA, 1991) as shown in Table 1.The acceptable limit of the heavy metals in the selected soil was exceeded due to the industrial activities and waste discharge.

Effects of Tomato Plants on Remediation

Lead Reduction

Seed box A containing 10 seedlings of tomato had the lowest remediating effect on the soil, among the set of boxes containing tomato plants. The Pb removal at the first week was 27 ppm and the total removal after the eighth week was 186 ppm.Seed box B containing 20 seedlings of tomato had a higher reduction level of Pb than seed box containing 10 seedlings of tomato, it was noticed that 33 ppm reduction was obtained at the first week while the total reduction was 219 ppm for the eight weeks.

Figure 1: Soil Sampling

Fig 2: Wooden seed boxes

Figure 3: Sampling glassware and tomato seed boxes

Figure 4: Stubborn grass seed boxes

Table 1: Initial and Stipulated Concentration of Metals

PARAMETER	Initial Concentration(ppm)	Stipulated Concentration(ppm)
Pb^{++}	692	250-500
Zn^{++}	913	300-600
Cu^{++}	326	50-150

In the group of boxes containing tomato plants, seed box C containing thirty seedlings of tomato had the highest reduction with respect to Pb and the initial reduction after the introduction of the tomato plants was 41 ppm while 257 ppm was the total reduction made for the period of experimentation. The trend observed in comparison with the control is shown in Figure 5.

Zinc Reduction

56 ppm reduction of Zn was obtained during the first week from the seed box containing 10 tomato seedlings and a total reduction of 365 ppm was achieved by 10 tomato plants at the end of 8 weeks. Seed box containing 20 tomato seedlings after week 1 had a zinc reduction of 66 ppm and the total reduction of 412 ppm after eight weeks.Seed box C having thirty tomato seedlings had the highest initial reduction of 77 ppm with respect to tomato plant extraction of zinc from the contaminated soil and 454 ppm was the total Zn reduction in the seed box C for eight weeks. The trend observed in comparison with the control is shown in Figure 6.

Copper Reduction

Seed box A containing 10 tomato seedlings have the lowest reduction of copper except for the control seed box. 16 ppm reduction was removed in week1, this is slightly higher than the 15 ppm reduction obtained in the control experiment box.

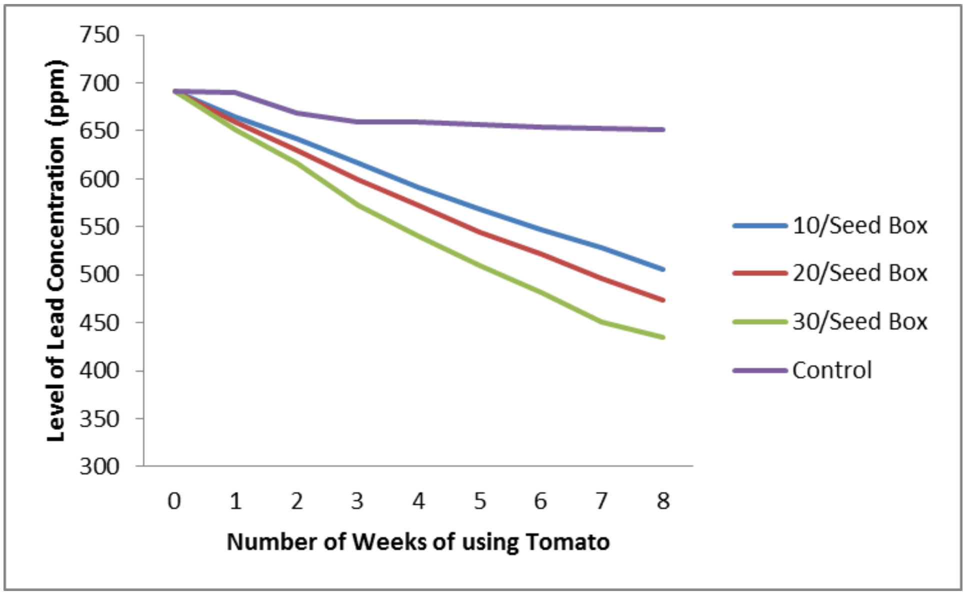

Figure 5: Lead Phytoremediation Using Tomato

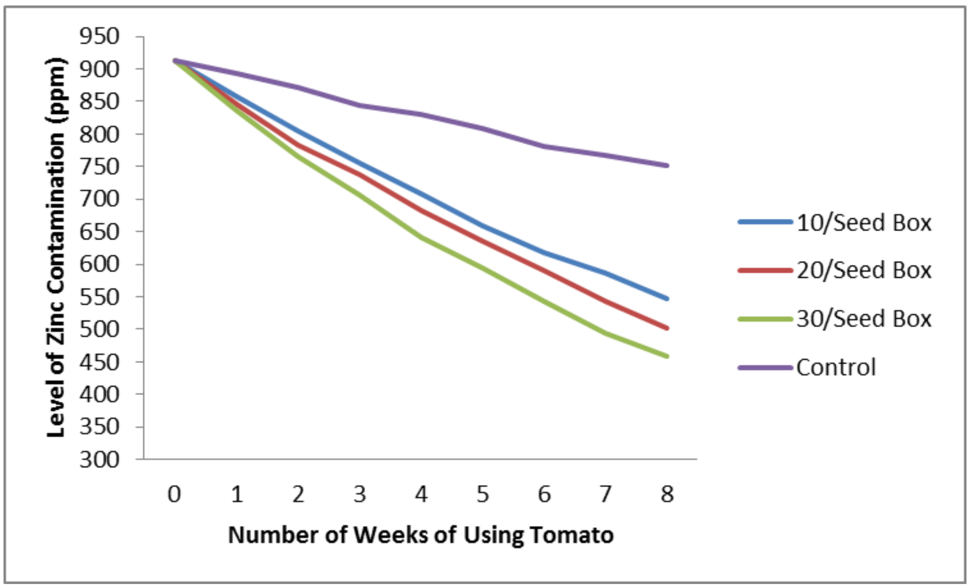

Figure 6: Zinc Phytoremediation Using Tomato

The sparse population of tomato plants can be considered not to have a much remediating effect on copper. The total copper removal after eight weeks was 109 ppm. The reduction of copper obtained at seed box containing 20 tomato seedlings after the first week was 25 ppm and a total reduction of 147 ppm for the period of experimentation. The seed box containing 30 tomato seedlings had the highest reduction of copper with respect to tomato plants, the reduction of copper in the first week was 29 ppm and the total reduction was 205 ppm. The trend observed in comparison with the control is shown in Figure 7.

Effects of Stubborn Grass on Remediation

Lead Reduction

Seed box D containing 10 seedlings of stubborn grass had a lesser reduction than seed box A containing 10 tomato seedlings. 24 ppm of Pb was removed at the first week and this was also lesser than the reduction in the seed box containing 10 seedlings of tomato. The total reduction of 189 ppm was obtained. Seed box E containing 20 seedlings of stubborn grass had 32 ppm reduction of lead in the first week and a total reduction of 224 ppm after eight weeks.

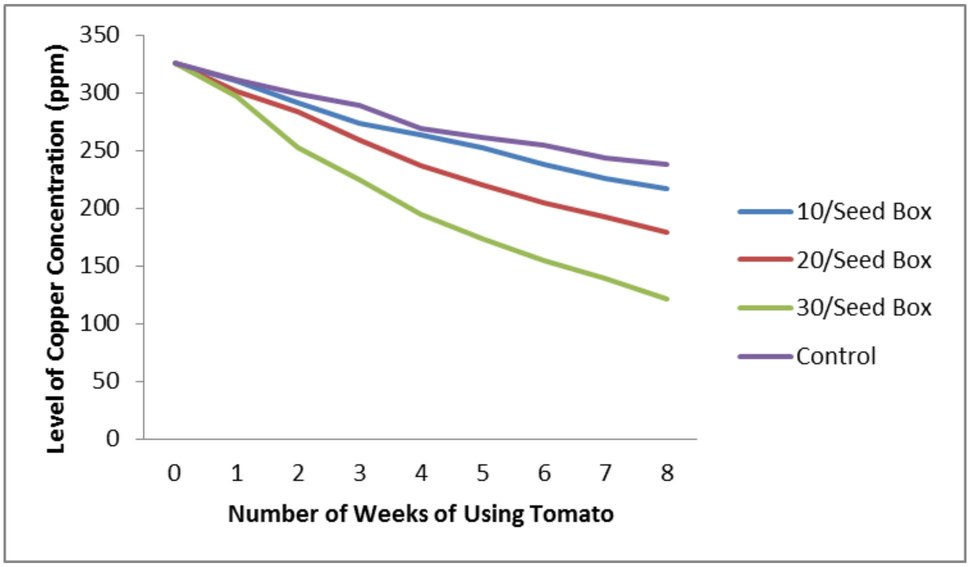

Figure 7: Copper Phytoremediation Using Tomato

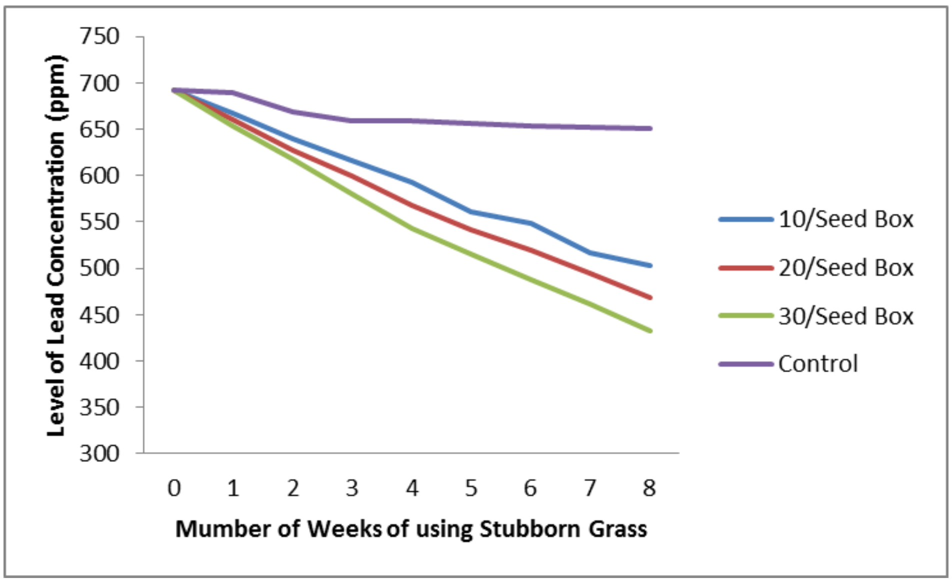

Figure 8: Lead Phytoremediation Using Stubborn Grass

Thirty stubborn grasses were contained in seed box F and its reduction of Pb at week 1 was 39 ppm, which is greater than the reduction in seed box D and E containing stubborn grass but less than seed box C containing tomato seedlings with corresponding number of plants. 259 ppm total reduction of Pb was achieved by the seed box F and this is the largest reduction with respect to lead reduction. The trend observed in comparison with the control is shown in Figure 8.

Zinc Reduction

Zinc reduction in seed box D containing 10 seedlings of stubborn grass for the first week was 58 ppm while the total reduction was 370 ppm. Reduction in the seed box containing 20 seedlings of stubborn grass was greater than that in seed box A, B, C and D. 486 ppm was the total reduction carried out by 20 stubborn grasses while the 1st week's reduction was 82 ppm.In seed box F containing 30 stubborn grass seedlings, the removal of zinc after week 1 was 88 ppm and the average removal is 523 ppm. The reduction noticed in seed box F is greater than the other seed boxes used. The trend observed in comparison with the control is shown in Figure 9

Copper Reduction

Seed box D had the lowest reduction of copper using stubborn grass, but this reduction is still higher than the remediation obtained from seed box A having 10 tomato seedlings. 184 ppm of copper was removed in seed box E containing 20 stubborn grass seedlings after the period of 8 weeks, the

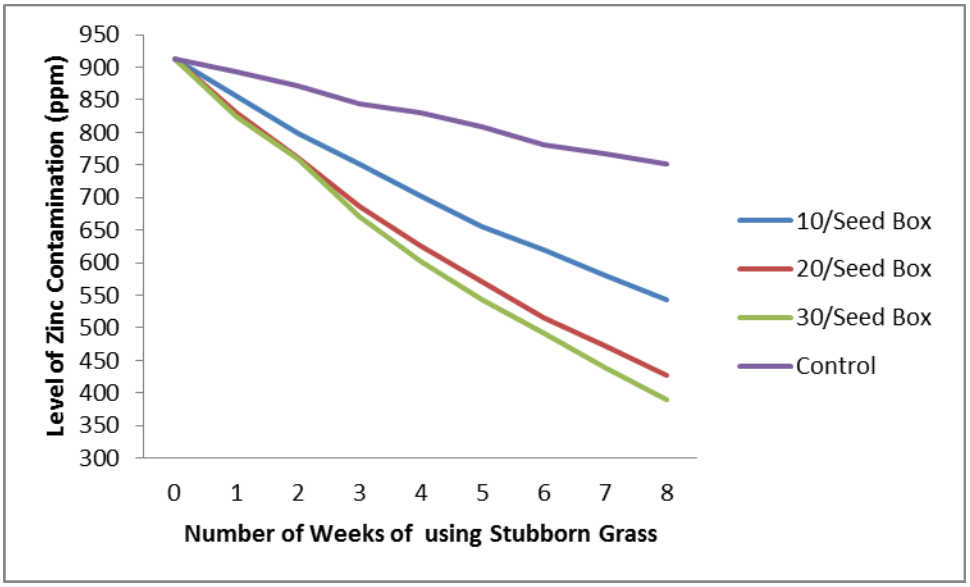

Figure 9: Zinc Phytoremediation Using Stubborn Grass

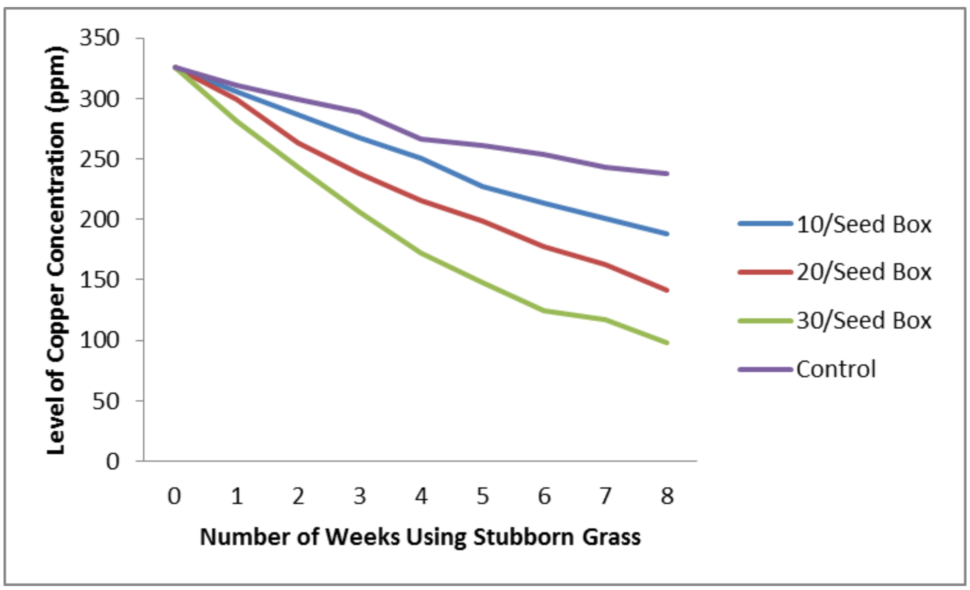

Figure 10: Copper Phytoremediation Using Stubborn Grass

uptake at week 1 in this box was 27 ppm. Seed box containing 30 stubborn grass seedlings had the highest copper removal of 228 ppm, the removal after week 7 was higher than the total removal of copper made by each of the seed boxes A, B, C, D, E and O. The trend observed in comparison with the control is shown in Figure 10.

Comparative Analysis of Tomato Plant and Stubborn

Grass on Soil

The reduction in concentration of Pb, Zn and Cu in each of the seed box for the eight weeks of experimentation varies due to the characteristics of the plants used. The pollutant removal can also be attributed to the population of the plants and the different plant type, except for the control box which had no plant and the trend of its reduction was low as compared to other boxes containing plants.

The tomato plant had a high initial extraction rate compared to stubborn grass. The reduction rate of tomato at the beginning of the remediation was a little higher than the stubborn grass. But it was observed that the stubborn grass had higher remediating strength more than the tomato. Extraction of Zn from the soil was higher in stubborn grass than in a tomato plant, the reduction of zinc at week 1 in seed box E containing twenty stubborn grasses was higher than the reduction in seed box C containing thirty stubborn grasses. Copper reduction of the two plants differs greatly because the total removal by ten tomato plants was 109 ppm, while ten stubborn grasses had total removal of 138 ppm. The initial reduction of copper in stubborn grass seed boxes is higher than those in tomato plant seed boxes. This is shown by the extraction of 45 ppm in seed box F and 29 ppm in seed box C that contain the corresponding number of plants.In the extraction of Lead from the polluted soil, tomato had a higher initial rate of uptake and a lower total reduction than stubborn grass which had a lower initial rate of up take but higher total reduction. Also, the removal of zinc by tomato is lower compared to stubborn grass throughout the study. Seed box A containing 10 tomato seedlings met the stipulated standard for only zinc on weeks 7 and 8. In seed box B containing 20 tomato seedlings, the standard for Pb was attained at week 7, Zn at week 6 while the standard for copper was not achieved. Seed box C containing 30 tomato seedlings attained the stipulated range of Pb at week 6, copper at week 5 and zinc was achieved at week 7. For stubborn grass, seed box D containing 10 stubborn grass seedlings met the stipulated standard only for zinc in week 7. In seed box E, stubborn grass attained stipulated concentration for Pb at week 5, copper at week 8 and zinc at week 5 with 570 ppm, while copper standard was achieved at week 8. Stubborn grass attained stipulated standard for Lead at week 6, zinc with 543 ppm at week 5 and copper at week 5 in seed box F.

CONCLUSIONS AND RECOMMENDATIONS

Both plants used for the Phytoremediation process were capable of remediating the contaminated soil. It was discovered that stubborn grass was a very good alternative instead of using a plant that is edible and with economic value. Hence, apart from the use of stubborn grass to control soil erosion, it can also be used to clean up the environment. Variation in planting population affected the removal of the heavy metals from the contaminated soil as increasing plant population resulted in increased remediation. The growth of tomato was retarded and this can be attributed to the heavy metals present while stubborn grass grew without any sign of retardation.

Arising from the results, the following recommendations are made:

- The process of Phytoremediation should be improved on and promoted by Environmental Protection Agencies all over the world for environmental sustainability;
- A comparative study of crop yield on soils containing heavy metal contamination and on uncontaminated soil should be done;
- Heavy metal analysis should be carried out on soils, when planning for crop cultivation;
- Standards for waste disposal and effluent discharge on land or in water bodies should be strictly enforced by governments and Environmental Organizations.

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