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Seasonal Assessment of Heavy Metal Contaminants of a Hospital Wastewater and Potentials of Water Hyacinth, Water Lettuce and Vetiver Grass in Its Phytoremediation

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Abstract: Pollution is a major environmental issue in the world due to its adverse effect on living organism. In the past few decades, uncontrolled urbanization has caused serious pollution problem due to the disposal of sewage, industrial and hospital effluents to water bodies. In this study, the Heavy Metals concentration of a hospital wastewater treatment plants in Zaria, Kaduna state was assessed for a whole season to develop a baseline data on the pollution status of the water and the potentials of water hyacinth in the phytoremediation of the water was evaluated for further removal of the contaminants to reduce the pollution to a minimal status. Some Heavy Metals in the wastewater were analyzed like Co, Cr, Cu, Mg, Mn, Ni, Pb, Zn and Cd using Digestion and Atomic Absorbance Spectrometry method with T-test statistically and concentrations of 0.03±0.02, 0.13±0.01, 0.057±0.01, 1.00±0.40, 0.25±0.03, 0.18±0.04, 0.04±0.03, 1.31±0.33 and 0.46±0.29 respectively in dry season. And in wet season; Co (0.10±0.07), Cr (0.21±0.03), Cu (0.02±0.00), Mg (2.25±0.56), Mn (0.23±0.03), Ni (0.13±0.04), Pb (0.14±0.06), Zn (2.18±0.47) and Cd (0.47±0.23) were obtained respectively with significant differences at $p>0.05$ in Cr and Pb concentrations between dry and wet season. Ni and Pb were found to be above acceptable threshold for WHO and NESREA guidelines and standards but within permissible limit for FAO while Cd, Co and Mn were above acceptable limit for the standard guidelines. Phytoremediation is an attractive alternative to the conventional cleanup technologies that employ plants and their associated microorganisms to remove, contain, or rendered harmless environmental contaminants. In this study, Young Plants of water hyacinth (*Eichhornia crassipes*), water lettuce (*Pistia stratiotes*) and Vetiver grass (*Chrysopogon zizanoides*) were used hydroponically for further remediation of the treated effluent, as based on above values of Ni, Pb, Cd, Co, and Mn, showing the effluent is unfit for human consumption or irrigation purposes.

Keywords: Heavy Metals, Wastewater, Phytoremediation, Water Hyacinth, Hydroponically

1. Introduction

Heavy metals are elements with an atomic density greater than $6g/cm^3$ also known as trace metals and are one of the most persistent pollutants in wastewater. During rainfall, some heavy metal waste is washed into poor drainage systems and subsequently into nearby rivers [1]. Heavy metals are ubiquitous in nature and found naturally in the earth's crust and their compositions vary among different localities, resulting in spatial variations of surrounding concentrations [2]. The discharge of high amounts of heavy metals into water bodies leads to several environmental and health impacts [3]. The most common toxic heavy metals in wastewater include arsenic, lead, mercury, cadmium, chromium, copper, nickel, silver and zinc. The release of high amounts of heavy metals into water bodies creates serious health and environmental problems with the ability to accumulate in successive levels of the biological food chain which may lead to an upsurge in wastewater treatment cost [4]. Impact of heavy metals containing waste-water on agricultural produce and soil. Increasing discharge of heavy metals in water and soil from different sources is a matter of concern for the environment and health safety. Irrigation with heavy metal contaminated water can deteriorate the quality of soil as well as the agricultural produce [5]. Water (surface and ground) pollution by heavy metals is a global issue. Many areas in Europe have been reported to be greatly affected by heavy metals while in the USA, government statistics revealed that more than 19000 km of US streams and rivers have been contaminated by heavy metals from coal mine and acid mine drainage. In Asia, some countries such as India, Pakistan and Bangladesh are experiencing severe pollution of surface water due to untreated effluents being poured in surface drains by small industrial units and from the use of raw sewage in producing vegetables near big cities, which ends in surface water by runoff and groundwater by leaching processes. Generally, heavy metals identified in the polluted rivers in Asia include As, Cu, Cd, Pb, Cr, Ni, Hg and Zn. Heavy metals and organic pollutants are ubiquitous environmental pollutants affecting the quality of soil, water and air [6].

In different parts of Africa including North, East, South and West Africa, there are reports on heavy metal (notably Pb, Cd, Hg, Cu, Co, Zn, Cr, Ni, Mn, Fe, As and V) concentrations in surface water exceeding recommended limits, thereby polluting the surface waters in the region [7]. In Nigeria alone out of inland freshwater system estimated to be about 283,293.47 hectares, only about 84,988.041 is still useful due to pollution Irrigation with heavy metal contaminated water can deteriorate the quality of soil as well as the agricultural produce. Increased levels of heavy metal contaminants in water affect negatively the ecological function of water. Functions including recycling and primary production of nutrients. Also affected is the health of wildlife and humans through bioaccumulation in the food chain with the lasting impact of metal tolerance development among certain organisms. The effects of heavy metals on human health can even lead to death [2]. Generally, assessment of health risk of potentially toxic metals involves the quantitative assessment of the possibility of the deleterious impacts occurring in a given set of conditions [8].

Conventional treatment technologies to remove the pollutants from waste-water are usually costly, time-consuming, have logistic problems and technical complexity, environmentally destructive, and mostly inefficient. Therefore, alternative solution is needed for heavy metals removal from the environment. Phytoremediation is a cost-effective green emerging technology with long-lasting applicability, a process that uses plants to degrade and reduce or detoxify waste products and pollutants [9]. It is also an innovative and promising technology available for removal of heavy metals and recovery of the heavy metals in polluted water and lands [10].

Hydroponic systems, which utilize plants which are grown in nutrient solution without soil, are expanding and raising great interest in commercial and scientific community [11]. Water medium treatment involves the use of floating beds that can grow in water. These beds are installed in ponds of water in need of treatment. Nutrients are assimilated hydroponically through the plants root system [12].

Also [13] reported that *Chrysopogon zizanoides* (Vetiver grass), *Eichhornia crassipes* (Water hyacinth) and *Pistia stratiotes* (Water lettuce) has a great potential and effective on-site treatment system for removing nutrients and organics from domestic and industrial waste-waters.

The overall objective of any remediation approach after contaminants assessment is to create a final solution that is protective of human health and the environment [14].

2. Materials and Method

Water samples were collected in duplicates in the morning (between 7am-10am) from the Wastewater Treatment Plant (WWTP) of a Teaching hospital in Zaria**.** Water was collected using the dip sampling method, which involves de-capping the prewashed bottles and dipping them below the surface till full. The wastewater samples were filtered through Whatman no. 541 filter paper (Whatman, Germany) into sampling tight capped bottles and pH was adjusted to 2 by treatment with approximately 3mL of 1:3 HNO_3: Deionized water per 250 mL sample before digestion was initiated.

The samples were transported to the laboratory where they was preserved and kept in a room Temperature until analysis. The Samples was collected and stored such that degradation or alteration is minimized. The EPA vigorous digestion method described by [15] was adopted. Samples was allowed to stand in their original containers for 16 hours to allow potentially adsorbed metals to redissolve Samples was well shaken to homogenize before digestion. The varying concentrations of the following toxic metals: Cadmium (Cd), Lead (Pb), Chromium (Cr+6), Cobalt (Co), Copper (Cu), Magnesium (Mg), Manganese (Mn), Nickel (Ni), Lead (Pb), and Zinc (Zn) in the wastewater effluents was determined by Atomic Absorption Spectrophotometer (Model 4210, Agilent technology) according to [15]. Results were analyzed statistically using T-test. The three plants were immersed by hydroponic method and monitored for 21 days for phytoremediation potentials.

3. Result and Discussion

3.1. Seasonal Interaction Between Heavy Metals in Effluent

The figure 1 below shows highest concentration of Cu (0.057) and Ni (0.18) in dry season while Zn (2.18), Pb (0.14), Co (0.10), Cr (0.21) and Mg (2.25) were higher in wet season. Zn, Cd and Pb have positive relationship while Ni, Co, Cr and Mg have Negative relationship. Most of the higher concentrations of Heavy metals were obtain during wet season and there was increment in effluent showing inadequate removal and addition from external sources such as land fill near the treatment plant, Co, Zn, Pb, Cd and Mg were higher in wet season than dry season with only Cu and Ni being the highest in dry season. There was significant variation at p<0.05 between Cr and Pb during dry and wet season with higher conc. of 0.21 and 0.14 in wet season than dry season with 0.19 and 0.04 respectively. This could be due to increased contaminated water volume and flow, site specific activities and a source of metal contamination. This relate with the findings of [16] in the assessment of hospital wastewater in Enugu where Cr and as were above WHO limit standard and can pose environmental health risk. [17] also found that Cr and Cd were high above limit in the study of "Microbial and Heavy metals contamination of treated Hospital wastewater in Thailand.

But oppose to the study of [18] on the evaluation of Temporary seasonal variation of heavy metals and their potential ecological risk in Nzhelele River, South Africa where he obtained higher Mn, Pb, Cu, and Zinc in dry season; and stated that this could be due to reduced water volume and flow and increase evaporation from water bodies. Ni, Pb, Cd, Co, and Mn were above permissible limits standards while Cr is above for WHO but within for FAO and NESREA. Cu, Mg, and Zn were within permissible acceptable threshold for Effluent.

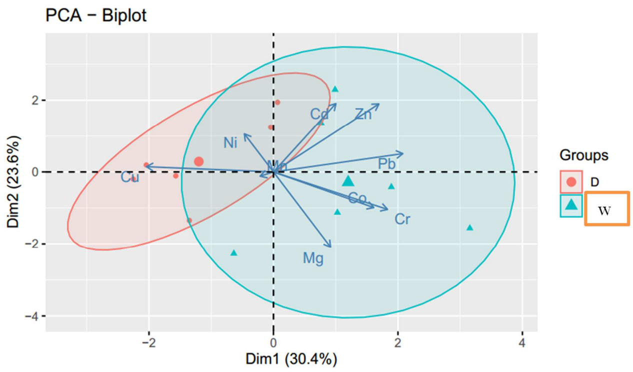

Figure 1. Principal Component Analysis of Heavy Metals Interaction Between Dry and Wet Seasons in Effluent.

3.2. Percentage Reduction in Heavy Metals (Co, Cr, Cu, Mg) by Phytoremediation Using the Three Plants

Figure 2A, 2B, 2C and 2D shows percentage reduction in cobalt (Co), Chromium (Cr), Copper (Cu) and Magnesium (Mg). Percentage reduction in the metals shows significant difference at P>0.05 between *V. zizanoides* and *P. stratiotes* while there was no significant difference between *E. crassipes* and *V. zizanoides*, with the latter having highest reduction potential.

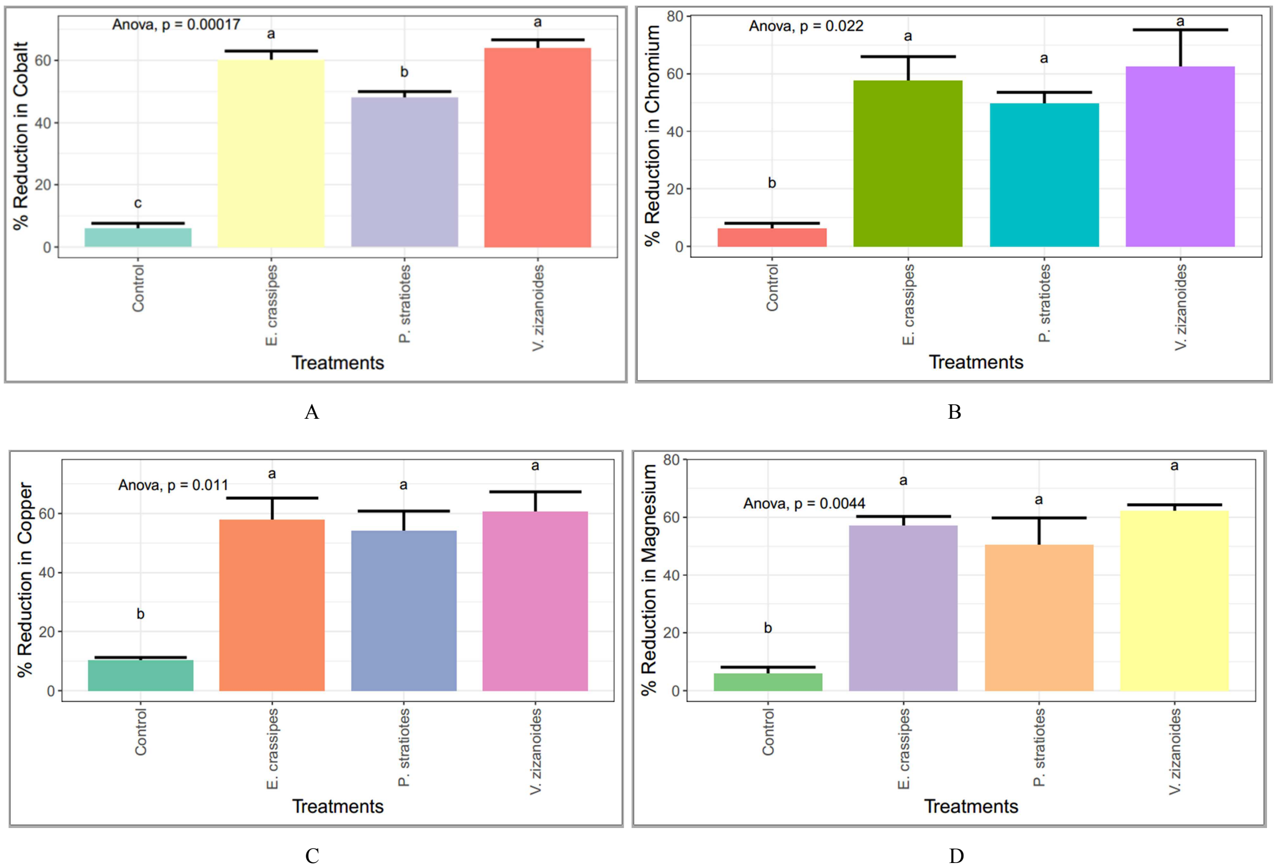

Figure 2. Percentage Reduction in Heavy Metals (Co, Cr, Cu, Mg) by Phytoremediation Using the Three Plants.

3.3. Percentage Reduction in Manganese (Mn), Lead (Pb), Zinc (Zn) and Cadmium (Cd)

Figure 3A, 3B, 3C, 3D shows percentage reduction in Mn, Pb, Zn, and Cd. There was significant difference at P>0.05

between *P. stratiotes* with both *V. zizanoides* and *E. crassipes,* but there was no significant variation between *V. zizanoides* and *E. crassipes. P. stratiotes* has slightly higher percentage than *E. crassipes* in the reduction of cadmium.

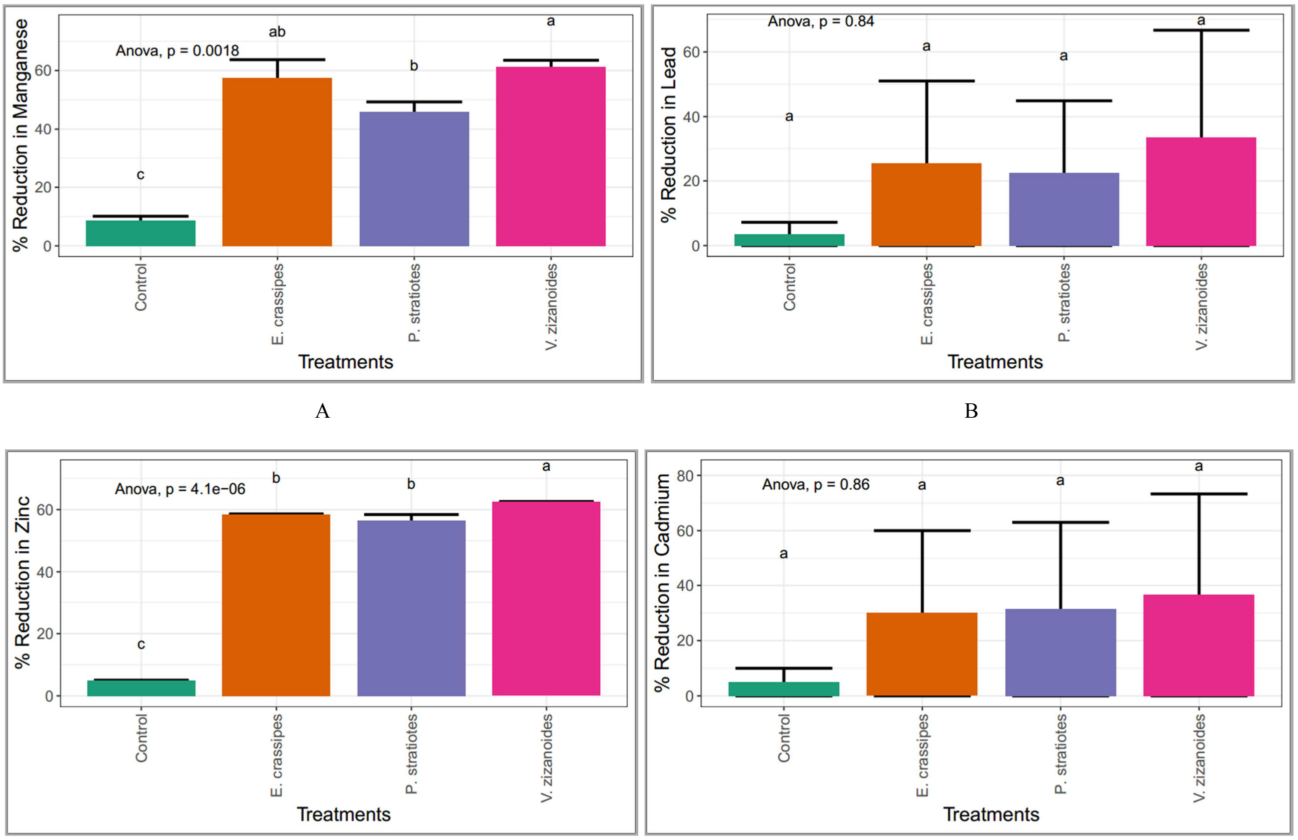

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Figure 3. *Percentage Reduction in manganese (Mn), Lead (Pb), Zinc (Zn) and Cadmium (Cd).*

Vetiver grass has the highest contaminant removal potential in this study. The removal efficiency of about 50% of contaminants (Zn, Cu, Cr, Ni, Mg and Mn) by waterhyacinth *(E. crassipes*) and water lettuce (*P. stratiotes*) and the roots of waterhyacinth showing higher absorbance capacity than its shoots in this study also aligned with the research of [19] in the study of Bioaccumulation of heavy metals from wastewaters in water hyacinth *(E. crassipes) and* water lettuce (*P. stratiotes*), were the bioaccumulation factor of the two plants was evaluated for 20 days and removal efficiency was more than 50%.

Water hyacinth (*Eichhornia crassipes*) possesses a well-developed fibrous root system and large biomass and has been successfully used in waste-water treatment systems to improve water quality. Removal rates by the plant in hydroponic solution for Cd, and Zn was 50-90% for both metals. While for Ni removal was 68% in field experiment [20] and 19.84% in hydroponics after 10 days exposure to 15 mg/L of Ni [21].

Roots of water hyacinth also proved better accumulator of the metals than the leaves.

4. Conclusion

There was higher concentration of some heavy metals (Ni, Pb, Cd, Co, and Mn) and therefore render the treated effluent unfit for either human consumption of irrigation, posing potential risk for inhabitants as it lead to several ailments such as bio magnification. Hence the need for further remediation. The plants used for phytoremediation shows a promising potential for the removal of contaminants in wastewater. There is need for proper management and constant monitoring of anthropogenic activities to ensure minimizing effects to the treated effluent.

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