***Chrysopogonnitrigana* (VETIVER GRASS) and *Chymbopogoncitratus* (LEMON GRASS) AS BIOSORBENTS FOR HEAVY METALS (Cadmium, Lead, Copper and Chromium) IN THE EFFLUENT WATER:A COMPARATIVE STUDY.**

 **ABSTRACT**

The introduction of foreign materials such as the heavy metals into the environment is attributed to the major reason of environmental adulteration and this has been linked to increased industrialization. Plants have shown great potency in the biosorption of these toxic elements from the environment*. Cymbopogon citratus* (lemon grass) and *Chrysopogonnitrigana* (vetiver grass) both terrestrial plants have been used in the present study for the uptake of heavy metals from a heavy metal containing effluent. A 50% (TRT 1) and 25% (TRT 2) effluent concentrations was used to hydroponically culture the plants for the heavy metal bioaccumulation. *Cymbopogon citratus* significantly (P<0.05) reduced the concentrations of cadmium by 97% and 99% in both TRT 1 and 2. Lead by 66% and 57%, chromium 48% and 38% and copper 99% and 73% in both treatments. *Chrysopogonnitrigana* significantly (P<0.05) took up the heavy metals from both treatments at 94% and 98% for cadmium, 29% and 20% for lead, 20% and 12% for chromium and 73% and 79% for copper. The data obtained from this study revealed that both plants have the capacity to take up heavy metals however, *Cymbopogncitratus* showed a higher removal efficiency of all the four studied heavy metals than *Chrysopogonnitrigana*.

**Keywords: Vetiver grass, Lemon grass, Heavy metals (Pb, Cu, Cd & Cr), Bioremediation, Hydroponics, Greenhouse.**

**INTRODUCTION**

Heavy metals discharged form industrial effluents, domestic wastes, physical and chemical weathering of rocks, soil erosion, agricultural run offs and sewage release could substantially damage the natural aquatic bodies (Alloway and Ayres, 1993). Heavy metals have been studied epidemiologically showing that they make up for a significant proportion of pollutants via industrial waste (Khalifa and Alkhakf, 2018). Chemical pollutants (such as the heavy metals) are involved greatly in the pollution of the aquatic ecosystem and they originate from dangerous chemical using industries left as a derivative of production process (Bill, 2010; Maczulak, 2010; Laboratory Chemical Waste Management Guidelines., 2016). Arsenic (As), cadmium (Cd), chromium (Cr), copper (Cu), mercury, lead (Pb), zinc (Zn) andnickel (Ni) are the eight top usual heavy metals linked with pollution according to Environmental Protection Agency (Athar and Vohora, 2001). Furthermore, subjection to heavy metals such as mercury, lead, cadmium and arsenic is the major cause of hazard to human health (Zeitoun and Mehana, 2014). The containment of heavy metals in the environment does more harm to life than good and should be as a matter of urgency not let into the biota by any means.Currently, heavy metals are a set of pollutant causing the most highly rated chaos in the environment including both land and water altering the natural ecosystem and giving rise to geo-ecological variances universally (Liu *et al,* 2003; Chabukdara and Nema, 2012). Threat is brought to humans, animals, aquatic resources and plants by the presence of heavy metals.

The process of utilizing plants for the eradication of harmful pollutants such as the heavy metals from the environment (soil, water and sediments) either via in situ or ex situ approach is referred to as phytoremediation (Aisien*et al,* 2010). The elimination of heavy metals from different parts of the ecosystem using plants has developed into an exploratory and practicable perspective (Mojiri., 2012). Phytoremediation was first discovered in the 16th century by Andrea Cesalpino and reports have shown that plants were proposed to be used in the remediation of polluted waters more than three hundred years back (Hartman, 1975; Brooks, 1998). According to Gupta *et al* (2013), a number of plant species adapt to growing in habitats contaminated with heavy metals. Plants employ two approaches to shield the organelles from the perturbing effects of heavy metals and they include; keeping under control the heavy metal take-up and applying tolerance mechanisms (Nedjimi, 2021). Phytoremediation involves biological, chemical and physical actions of plants in the biosorption, bioaccumulation and bio-detoxification of toxic pollutants in the ecosystem (Cunningham and Berti, 1993).Because phytoremediation is an inherent process of decontamination of toxic heavy metals, it does not require the use of heavy machineries (Babu*et al,* 2021). Plants present discriminating prospects in the bioaccumulation of heavy metals via phytoremediation (Bhargava *et al,* 2012). In the last two decennia, quite a number of plants with phytoremediation potentials for both polluted water and soil have been recognized (Liao and Chang, 2004). Hyper accumulator plants have gained much interest in recent times as a result of its usefulness in remediating heavy metal pollution (Nedjimi, 2021).So far, the use of plant based remediation particularly for the hyper accumulation of heavy metal waste has shown significant results and quite a number of examination have been carried out (Zhu *et al,* 1999). According to Baker *et al* (2000), records have it that over four hundred plant species have exhibited hyper accumulation potentials. Some plants have been successfully used in phytoremediation (Zhu *et al,* 1999; Gardea-Torresdey*et al,* 2005; Aisien*et al,* 2010).

Vetiver grass is a tropical plant known to withstand exceedingly frigid climatic conditions (Dorafshan*et al*, 2023). Vetiver grass has been extensively proliferated all over in the tropical locality and also all around the world for a long period of time (Gnansounou*et al*, 2017). Recently, Vetiver grass (*Vetiveriazizanioides*) was reclassified as *C. zizanioides* and it belongs to the family gramineae and was initially applied in the preservation and maintenance of water and soil (Roongtanakiat*et al*, 2007) and can also, an important tool in balancing of slope and controlling of erosion (Paz-Alberto and Sigua, 2013). According to Dorafshan et al (2023) and Paz-Alberto and Sigua (2013), Vetiver grass has the ability to breed and withstand very severe ecological situations. Due to the morphological and physiological attributes of Vetiver grass and high biomass production, it is therefore, regarded as a more potent and suitable agent in bioremediation and phytoremediation processes (Boonsong and Chansiri, 2008; Leguizamo *et al*, 2017; Davamani*et al*, 2021). Vetiver grass has exhibited very significant resilience to high concentrations of toxic metals like arsenic, chromium, lead, copper, nickel, zinc, mercury and selenium (Truong and Baker, 1996; Danh*et al*, 2009). Recently, macrophytes that possess rhizosphere microorganism (such as the Vetiver grass) have gotten recognition owing to the notable bioremediation properties they possess (Worku*et al*, 2018) and now has a global acceptance in the remediation of both inorganic and organic contaminants (Panja*et al*, 2020). Vetiver grass is a terrestrial macrophytes that grows favorably around wet ecosystem and does very well when subjected to soil-less culture media (Xia et al, 2000; Boonsong and Chansiri, 2008) and has been successfully cultivated hydroponically for the treatment of different types wastewater (Roongtanakiat*et al*, 2007; Ho *et al*, 2013; Darajeh*et al*, 2019; Davamani*et al*, 2021).

Lemon grass which is scientifically known as *Cymbopogon citratus*stapf (*C. citratus*) is a perennial crop or herb belonging to the section of Andropogoneae called *Cymbopogon* of the family of poaceae/gramineae possessing a somewhat branched partly aerial rhizome (Vaqar*et al,* 2007). They are very fast-growing plants also known as plants of warm climatic conditions (Vaqar*et al,* 2007; Shamsheer*et al,* 2020). Lemon grass contains citral; this is a cyclic monterpene the gives rise to the lemon-like smell hence, the prefix “lem” (Manvitha and Bidya, 2014). Lemon grass is made up of about 500 genus approximately and 8,000 herbs with a life span of about 5 years (Manvitha and Bidya, 2014; Sobh*etal,* 2014). This tropical aromatic herb or grass have the ability to grow up to a height of six feet also, it possesses bulging stem and glabrous leaves (Shah *et al,* 2011). Subject to the habitat, lemon grass contains a collection of compounds such as flavonoids, alkaloids and terpenes (Babarinde*et al,* 2016). The biosorption of heavy metals (copper, nickel, zinc, cadmium and lead) have been studied using lemon grass biomass (Zou *et al,* 2012; Lee *et al,* 2014; Sobh*et al,* 2014; Babarinde*et al,* 2016). The metabolism of glutathione and organic acids play a very vital role in the tolerance of plants to metals in which organic acids detoxifies the metals by creating complexes with the existing metals (Prasad and Freitas, 2003). *Cymbopogon citratus* (lemon grass) have been successfully grown under hydroponic conditions (Mairapetyan and Tadevosyan, 1999).

**MATERIALS AND METHODS.**

The present research was conducted in the University of Abuja, FCT, Nigeria. Abuja is located at the Nigerian central with latitude 8o86’N to 8o95’N and longitude 7o18’E to 7o29’E with a population of about 1,406,239 (Nnodu*et al,* 2017).



 **Map 1: Map of Abuja, FCT with the six Area Councils (Obi-Anike*et al*, 2017).**

**Effluent Collection**

The collection of the effluent was done according to Nanda *et al* (2010) and Woldeamanuale and Hassen (2017). Untreated paint effluent was obtained from a paint industry located (state the name of the facility and its location co-ordinates?) within Abuja, Nigeria. The preservation of the collected samples was done by storing the samples at the temperature of 4oC until use (State where the storage took place?).

**Plant Collection and Preparation**

As described by Savitha and Rajan (2018), viable plants of the same size (how many?) *Cymbopogon citratus* were collected from a neighborhood in Gwagwaglada, Abuja while *Chysopogonnigritana how many plants* was collected from the faculty of Agriculture, University of Abuja all within the FCT what is the location co-ordinates. The collected plants were allowed to acclimatize state the period of time (during)? and established to their new environment for a period of time (Gupta *et al*, 2022).

**Acid Digestion of the Effluent and Heavy Metal Determination**

The method described by by Juliani*et al* (2021), was adopted for the digestion of the effluent sample and the heavy metal contents of the paint based industrial effluent in this study was analysed using the Atomic Absorption Spectroscopy (AAS) Hanna HI Variian AAS SpectraAA 240FS, Italy. A standard solution was run with certified reference material in line with (Zulkafflee*et al,* 2020).

**Experimental Setup**

The method illustrated by Kumar *et al* (2018), Wang *et al* (2018) and Savitha and Rajan (2018), for greenhouse effect with a slight modification was adopted in the present study. Adapted plants of *Cymbopogncitratus* and *Chrysopogonnitrigana* species were transplanted into a 5 litres size tub with two effluent concentrations (50% and 25%). The tubs were kept were the plants could get enough sunlight. Samples were harvested after a six week period (Echiegu*et al*, 2021) for the final heavy metal determination. Both treatment period and acclimatization time lasted for about 63 days.

**Determination of Removal Efficiency (%) of the Test Plants**

The evaluation of the removal efficiency was carried out using the following formula (APHA, 2012).

Removal Efficiency (%) = Ci - Ce x 100 …………………….. Equation I

 Ci

Where;

Ci = initial concentration of the pollutant.

Ce = final concentration of the pollutant.

**Determination of Relative Growth Rate (RGR) of the Test Plants**

The relative growth rate (RGR) was evaluated at the beginning (before exposure to the effluent) and the end of the plant exposure to the effluent. The weight of the plant was determined with the use of analytical weighing scale while the length of the leaves and root was taken with the use of measuring tape in inches before conversion to centimeters (cm) as described by (Kumar *et al,* 2018) and (Gupta *et al*, 2022).

The formula below was used to calculate the relative growth rate (Aron, 1949).

Relative Growth Rate (RGR) = Ln W2 – Ln W1  ………… Equation II

 T2 – T1

Where;

W1 = initial weight of fresh biomass

W2 = final weight of the harvested biomass

T1 and T2 = the duration of the experiment in days.

**Statistical Analysis**

All values described were the means of the replicates. Microsoft excel were used in the calculation of mean, standard error, standard deviation and in the plotting of statistical graphs. Statistical Package for the Social Sciences (SPSS) version 25 for Windows was used for the Descriptive statistics, Kolmogorov-Smirnov-Test, One-way Analysis of Variance (ANOVA) and Turkey Post Hoc Test.

**RESULTS**

**Heavy Metal Uptake**

Two varying dilution factor of the effluent was used labelled TRT 1 (50% effluent concentration) and TRT 2 (25% effluent concentration). The uptake of four heavy metals (lead, cadmium, chromium and copper) was studied using *Cymbopogon citratus* and *Chrysopogonnitrigana*. In TRT 1, *Cymbopogon citratus* recorded the highest (P<0.05) uptake for all the four elements. *Cymbopogon citratus* significantly reduced the concentration of lead from 5.34 mg/L to 1.79 mg/L. Cadmium was reduced from 7.77 mg/L to 0.1 mg/L. chromium had initial and final concentrations of 0.20 mg/L and 0.13 mg/L and copper was reduced from 0.53 mg/L to 0.002 mg/L (figure 1). *Chrysopogonnitrigana*also significantly (P<0.05) reduced the concentrations of the heavy metals from the effluent. Lead was reduced to a final concentration of 3.79 mg/L, cadmium 0.13 mg/L, chromium 0.195 mg/L and copper 0.14 mg/L all by *Chrysopogonnitrigana*(figure 1).

**Figure 1. Heavy Metal Uptake by *Cymbopogon citratus* and *Chrysopogonnitrigana* in TRT 1.**

The second treatment (TRT 2) was also analysed for the heavy metal uptake by both plants. A similar pattern as obtained in TRT 1 was also observed in TRT 2 where the highest (P<0.05) heavy metal uptake was observed in the tub with *Cymbopogon citratus*.It reduced the concentration of lead from the initial concentration of 2.9 mg/L to 1.22 mg/L. Cadmium went from 3.96 mg/L to 0.12 mg/L, chromium (0.14 mg/L to 0.12 mg/L) and lastly, copper went down 0.03 mg/L from 0.27 mg/L. For *Chrysopogonnitrigana*, lead was reduced to 2.9 mg/L from 2.9 mg/L, cadmium, chromium and copper had the final concentrations of 0.24 mg/L, 0.12 mg/L and 0.03 mg/L (figure 2).

**Figure 2. Heavy Metal Uptake by *Cymbopogon citratus* and *Chrysopogonnitrigana* in TRT 2.**

**Removal Efficiency (%) of the Heavy Metals by the Plants.**

The removal efficiency for each plant on the four heavy metals was evaluated and *Cymbopogon citratus* had 66% and 57% lead removal from both TRT 1 and 2. 97% and 99% for cadmium, 48% and 38% for chromium while copper recorded 99% and 73% removal. The removal efficiency recorded for *Chrysopogonnitrigana* for lead in both treatments were 29% and 20%. Cadmium 94% and 98%. Chromium was at 20% and 12% while copper had a total removal upto 73% and 79% (figure 3).

**Figure 3. Removal Efficiency by *Cymbopogon citratus* and *Chrysopogonnitrigana* in TRT 1 and 2.**

**Relative Growth Rate (RGR) of the *Cymbopogon citratus* and *Chrysopogonnitrigana***

Both plants recorded reduced growth at the end of the study however, higher plant biomass reduction was observed in the TRT 2 pots. The TRT 1 pot had a more slight reduction. *Chrysopogonnitrigana* recorded a higher reduced growth rate compared to *Cymbopogon citratus* in this study (figure 3).

**Figure 4. RGR of *Cymbopogon citratus* and *Chrysopogonnitrigana* in the Effluent.**

**DISCUSSION**

The use of terrestrial plants in environmental cleanup has become a great and promising step in combating the menace of environmental pollution particularly that with heavy metals. Considering the hazardous effects of these elements, their eradication from the environment has become a matter of necessity and urgency. In this study, two terrestrial plants, *Cymbopogon citratus* and *Chrysopogonnitrigana* were studied to check for the plant with better heavy metal uptake from an effluent sample. In all the treatments (TRT 1 and 2) and for all the heavy metals (cadmium, lead, chromium and copper) analyzed, significant uptake has been observed by the two plants. However, *Cymbopogon citratus* gave the highest uptake for the four heavy metals when compared to its counterpart, *Chrysopogonnitrigana*. Aphytoremedial approach was employed in an integrated industrial wastewater for the bioremoval of chromium, iron, copper, lead and zinc using *Cannabis indica* and the removal efficiency recorded ranged between 40%-100% (Gupta *et al*, 2022).Jha et al (2023) also studied the bioaccumulation of heavy metals via plant roots and recorded 99.86%, 87.09% and 70.25%. *Chrysopogonzizanoides* was used in a hydroponic system for the bioremoval of lead and cadmium from the medium and the removal efficiency reported for both metals were 65.63% and 64.29% respectively (Davamani*et al*, 2021). Chromium has also been reduced by 92% while lead, copper and cadmium were reduced by more than 60% in a hydroponic system (Rababah and Al-Shuka 2009).*Cymbopogon citratus*has been reported in previous report to have significantly brought low the levels of lead and cadmium in a system by 95% and 83% (Ogucheet al, 2022).

In the present study, the maximum weight was recorded in *Cymbopogoncitratus* at 1.35kg final weight and the maximum length of plant was observed in *Chyrsopogonnitrigana* at 120.65 cm even with the reduced weight of the biomass that was observed.According to Hassan et al (2020), there was a reduction in the length of vetiver grass with elevated levels of leachate; however, there was no significant change in the biomass. Studies have shown that the biosynthesis of chlorophyll has been altered due to the accumulation of heavy metals in vital parts of the plants and as a result, has hindered the process of photosynthesis and also, alteration of cellular division in the leaves (Igwe and Nwachukwu, 2016). On another view, there were a few green leaves left on some of the plants (*Cymbopogon citratus*and *Chrysopogonnitrigana*). There could be lack of obvious growth inhibition by different plants from cadmium bioaccumulation even at saturation level, a great menace on the security and safety of food and the environment (Akinola and Ekiyoyo, 2006; Dong *et al*, 2007; Igwe and Nwachukwu, 2016).

**CONCLUSION**

The present study aimed to investigate the potential of two terrestrial plants (*Cymbopogon citratus* and *Chrysopogonnitrigana*) that could be efficient in the uptake of heavy metals (lead, cadmium, chromium and copper) from a metal containing effluent. Cadmium in particular was reduced from an initial concentration of 7.77 mg/L to 0.1 mg/L (which is the permissible concentration limit given for effluent by the WHO) by both plants. Significant reductions were also observed for the other heavy metals. The results obtained proved that both plants can be used effectively for the purpose of phytoremediation with special reference *to Cymbopogon citratus* which showed a higher and more efficient uptake of all heavy metals that were studied.

**REFERENCES**

Aisien, F.A., Faleye, O. &Aisien, E.T. 2010. Phytoremediation of Heavy Metals in Aqueous Solutions. *Leonardo Journal of Sciences*, 17: 37-46.

Akhtar, M., Sarwar, N., Ashraf, A., Ejaz, A., Ali, S. & Rizwan, M. 2021. Beneficial Role of *Azolla* sp. in Paddy Soils and their Use as Bioremediators in Polluted Aqueous Environments: Implication and Future Perspectives. *Archives in Agronomyand Soil Science,* 67(9): 1242-1255.

Akinola, M.O. &Ekiyoyo, T.A. 2006. Accumulation of Lead, Cadmium and Chromium in some Plants Cultivated along the Bank of River Ribila at Odonla Area of Ikorodu, Lagos state, Nigeria. *Journal of Environmental Biology*, 27: 597-599.

Alloway, B.J. & Ayres, D. 1993. Chemical Principles of Environmental Pollution. Blackie Academic, UK, pp. 140-149.

APHA, 2012. In: Standard Methods for the Examination of Water and Wastewater. Washington (DC): American Public Health and Association.

Athar, M. &Vohora, S.B. 2001. Heavy Metals and Environment; New Delhi New Age International Publisher, 3-40.

Aron, D. 1949. Copper Enzymes Isolated Chloroplast, Polyphenoloxidase in *Beta vulgaris*. *Plant Physiology*, 24: 1-15.

Babarinde, A., Ogundipe, K., Sangosanya, K.T, Akintola, B.D. & Hassan, A.E. 2016. Comparative Study on the Biosorption of Pb (II), Cd (II) and Zn (II) Using Lemon Grass (*Cymbopogon citratus*): Kinetics, Isotherm and Thermodynamics. *Chemistry Journal*, 2(2): 89-102.

Babu, S.M.O.F., Hossain, M.B., Rahman, M.S., Rahman, M., Ahmed, A.S.S., Hassan, M.M., Rakib, A., Emran, T.B., Xiao, T. &Simal-Gandara, J. 2021. Phytoremediation of Toxic Metals: A Sustainable Green Solution for Clean Environment. *Applied Sciences*, 11: 10348-10381.

Baker, A.J.M., McGrath, S.P., Reeves, R.D. & Smith, J.A.C. 2000. Ecology and Physiology of a Biological Resource for Phytoremediation of Metal Polluted Soils. *Phytoremediation of Contaminated Soil and Water*, 86-107.

Bhargava, A., Carmona, F.F., Bhargava, M. & Srivastava, S. 2012. Approaches for Enhanced Phytoextraction of Heavy Metals. *Journal of Environmental Management*, 105: 103-120.

Bill, H. 2010. Techniques for Efficient Hazardous Chemical Handling and Disposal. Pollution Equipment News. Pp. 13.

Boonsong, K. &Chansiri, M. 2008. Domestic Wastewater Treatment using Vetiver Grass Cultivated with Floating Platform Technique. *A.U. Journal of Technology*, 12(2): 73-80.

Brooks, R.R. 1998. Phytoremediation by Volatilization in Plants that Hyper-Accumulate Heavy Metals: Their Role in Phytoremediation, Microbiology, Archaeology, Mineral Exploration and Phytomining; CAB International: Wallingford, UK, 289-312.

Chabukdhara, M. &Nema, A.K. 2012. Assessment of Heavy Metal Contamination in Hindon River Sediments: A Chemo metric and Geochemical Approach. *Chemosphere*, 87(8): 945-953.

Cunningham, S.D &Berti, W.R. 1993. Remediation of Contaminated Soil with Green Plants: AN Overview. *In Vitrocellular and developmental Biology*, 29: 207-212.

Danh, L.T., Truong, P., Mammucari, R., Tran, T. & Foster, N. 2009. Vetiver Grass, *Vetiveriazizanioides*: A Choice Plant for Phytoremediation of Heavy Metals and Organic Wastes. *International Journal of Phytoremediation*, 11(8): 664-691.

Darajeh, N., Truong, P., Rezimia, s., Alizadeh, H. & Leung, D.W.M. 2019. Effectiveness of Vetiver Grass versus other Plants for Phytoremediation of Contaminated Water. *Journal of Environmental Treatment Techniques*, 7(3): 485-500.

Davamani, V., Parrameshwari, C.I., Subramanian, A., John, J.E. & Poornima, R. (2021). Hydroponic Phytoremediation of Paperboard Mill Wastewater by using Vetiver (*chrysopogonzizanioides*). *Journal of Environmental Chemical Engineering*, 9(4): 105528.

Dong, D.M., Liu, L., Xua, X.Y. & Lu, Y.R. 2007. Comparison of Lead, Cadmium, Copper and Cobalt Adsorption onto Metal Oxides and Organic Materials in Natural Surface Coatings. *Microchemical Journal*, 85: 270-275.

Dorafshan, M.M., Abedi-koupi, J., Eslamian, S. &Amiri, M.J. 2023. Vetiver Grass (*Chrysopogonzizanioides L.*): A Hyper-Accumulator Crop for Bioremediation of Unconventional Water. *Sustainability*, 15(4): 3529.

Echiegu, E.A., Ezimah, C.O., Okechukwu, M.E. &Nwoke, O.A. 2021. Phytoremediation of Emulsion Paint using *AzollaPinnataEichhorniacrassipies* and *Lemna minor*. *Nigerian Journal of Technology*, 40(3): 550-557.

Gardea-Torresdey. J.L., Peralta-Videa, J.R., la Rosa, G. & Parsons, J.G. 2005. Phytoremediation of Heavy Metals and Study of the Metal Coordination by X-Ray Absorption Spectroscopy. *Coordination Chemistry Reviews*, 249(1218): 1797-1810.

Gnansounou, E., Alves, C.M. & Raman, J.K. 2017. Multiple Application of Vetiver Grass – A Review. *International Journal of Environmental Sciences*, 2: 125-141.

Gupta, A.K., Verma, S.K., Khan, K. & Verma, R.K. 2013. Phytoremediation using Aromatic Plants: A Sustainable Approach for Remediation of Heavy Metal Polluted Sites. *Environmental Science and Technology*, 47(18): 10115-10116.

Gupta, U., Sharma, S.K., Goya, S.K. & Sharma, R. 2022. Removal of Heavy Metals from Integrated Wastewater (IIWW) using Canna Lilly (*Canna indica L.*): A Hydroponic System for Phytoremediation Potential. *International Advances Research Journal in Science, Engineering and Technology*, 9(4): 17-29.

Hassan, M.M., Haleem, N. Bac, M.A. & Jamal, Y. 2020. Phytoaccumulation of Heavy Metals from Municipal Solid Waste Leachate using Different Grasses under Hydroponic Condition. *Scientific Reports*, 10: 1-8.

Hartman, W.J. 1975. An Evaluation of Land Treatment of Municipal Wastewater and Physical Siting of Facility Installations. Washington D.C. US Department of Army. 432-467.

Ho, Y., Hsieh, J. & Huang, C. 2013. Construction of a Plant-Microbe Phytoremediation System: Combination of Vetiver Grass with a Functional Endophytic Bacterium, AchromobacterXylosoxidans F3B, for Aromatic Pollutants Removal. *Bioresource Technology*, 145: 43-47.

Igwe, A.C. & Nwachukwu, O.I. 2006. Soil Health, our Health: Effect of Paint Effluent Contaminated Soil on the Heavy Metal Content of Okra (*AbeelmoschusesculentusMoench*). *Nigerian Journal of Soil Science*, 26: 68-77.

Jha, G., Kawatra, N. & Dubey, A. 2023. Phytoremediation of Selected Heavy Metals Contaminated Water by *Amaranthus hybridus* in Hydroponic System. *Materials Today Proceedings*, 90(2):72-17.

Juliani, A., Rahmawati, S. &Yoneda, M. 2021. Heavy Metal Characteristics of Wastewater from Batik Industry in Yogyakarta Area, Indonesia. *International Journal of GEOMATE*, 20(80): 59-67.

Khalifa, F.K. &Alkhalf, M.I. 2018. Phytoremediation as a Cleansing Tool from Nanoparticles and Pharmaceutical Wastes Toxicity. In: Ansari A., Gill R., R. Lanza G. 435-464.

Kumar, V., Singh, J. & Chopra, A.K. 2018. Assessment of Growth Attribute, Bioaccumulation, Enrichment and Translocation of Heavy Metal in Water Lettuce (*Pistia stratiotes L*.) Grown in Sugar Mill Effluent. *International Journal of Phytoremediation*, 20(5): 507-521.

Lee, L.Y., Lee, X.J., Chia, P.C., Tan, K.W. & Gan, S. 2014. Utilization of *Cymbopogon citratus* (Lemon Grass) as Biosorbent for the Sequestration of Nickel ions from Aqueous Solution: Equilibrium, Kinetic Thermodynamics and Mechanism Studies. *Journal of the Taiwan Institute of Chemical Engineers*, 45(4): 1764-1772.

Leguizamo, M.A.O., Gomez, W.D.F. &Sarmient, M.C.G. 2017. Native Herbaceous Plant Species with Potential use in Phytoremediation of Heavy Metals, Spotlight on Wetlands – A Review. *Chemosphere*, 108: 1230-1247. Lenntech Water Treatment and Air Purification. “Water Treatment”, Published by Lenntech, 2004.

Liao, S.W. & Chang, W.C. 2004. Heavy Metal Phytoremediation by Water Hyacinth at Constructed Wetlands in Taiwan. *Journal of Aquatic PlantManagement*, 42: 60-68.

Liu, W.X., Li, X.D., Shen, Z.G., Wang, D.C., Wai, O.W.H. & Li, Y.S. 2003. Multivariate Study of Heavy Metals Enrichment in Sediments of the Pearl River Estuary. *Environmental Pollution*, 121(3): 377-388.

Maczulak, A. 2010. Pollution: Treating Environmental Toxins. New York: InfoBase Publishing, 120.

Mairapetyan, S.K. &Tadevosyan, A.H. 1999. Aromatic Plant Culture in Open-Air Hydroponics. *Acta Horticulture*, 502(3): 33-41.

Manvitha, K. &Bidya, B. 2014. Review on Pharmacological Activity of *Cymbopogon citratus*. *International Journal of Herbal Medicine*, 1(6): 5-7.

Mojiri, A. 2012. Phytoremediation of Heavy Metals from Municipal Wastewater by *Typha domingensis*. *African Journal of Microbiology Research*, 6(3): 643-647.

Nanda, M., Sharma, D. & Kumar, A. 2010. Removal of Heavy Metals from Industrial Effluent using Bacteria. *International Journal of Environmental Sciences*, 2(2): 781-787.

Nedjimi, B. 2021. Phytoremediation: A Sustainable Environmental Technology for Heavy Metals Decontamination. *Springer Nature Applied Sciences*, 36(286): 1-19.

Nnodu, V.C., Obiegbu, M.E. &Eneche, P.S.U. 2017. An Assessment of Sustainable Energy-Efficient Strategies for Retrofitted Building Development in Abuja, Nigeria. *Archives of Current Research International*, 9(1): 1-12.

Obi-Anike, H.O., Abomeh, O, S. & Okafor, C.N. 2017. Manpower Development and Employees’ Performance: Qualitative Assessment of Small and Medium Scale Business in Abuja Nigeria. *Journal of Economics, Management and Trade*, 18(3): 1-6.

Panja, S., Sarkar, D. & Datta, R. 2020. Removal of Antibiotics and Nutrients by Vetiver Grass (*Chrysopogonzizanioides*) from Secondary Wastewater Effluent. *International Journal of Phytoremediation*, 22(7): 464-773.

Paz-Alberto, A.M. &Sigua, G.C. 2013. Phytoremediation: A Green Technology to Remove Environmental Pollutants. *American Journal of Climate Change*, 2:71-86.

Rababah, A. & Al-shuha, A. 2009. Hydroponic Reducing Effluents Heavy Metal Discharge. *Water Science and Technology*, 59(1): 175-183.

Truong, P.N. & Baker, D. 1996. Vetiver Grass System for Environmental Protection. Royal Development Projects Protection. Technical Bulletin 1998/1, Pacific Rim Vetiver Office of the Royal Developmental Project Board.

Vaqar, H., Muhammed, S., Nusrat, S., Kamat, D. & Muhammed, Q. 2007. Lemon Grass: Botany, Ethnobotany and Chemistry- A Review. *Pakistan Journal of Weed Science Resource*, 13(1-2): 129-134.

Woldeamanuale, T.B. & Hassen, A.S. 2017. Toxicity Study of Heavy Metal Pollutants and Physico-Chemical Characterisation of Effluents Collected from Different Paint Industries in Addis Ababa, Ethiopia. *Journal of Forensic Sciences*, 5(5): 001-006.

Worku, A., Tefera, N., Kloos, H. &Benor, S. 2018. Bioremediation of Brewery Wastewater using Hydroponics Planted with Vetiver Grass in Addis Ababa, Ethiopia. *Bioresource and Bioprocessing*, 5(390): 1-12.

Xia, H., Liu, S. &Ao, H. 2000. Study on Purification and Uptake of Garbage Leachate by Vetiver Grass. In: Proceedings of the Second International Conference on Vetiver, Thailand, 18-22 Jan, 2000. 394-406.

Zeitoun, M.M. &Mehana, E.E. 2014. Impact of Water Pollution with Heavy Metals on Fish Health: Overview and Updates. *Global Veterinairia*, 12(2): 219-231.

Zhu, Y.L., Zayeed, A.M., Qian, J.H., De Souza, M. & Terry, N. 1999. Phytoremediation of Trace Elements by Wetland Plant: Water Hyacinth. *Journalof Environmental Quality,* 28: 339-344.

Zuo, X.J., Balasubramanian, R., Fu, D.F. & Li, H. 2012. Biosorption of Copper, Zinc and Cadmium Using Sodium Hydroxide Immersed *Cymbopogon schoenanthus L. Spreng* (Lemon Grass). *Ecotoxicological Engineering*, 49: 186-189.

Zulkafflee, N.S., Redzuan, N.A.M., Selamat, J., Ismail, M.R., Praveena, S.M. &Rajis, A.F.A. 2020. Evaluation of Heavy Metal Contamination in Paddy Plants at the Northern Region of Malaysia using ICP-Ms and its Risk Assessment. *Plants (Basel)*, 10(1): 3.

Roongtanakiat, N., Tangruangkiat, S. &Meesat, R. 2007. Utilization of Vetiver Grass (*Vetiveriazizanioides*) for Removal of Heavy Metals from Industrial Wastewater. *Science Asia*, 33: 397-403.

Savitha, J. &Rajan, T.V. 2018. Industrial Effluent Treatment by Phytoremediation. *International Journal of Innovative Research in Sciences, Engineering and Technology*, 7(1): 477-482.

Shah, G., Shri, R., Panchal V., Sharma, N., Singh, N. & Mann, A. 2011. Scientific Basis for the Therapeutic use of *Cymbopogon citratus*stapf (Lemon Grass). *Journal of Advanced Pharmaceutical Technology and Research*, 2(1): 3-8

Shamsheer, H.B., Yousaf, Z., Aftab, A., Younas, A., Riaz, N. & Rashid, M. 2020. Phenotypic Intraspecific Diversity Exploration among the Accessions of *Cymbopogon citratus* (D.C.) Stapf from Asia and American Sub-Continent through Multivariate Techniques. *International Journal of Biology and Biotechnology*, 17(4): 679-691.

Sobh, M., Moussaw, M.A., Rammal, W., Hijazi, A., Rammal, H., Reda, M., Toufaily, J. &Hamieh, T. 2014. Removal of Lead (II) Ions from Wastewater by Using Lebanese *Cymbopogon citratus* (Lemon Grass) Stem as Adsorbent. *American Journal of Phytomedicine and Clinical Therapeutics*, 2(9): 1070-1080.