PLANT BREEDERS ASSOCIATION OF NIGERIA
HYBRID ANNUAL CONFERENCE, MAKURDI 2023
(ISSN: 3027-088X)

IMPACT OF SELECTED JATROPHA PLANTS IN HEAVY METAL SOIL PRE AND POST INVESTIGATION FROM VICINITY OF DANGOTE CEMENT FACTORY, GBOKO BENUE STATE

Benjamin Paul Edoka, Thomas Okoh, Joseph Olalekan Olasan, Maureen Nkendilin Chukwu Godspower Ekeruo
Department of Botany, Joseph Sarwaarn Tarkaa University Makurdi Benue State
Department of Biological Sciences, National Open University of Nigeria, Abuja
Department of Plant Breeding and Seed Science, Joseph Sarwaarn Tarkaa University Makurdi Benue

Correspondence: edokapaul2014@gmail.com.

Abstract
Cement factory waste are soil pollutants which are repositories of heavy metals leading to wash off into agro- environments. This study evaluated Selected Jatropha plants in heavy metal Soil Pre and Post investigation from vicinity of Dangote cement factory, Gboko Benue State. A total of ninety-six soil pots 3x 4 x 8 factorials. 3 plants variety, 4 treatments and 8 replicates was arranged in a complete randomized design. Soil pots treatment composition T_0 (30kg undisturbed soil and 0 kg cement waste), T_1 (30kg undisturbed soil and 1kg cement waste), T_2 (30kg undisturbed soil and 2kg cement waste), T_3 (30kg undisturbed soil and 3kg cement waste). The plant seeds sown for 4 months after preliminary soil investigation of eight heavy metals (Mg, Cr, Pb, Co, Fe, Ca, Ni, and Hg). 36 plant tissues was harvested and taken to laboratory for acid digestion and subsequently analysed for heavy metals using an atomic absorption spectrophotometer. Post Soil investigation also conducted. Descriptive and inferential statistics using Mean, standard error of the mean, ANOVA, mean separation (post-hoc analysis was done using LSD method at 95% confidence limit. Result of the preliminary and post soil shows significant concentration level reduction in Mg, Cr, Pb, Co, Fe, Ca, Ni and Hg. (Pb 0.651 - 0.404 mg/l) (Cr 0.728- 0.459mg/l) (Ni 12.930 -5.895mg/l) (Co 0.649- 0.317mg/l), (Mg 30.270- 14.417mg/l), (Hg 0.649- 0.0005mg/l), (Ca 53.560- 28.864mg/l). Post Soil showed significant decrease. Uptake of heavy metals from the soil by Jatropha curcas Jatropha podagrica and gossipifolia showed greater efficacy. However, Nickel uptake in Jatropha podagrica showed greater efficacy of (1.684mg/L) while Cobalt level concentration in the three Jatropha species is significantly not different. Control soil (T_o) effect showed significant higher amount of calcium above T_1, T_2, and T3. Mg, Pb, Co, Fe, Ca, Ni and Hg were accumulated in the roots except chromium translocation from root to shoots. Pollution index, Bioconcentration index and Translocation index exceeds WHO Permisible level of 1.00. In conclusion, J. curcas, J. podagrica and J. gossipifolia shows great economical values and efficacy in clean-up of polluted soil.

Keywords: Cement waste, Contaminanted Soil, Heavy metals, Phytoremediation, Jatropha,

Introduction
Soil pollution with heavy metals is increasing day by day due to urbanization and industrialization (Zerrouqi *et al.,* 2018) and become a major global concern because of its toxicity and threat to human life and environment. Mining and smelting of metalliferous ores, sewage sludge application to agricultural soils are responsible for the migration of contaminants into non-contaminated sites as dust or leachate and contribute towards contamination of our ecosystem. Metal-contaminated sites are notoriously hard to remediate (Gupta *et al*., 2010). Remediation methods, such as excavation and landfill, thermal treatment, acid leaching and electro reclamation are not suitable due to their high

cost, low efficiency, large destruction of soil structure and fertility and high dependence on the specific conditions of the contamination, soil properties, site condition and so on. The use of plants to remove toxic metals from soils (phytoremediation) is being developed as a method for cost-effective and environmentally sound remediation of contaminated soils (Diwan, *et al*., 2010); Dhankher, 2011); Ganesan, V. 2012). Metal (hyper) accumulating plants have been sought that have the ability to accumulate and tolerate unusually high concentrations of heavy metals in their tissue. Several plants are accumulators of Nickel (Ni) and Colbat (Co) from contaminated soil. This process of extracting metals from the soil and accumulating and concentrating metals in the above-ground plant tissues enables plants to be used as part of a soil clean up technology (Conesa *et al.,* 2012). The study was conducted determine the impact of selected Jatropha plants in soil heavy metal pre and post investigation from vicinity of Dangote cement factory, Gboko Benue state.

Materials and Methods

Study Area

Fig1. Map Showing the Study Area **Source:www.maplandia.com/nigeria/benue**

Experimental Design

The pot experiment was conducted at the Biological garden (Botany Department of Joseph Sarwuan Tarkaa University Makurdi (JOSTUM), in January to March 2023. The Seeds of *Jatropha curcas, Jatropha gossypifolia* and *Jatropha podagrica* were sourced from the locality around Benue State. Identification was done at the Taxonomy and Agronomy Department respectively. Soil samples within the depth of 0 – 15cm was collected randomly around the location with a soil auger at the dump site sited at around the Cement Plant Gboko Benue state, Nigeria (7°18'N and 3°50'E), this dumb waste had been in use since 1992 (Abatyough and Bernard 2005). Coarse and other unwanted materials were removed from the soil samples before potting.

Control (undisturbed soil) was sourced from around the experimental site.

Samples from the waste site soil and control (undisturbed soil) were mixed, air dried, sieved with 2 mm mesh, followed by routine soil physico-chemical analysis and determination of heavy metals. Chromium (Cr), Lead (Pb), Mercury (Hg) Cobalt (Co) Iron (Fe) Magnesium (Mg) Calcium (Ca) and Nickel (Ni) using standard procedures. Seeds of *J. curcas*, *J. gossypifolia* and *J. podagrica* were planted into a germination tray, seedlings of about 5cm, and in good condition were transplanted into polythene pots containing 30kg contaminated soil. The experiment was set up in a 3 × 4 factorial, laid out in complete randomized design (CRD) and replicated eight times (Olamilekan *et al.,* 2019). The soil treatments composition (T_0, T_1, T_2, T_3) represented as: T_0 (30kg undisturbed soil and 0kg cement waste), T_1 (30kg undisturbed soil and 1kg cement waste), T_2 (30kg undisturbed soil and 2kg cement waste), T_3 (30kg undisturbed soil and 3kg cement waste). A total of 96 pots was generated per plant. Physico- chemical and heavy metal Preliminary study of the soil experimental pots was conducted, results shown of the pre-planting analysis in (Table 3). Consequently, post- planting investigation. Samples of the plants part (root and shoot) were harvested and soil samples taken from the pots after 12-15weeks of cultivation for heavy metal analysis. Heavy metals were analysed using Atomic Absorption Spectrophotometer (AAS) after acid digestion with diacid mixture of HCl and at 100ºC for 3h (Waterlot *et al*., 2012). A two-way ANOVA tests were done using the Minitab 16.0 software for analysis of data on soil metals, and physico-chemicals properties, plant growth parameters and plant's tissues uptake of heavy metals (Olamilekan *et al.,* 2019). A comparison using the Student's t-test at a 5% level was done to detect any significant differences between soil samples taken before planting and after harvest.

Plant Species

The three plant species selected for the pot experiment include *Jatropha curcas, Jatropha gossipifolia and Jatropha podagrica*. The seeds collected locally and screened in agronomy laboratory Joseph Sarwuan Tarkaa University Makurdi (JOSTUM) before planting. The genus *Jatropha*, which belongs to the family Euphorbiaceae and consists of 175 species (Olowokudejo, 1993) is so diverse both in vegetative and floral structure that it has been variously split or subdivided by taxonomists based on both the morphological and anatomical characteristics of the various species (Dehgan and Webster 1979; Abdul Rahaman and Oladele, 2010). The leaves in a decoction are used to treat fever in the form of a bath, while the juice is given to treat sores on the tongue of infants (Nadkami *et al.,* 1976; Odugbemi, 2008). Further, leaf decoction of *Jatropha gossypifolia* and *podagrica* has been used for bathing wounds, while its seeds are used as purgative and for treatment of body aches. Dehgan and Webster (1979) however considered the physic nut (*Jatropha curcas* L. [sect. *curcas* (Adans.) Griseb. subg. *Curcas* (Adans.) Pax) to be the most primitive form of the genus *Jatropha* and that species in other sections evolved from the physic nut or another ancestral form, with changes in growth habit and flower structures. It is generally believed that chemical identification of specific compounds will provide a greater insight into the relationships and differences among plant taxa (Akpabio, 1988; Oladipo and Illoh, 2012a).

Seed Planting and Growth Parameters

Jatropha curcas, gossypifolia and podagrica healthy seeds obtained locally was screened in Agronomy laboratory before planting. The pot experiment was carried out in botanical garden of Botany Department Joseph Sarwarn Tarkaa University Makurdi (JOSTUM) between

February and May, 2023. Prior to seed planting the 30kg soil pots contain various trace of cement waste contaminant homogeneously mixed. The soil is obtained from undisturbed fallow land. The pot experiment had four treatments, eight replicate and three Jatropha species and the study lasted four months. Seeds Germination rate of the variables was investigated, number of leaves. Plant height Stem girth, Leaf area measured monthly within the studied periods.

Soil Digestion

Soil pots samples were collected prior to seed planting and after using corer/auger. Sieved using a 0.5mm sieve size to remove debris as described by (Abatyough *et al.,* 2005). The sample was packed into sealable nylons bags, labelled and transferred to the Laboratory. One gram (1g) of soil was weighted into a beaker which was then digested with 10ml of concentrated hydrochloric acid and 5.0 ml of hydrogen peroxide in a ratio 2:1 (HCl 70% H_20_2, 30% 5ml). The beaker was covered with a watch glass and set aside during which the reaction would have subsided. The beaker and content were heated to not above 110^0c on a hotplate at 95^0c for 30sec interval until the volume in the beaker was about 2.5ml, soil dissolved and become colorless. The digest was allowed to cool and then transferred into a volumetric flask and subsequently diluted to a volume of 25ml using distilled Water hydrogen peroxide (H_20_2, 30% 25ml) in a volumetric flask. The resultant solution was then analysed for cadmium, chromium, copper, nickel, manganese with Atomic Absorption Spectrometer (AAS) instrument according to the method of APHA (1992). Calibration standards were prepared from the multi- element calibrated standard 2A (Agilent, USA, P/N 8500-6940) before analyzing each batch of the samples in triplicates.

Plant Tissue Preparation and Digestion

At fourth month, the harvested plant total fresh weight (FW) biomass, root length (RL) and shoot length (SL) was measured and recorded. Dried weight biomass was also measured after oven dried at 80^0c for 4hours in the laboratory. The plants were cut with Clippers at 1cm above soil into two parts Root(R) and Shoot(S) and were separated and labelled accordingly for proper identification. The plant roots and shoots were oven dried at 40^oc for 6hours until a constant dry weight was obtained and stored for chemical digestion. 5g roots and shoots dry samples was ground into powder with a cutting mill (Gm200 knife blender), while shoot leaves with an ultracentrifuge mill (Walkley and Black, 2003). 0.5 g of roots and shoots dry mass was weighed into a digestion tube, concentrated nitric acid ($HN0_3$, 70%, 5ml) was added. Afterwards, heated at 95% for 75min using a digestion plate (Hotblock 36. Position, 50ml environmental express, USA). After cooling, hydrogen peroxide (H_20_2, 30% 5ml) was added and the mixture was heated again at 95^oc for 30sec. The sample when cooled was diluted to 25 mL using distilled water and analyzed for total metals by ICP (U.S. EPA, 1983).

The digested samples was taken for Atomic Absorption Spectrometer (AAS) analysis. The analysis begin with selection and adjustments of various units of the machines, begin with selection and adjustment s of various units of the machines(i.e. lamp selection, wavelength selection, slit adjustment and flame adjustment) and the machine was standardized by aspirating 1000mg/l for all the metals were prepared and from their working solutions with concentrations within the range of 0.5mg/l were prepared by Seria dilutions (APHA, 1992; and Azumi and Bichi, 2010).The standard solutions were taken through the same digestion techniques as mentioned. After digestion, the solutions were taken as AAS and the absorbance value read and recorded. Graphs of absorbence vs concentration (i.e.) the caliberation curves) were plotted. The sample was then aspirated into the machine

and the absorbance value read and recorded. The concentration (in mg/l) was obtained by interpolating /extrapolating the values of absorbance from the caliberation curve. The procedure was repeated for all the 36 samples.

Statistical Analysis

The data generated were subjected to descriptive/inferential statistics and analysis of variance ANOVA at 5% level of significance. Statistical analysis for preciseness and fixed effect using two way analysis Variance (ANOVA) at 5% significant level. Post hoc (Turkey Honest (HSD) tests to check for differences between the values of the mean while comparism of the mean was done using Turkey Honest test (Diwan *et al.,* 2010). Finally, Soil Pollution assessment, Pollution Index (PI), Bioaccumulation Factor (BF) and Translocation Factor (TF) was calculated using equation as proposed by: (Zhuang, *et al.,* 2007; Barman *et al.,* 2000; Gupta *et al.,* 2008; Ramana , 2015; Paliza *et al.,* 2019).To assess contamination level of soil metal, (PI) of each metal was attributed to concentration of each metal post and pre soil interaction using equation below: $PI = C_n/B_n$ where C_n (mg/kg) is the measured concentration of each heavy metal and B_n is background value for each metal. The PI of each metal was classified as either low (p </1), moderate (1<PI<3) or highly contamination (PI>3). The Bio-accumulation Factor (BAF) was calculated according to the equation $BAF = P_{harvested\ tissue} / P_{soil}$ by (Rezvani and Zaefarian 2011). Where $P_{harvested\ tissue}$ is concentration of the target ions in the plant harvested tissue (roots, stem, and leaves) and P_{soil} is concentration of the same ions in soil. The Translocation Factor (TF) was calculated using equation below proposed by Ramana (2015): $TF = P_{shoots} / P_{roots.}$

Results

Preliminary Soil Investigation of four different soil treatment is presented in Table 2 below. The result showed significant difference in amount for all Heavy metals (Lead, Chromium, Nickel, Cobalt, Iron, Calcium and Mercury) quantified in milligram per litre (mg/L) Variations in the amount of measured Lead revealed that T_3 (30kg undisturbed soil and 3kg cement waste) recorded the highest amount of Lead metal (1.178 mg/L), significantly more than 0.876 mg/L of Lead recorded from T_2 (30kg undisturbed soil and 2kg cement waste), 0.500 mg/L of Lead recorded from T_1 (30kg undisturbed soil and 1kg cement waste) and 0.048 mg/L of Lead recorded from T_0-control (30kg undisturbed soil and 0kg cement waste).

Table 3: Preliminary Soil Investigation prior to planting.

Treatments	Pb	Cr	Ni	Co	Fe	Mg	Ca	Hg
T_0	0.048d	0.573d	14.690a	0.434c	0.583c	28.030b	57.170a	0.0001d
T_1	0.500c	0.648c	13.750ab	0.442c	0.607bc	28.690b	53.080ab	0.0011c
T_2	0.876b	0.813b	10.960b	0.510b	0.660b	31.240a	54.390a	0.0021b
T_3	1.178a	0.876a	12.300ab	0.541a	0.745a	33.120a	49.610b	0.0031a
LSD	0.072	0.061	3.334	0.024	0.056	2.191	4.509	0.0002
Mean	0.651	0.728	12.930	0.482	0.649	30.270	53.560	0.0016
SE	0.035	0.029	1.615	0.0118	0.027	1.061	2.184	0.0001

Table 7 shows the effect of Jatropha species on Heavy metals uptake. The result reveals differential responses among the three varieties of Jatropha in the uptake of all Heavy metals. Variations in the amount of lead showed that a higher uptake (0.0440 mg/L) was recorded for *Jatropha podagrica*, significantly different from the amount of lead uptake of 0.0370 mg/L and 0.0300 mg/L recorded for *Jatropha gossipifolia* and *Jatropha curcas* species respectively. Significant difference in the amount of chromium showed that *Jatropha gossipifolia* which recorded the highest uptake amount of chromium (0.1174 mg/L), differed statistically from chromium uptake amounts of 0.0589 mg/L and 0.0496 mg/L recorded for *Jatropha curcas* and *Jatropha podagrica* respectively. With respect to the amount of nickel taken up by plants, result showed that *Jatropha gossipifolia* recorded the highest uptake amount of nickel (2.0864 mg/L), significantly different from nickel uptake amounts of 1.5603 mg/L and 1.6847 mg/L recorded for *Jatropha curcas* and *Jatropha podagrica* respectively.

Table 7: Jatropha Species Uptake of Soil Heavy Metals

Jatropha	Pb	Cr	Ni	Co	Fe	Mg	Ca
J. gossipifolia	0.0370b	0.1174a	2.0864a	0.0637a	0.1272c	5.9553a	8.8000c
J. curcas	0.0300c	0.0589b	1.5603c	0.0634a	0.1384b	5.3172b	11.0407a
J. podagrica	0.0440a	0.0496c	1.6847b	0.0599b	0.1394a	4.9445c	9.9909b
LSD	0.0002	0.0005	0.0209	0.0006	0.0006	0.0015	0.0036
Mean	0.0372	0.0753	1.7771	0.0624	0.1349	5.4057	9.9439
SE	0.0001	0.0002	0.0104	0.0003	0.0003	0.0007	0.0018

Means that do not share same letter within a column are significantly different.

Table 17 shows the effect of Jatropha x treatment interaction on residual Heavy metals in post soil investigation. Differences in the amount of lead showed that the residual amount present in soil treatment T_3 planted with *Jatropha curcas* was higher (0.573 mg/L), significantly different from the amount of residual lead (0.188 mg/L) recorded in soil of T_1 planted with *Jatropha podagrica*. With respect to the amount of chromium found in soils however, result showed that soil treatment T_0 planted with *Jatropha curcas* also recorded the highest residual amount of chromium (0.586 mg/L), statistically different from the amount of residual chromium (0.326 mg/L) present in soil of treatment T_2 planted with same *Jatropha curcas*. The effect of Jatropha x treatment interaction on the residual amount of nickel from post soil investigation showed that soil treatment T_0 planted with *Jatropha gossipifolia* recorded the highest amount of residual nickel (8.355 mg/L), significantly different from the residual amount of nickel (4.914 mg/L) present in same soil of T_0, but planted with *Jatropha podagrica*. The interaction of Jatropha x treatments was also found to significantly influence the residual amount of cobalt from post soil investigations. Result showed that the residual amount of cobalt was highest (0.883 mg/L) in soils of T_1 planted with *Jatropha podagrica*, and was significantly different from residual cobalt amount of 0.216 mg/L recorded in soils of T_1 planted with *Jatropha gossipifolia* specie. Variations in the quantity of residual iron as influenced by Jatropha x treatment interaction showed that a higher iron quantity of 0.615 mg/L was recorded in soil of T_2 planted with *Jatropha podagrica*, and differed significantly from the residual iron amount of 0.285 mg/L recorded in soil of treatment T_1 planted with *Jatropha gossipifolia*. Different Jatropha x treatment interaction was also found to significantly

influence the residual amounts of magnesium. Result showed that when planted with *Jatropha podagrica*, the residual quantity of magnesium present in soil was highest (16.620 mg/L) in soils of T_1, significantly different from the residual quantity of magnesium (11.230 mg/L) present in soils of T_1 planted with *Jatropha curcas* specie.

Table 17: Post Soil Investigation after Plant Harvest

Jatropha	Treatments	Pb Soil	Cr Soil	Ni Soil	Co Soil	Fe Soil	Mg Soil	Ca Soil	Hg Soil
J. curcas	T_0	0.373c	0.586a	7.464b	0.296e	0.456g	14.640e	27.220g	0.000b
J. curcas	T_1	0.326d	0.474e	5.247j	0.253h	0.397h	11.230k	23.420k	0.000b
J. curcas	T_2	0.533b	0.326k	6.233f	0.273f	0.402h	12.120j	24.320j	0.0013a
J. curcas	T_3	0.573a	0.418g	7.373c	0.301d	0.543d	15.340c	26.220h	0.0012a
J. gossipifolia	T_0	0.294g	0.414h	8.355a	0.324c	0.285j	15.370c	37.640a	0.000b
J. gossipifolia	T_1	0.247j	0.363j	6.748d	0.216j	0.572c	14.430f	19.720l	0.000b
J. gossipifolia	T_2	0.253i	0.373i	5.713i	0.267g	0.322i	14.800d	25.910i	0.000b
J. gossipifolia	T_3	0.316e	0.424f	6.376e	0.243i	0.525e	16.420b	31.760d	0.000b
J. podagrica	T_0	0.304f	0.536c	4.914k	0.355b	0.463f	14.320g	29.320f	0.000b
J. podagrica	T_1	0.188k	0.566b	0.516l	0.883a	0.612ab	16.620a	32.620c	0.0011a
J. podagrica	T_2	0.275h	0.495d	5.793h	0.196l	0.615a	13.920h	31.640e	0.000b
J. podagrica	T_3	0.324d	0.533c	6.002g	0.202k	0.611b	13.81i	36.590b	0.0010a
LSD		0.002	0.002	0.002	0.002	0.002	0.026	0.017	0.0002
Mean		0.334	0.459	5.895	0.317	0.483	14.417	28.864	0.0004
SE		0.001	0.001	0.001	0.001	0.001	0.013	0.008	0.0001

Means that do not share same letter within a column are significantly different.

Pollution Index for Heavy metals in cement waste contaminated soils

The pollution indices (PI) of Heavy metals in soils contaminated from dump waste is presented in figure 3 below. PI for all Heavy metals revealed values less than one in the various soil treatments except for the amount of cobalt in soil treatment T_1 with PI score of 1.02.

Bio-cumulative factor for Heavy metals in cement waste contaminated soils using Jatropha species

Figure 4 shows the estimates of Bio-Cumulative Factor (BCF) in soils contaminated from Cement waste. The result of the study showed that the scores of BCF was less than TF for all Heavy metals (Table 22). Also, TF in Jatropha species were less than 1 for all Heavy metals except Chromium which recorded TF of 1.157. Results also showed that the use of Jatropha species recorded higher BCF in Iron (0.191) while the Lead metal recorded the least BCF of 0.048.

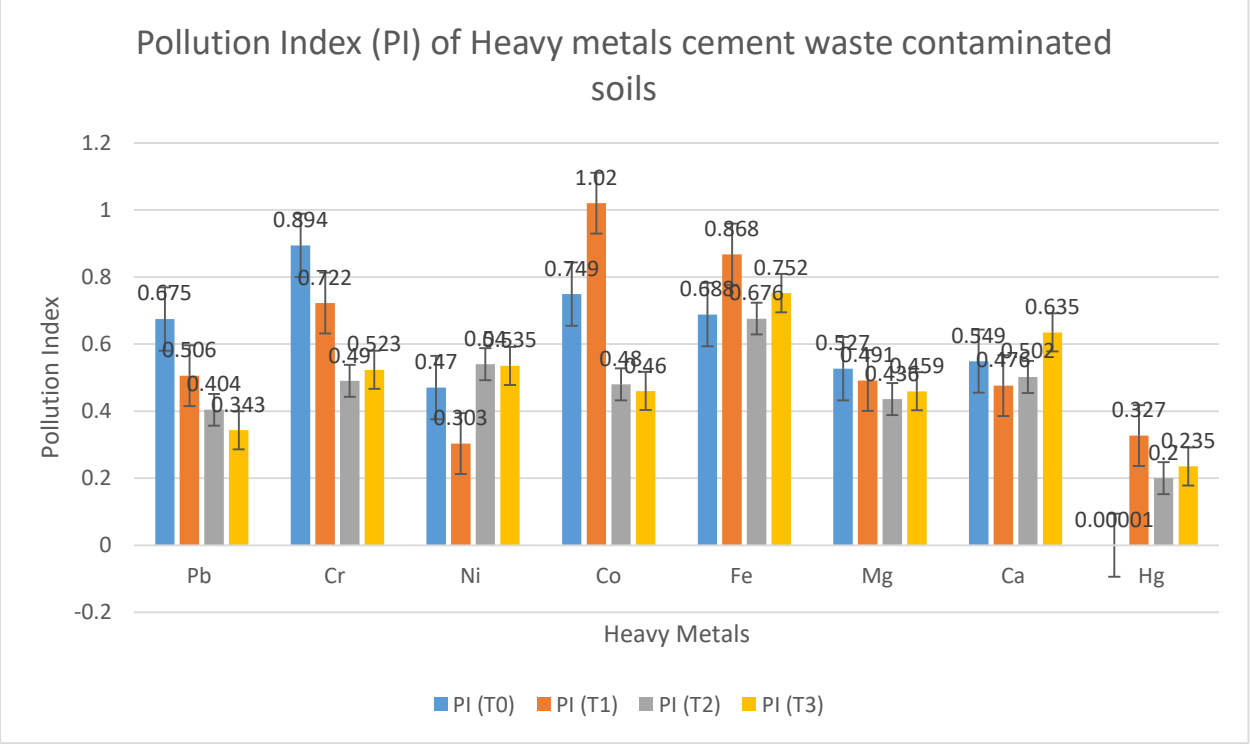

Figure 2: PI of Heavy metals in dump waste contaminated soils

Bio-cumulative factor for Heavy metals in cement waste contaminated soils using Jatropha species

Figure 4 shows the estimates of Bio-Cumulative Factor (BCF) in soils contaminated from Cement waste. The result of the study showed that the scores of BCF was less than TF for all Heavy metals (Table 22). Also, TF in Jatropha species were less than 1 for all Heavy metals except Chromium which recorded TF of 1.157. Results also showed that the use of Jatropha species recorded higher BCF in Iron (0.191) while the Lead metal recorded the least BCF of 0.048.

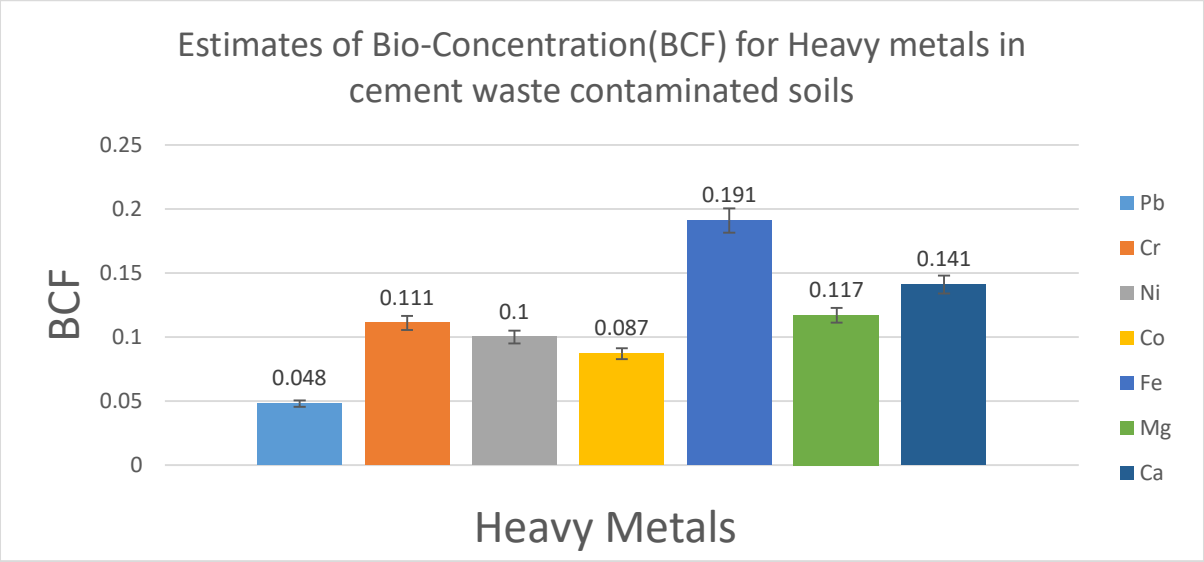

Figure 4: Estimates of BCF for Heavy metals in cement waste contaminated soils

Discussion

Cement based factories gives harmful leachates into soil and local water bodies, creates environmental hazards by way of depositing toxic heavy metals. The findings of the study reveals the presence of different heavy metals in the pre-soil pot investigation such as Lead, Chromium, Nickel, Cobalt, Iron, Magnesium and Calcium in varying concentrations at the cement site of Dangote cement factory in Benue State. And are dependent on the soil physiochemical such as electric conductivity, cation exchange capacity and pH values of the soil as observed to vary among the different soil treatments (Youssef and Chino 1989). The current study also validates Jatropha species an important perennial crop in phytoremediation and removal of heavy metals in soils. Following post investigation, the concentrations of heavy metals were observed to significantly decrease after planting the different species of Jatropha. This is affirmed in the findings of Sarma, (2011). With higher concentrations present in root than in shoot, it could be concluded that Jatropha species are characteristically successful in mobility and translocation of heavy metals into its biomass. Thus with reduced effect of toxic transfer into food chains (Pandey *et al.,* 2019). The phytoremediation of soil contaminated with hazardous substances while exploiting the inherent abilities of plants will provide ecological balance to the threatened environment polluted with various toxic (Abatyough *et al.,* 2015).

Conclusion

Findings from pre and post investigation as indicated in table 5, 7 and 17 shows *Jatropha caucas, Jatropha gosipifolia and Jatropha podagrica* have significant reduction of soil heavy metal concentration in the post soil when compared to the pre soil investigation findings, the vicinity of the industrial area under study is largely polluted with heavy metals from cement dust emmision and other mine activities.

Recommendation

All three species (*J.Curcas, J. gossipifolia and J. podagrica*) can be used in phyto-remediation of contaminated soil and a biomonitor of Heavy metal pollution. They can also be as demarcation around border line from the mine area.

References

Abatyough, M., Uyeh, D., Jibrin, U. and Abatyough, B. (2015). Distribution and Variation of Heavy Metals and Soil Properties around a Mega Cement Factory in Gboko, Benue State, Nigeria. MATTER: *International Journal of Science and Technology*, 4:385-394.

Abdulllahi, U.A., and Shuaibu, K.L. (2016). Phytoremediation of Contaminated Soils from Challawa Industrial Estate, Kano-Nigeria. *ScienceJournal ofAnalytical Chemistry*. 4(5):59-65.

Addo, M.A. *(*2012). Evaluation of Heavy Metals Contamination of Soil and Vegetable in the Vicinity of a Cement Factory in the Volta Region, Ghana. *International Journal of Science and Technology*, 2(1): 40-50.

Chaney, L. Angle, C. Broadhurst, C. Peters, R. Tappero, V. Donald, S. (2017). Improved understanding of hyperaccumulation yields Commercial Phyto extraction and phytomining Technologies, *Journal Environment Quality*, 36: 1429-1442.

Chang, F.C. Ko, C.H. Tsai, M.J. Wang, Y.N. Chung, C.Y. (2014). Phytoremediation of Heavy Metal Contaminated Soil by *Jatropha curcas*. *Journal of Ecotoxicology*, 23:1969–1978.

Dhankher, O.P. (2011). Biotechnological Approaches for Phytoremediation: In Plant Biotech. Agric. Ed A. Altman and P.M. Hasegawa. *Academic Press, Oxford*. Pp 309-328.

Diwan, H., Ahmed, A. and Iqbal, M. (2010). Uptake Related Parameters as Indices of Phytoremediation Potential. *Biologia* 65(6):1004-1011.

EL- Sherbiny, M. Ismail, M. and Al-Hefnawy, M. E. (2019). A Preliminary Assessment of Potential Ecological Risk and Soil Contamination by Heavy Metals around a Cement Factory, Western Saudi Arabia. *Open Chemistry*, 17:671-684.

Ganesan, V. (2012). Rhizoremediation: A Pragmatic Approach for Remediation of Heavy Metal-Contaminated Soil. In A. Zaidi et al. (eds.), Toxicity of Heavy Metals to Legumes and Bioremediation, *Springer-Verlag Wie*, 10:3-9.

Gupta, N., Yadav K.K. and Kumar, V. (2015). A Review on Current status of Municipal Solid Waste Management in India. *Journal of Environmental Science* 37:206-217.

He, Q., Ren, Y., Mohamed, I., Maha, A., Waseem, H. and Fangui, Z. (2013). Assessment of Trace and Heavy Metal Distribution by four Sequential Extraction Procedures in a Contaminated Soil. *Soil and Water Research*, 8:71–76.

Luhach, J. and Chaudhry, S. (2012). Phytoremediation potential of *Jatropha curcas* for removal of heavy metals from refinery sludge. *International Journal of Scientific and Engineering Research*, 3(10): 1-5.

Pandey, J., Verma, R. and Singh, S. (2019). Suitability of aromatic plants for phytoremediation of heavy metal contaminated areas: a review. *International Journal of Phytoremediation*, 21:1-14.

Sarma, H. (2011). Metal Hyperaccumulation in Plants: A Review Focusing On Phytoremediation Technology. *Journal of Environmental Science and Technology*, 4:118-138.

Schnoor, J.L. (2000). Phytoremediation of Toxic Metals, Using Plants to Clean Up the Environment (Eds: I. Raskin, Y. B. D. Ensley), *John Wiley and Sons*, New York, pp. 133–150.

Zerrouqi, Z., Shaa, M., Oujidi, M., Elkharmouz, M., Bengamra, S. and Zerrouqi, A. (2018). "Assessment of Cement's Dust Impact on the Soil Using Principal Component Analysis and GIS". *International Journal of Environmental Science and Technology*, 591: 125-134.

Wang, J., Anderson, C., Xing, Y., Fan, Y., Xia, J., Rinklebe, J. and Feng, X. (2018). Thiosulphate –Induced Phytoextraction of Mercury in *BrassicaJuncea*: Specttroscopic Investigations to Define a Mechanism for Hg Uptake. *Journal of EnvironmentalPollution* 242:986-993.

Waterlot, C. and Douay, F. (2012). Minimizing Chloride Interferences Produced by Calcium Chloride In: The Determination of Cd by Graphite Furnace Atomic Absorption Spectrometry. *ISRN Spectroscopy* 2012:1–10.

Waterlot, C., Bidar, G., Pruvot, C. and Douay, F. (2012). Effects of Grinding and Shaking on Cd, Pb and Zn Distribution in Anthropogenically Impacted Soils. *Talanta*, 98: 185–196.

Wu, Q., Wang, S., Thangavel, P., Li, Q., Zheng, H., Bai, J. and Qiu, R. (2011). Phytostabilization potential of *Jatropha curcas* L. in polymetallic acid mine tailings. *International Journal of Phytoremediation*, 13(8): 788-804.

Wuana, R. and Okieimen, F. (2011). Heavy Metals in Contaminated Soils: A Review of Sources, Chemistry, Risks and Best Available Strategies for Remediation. *ISRN Ecology*. 2011:1-20.

Wuana, R.A., Okieimen, F.E. and Imborvungu, J.A. (2010). Removal of Heavy Metals from a Contaminated Soil Using Organic Chelating Acids. *International Journal of Environmental Science and Technology*, 7: 485–496.

Yadav, S.K., Juwarkar, A.A., Kumar, G.P., Thawale, P.R., Singh, S.K., Chakrabarti, T.(2019). Bioaccumulation and Phyto-Translocation of Arsenic, Chromium and Zinc by *Jatropha curcas* L.: Impact of Dairy Sludge and Biofertilizer. *Journal of Bioresource and Technology*, 100: 4616–4622.

Yao, Z., Li, J., Xie, H. and Yu, C. (2012). Review on Remediation Technologies of Soil Contaminated by Heavy Metals. *Procedia Environmental Science Journal*,16:722-729.

Youssef, M.A. and Chino, M. (1989). Root-Induced Changes in the Rhizosphere of Plants. I. pH Changes in Relation to the Bulk Soil. *Journal of Soil Science and Plant Nutrition*, 35: 461–468.