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Phytodegradation of Compost Leachate by Water Hyacinth (*Eichhornia Crassipes*) from Aqueous Solutions

Ibezute A.C.[1], Tawari-Fufeyin P.[2]

[1]Department of Environmental Science, Federal University of Petroleum Resources, Effurun, Delta State, Nigeria.

[2]Department of Animal and Environmental Biology, Faculty of Life Science, University of Benin. Benin City, Edo State, Nigeria.

Abstract: ***Fifty (50) litres of untreated compost leachate from shell farm, Jeddo, Delta state was filtered and transferred to a treatment tank of about 60 litres capacity containing water hyacinth. The experiment was allowed to stand for 112 days without aeration. Leachate and plant samples were collected and analyzed before and after the treatment. The result showed that all physical, chemical and microbial parameters analyzed in the untreated leachate were within the WHO limit except for TDS, TSS, EC, colour, DO, BOD_5, COD, chloride, lead, iron, cadmium and total coliform. However, after treatment pH was reduced by 5.41%, total dissolved solid 91.00%, total suspended solids 71.12%, electrical conductivity 18.70%, biological oxygen demand 69.05%, chemical oxygen demand 68.81%, colour 90.48%, chloride 94.32%, sodium 90.37%, magnesium 93.40%, sulphate 89.07%, phosphorous 90.94%, lead 98.83%, iron 98.40%, zinc 81.95%, cadmium 100.00%, copper 0.00%, total fungi count 91.39%, total bacterial count 86.48% and total coliform count 87.45%; while dissolved oxygen and nitrate increased by 24.00% and 94.75% respectively Comparison of the results of the analyses after treatment with WHO standards showed that the values of dissolved oxygen and total coliform count were still not within WHO limit. The chemical characteristics of the leachate clearly indicated that it is of a high threat to the environment especially the aquatic environment which is the final recipient of this waste. However, Water hyacinth exhibited quite a distinct response and is recommended for the bio-purification of compost leachate.***

Keywords: Compost leachate, Bioremediation, phytoremediation, Water hyacinth, aquatic plants

1. Introduction

Water purification is the process of removing undesirable chemicals, materials, and biological contaminants from contaminated water. The goal is to produce water fit for human consumption (drinking water) and other purposes, including meeting the requirements of medical, pharmacology, chemical and industrial applications. Amongst the various methods used for water purification, the application of chemicals for purification of leachate has been carried out for many years with a good success rate. However, the main concern when using these chemicals is the environmental and health related effects. Lately, more environmentally friendly approaches are preferable and it comprises of bioremediation and phytoremediation. This is due to the facts that they are more economical and environmental friendly, requiring fewer chemicals, harmless, and uncomplicated to maintain.

Plant based bio-purification technologies have been collectively termed as phytoremediation, This refers to the use of green plants and their associated micro biota for the treatment of contaminated soil, ground and surface water [1]. Large green plants have the capability to move large amounts of solution into the plant body through the roots and evaporate this water out of the leaves as pure water vapour in a process called transpiration. Plants transpire water to move nutrients from the soil solution to leaves and stems, where photosynthesis occurs, and to cool the plant. During this process, contaminants present in the water are also taken up and sequestered, metabolized, or vaporized out of the leaves along with the transpired water.

The use of water hyacinth as the functional unit in wastewater treatment systems has been increasingly demonstrated and treatment regimens developed as a result of successful pilot projects [2][3]. Water hyacinth has successfully resisted eradication by chemical, biological, mechanical, or hybrid means. It has a huge potential for removal of the vast range of pollutants from wastewater [4][5][6][7] and has the ability to grow in severe polluted waters [8]. It is also used to improve the quality of water by reducing the levels of organic, inorganic nutrients [9] and heavy metals [10][11][12][13][14]. The presence of its fibrous root system and broad leaves help them to absorb higher concentrations of heavy metals [15]. It readily reduces the level of heavy metals in acid mine drainage water [16] and silver from industrial wastewater in short time [17]. This capability makes them a potential biological alternative to secondary and tertiary treatment for wastewater [18][19][20]. Water hyacinth has been found to stabilize temperature in experimental lagoons, thereby preventing stratification and increasing mixing within the water column [21]. Water hyacinth can convert alkaline pH into neutral [22][23]. The reduction in pH is due to absorption of nutrients or by simultaneous release of H+ ions with the uptake of metal ions [22]. Borges *et al.*, [24] obtained EC reduction by 18.1% in 5 days and TDS removal by 39.1% in 20 days. Lissy and Madhu [25] observed an increase in TDS when plant placed in the tank; which they stated that the increase was due to the presence of clay or other fine particles present in the plant roots and or the presence of high Cr concentrations. On subsequent days, it showed that the TDS value considerably decreased by the accumulation process. At present, water hyacinth has been used to purify other form

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of leachate, and no study on compost hence this study which is aimed at exploring the bio-purification of compost leachate using water hyacinth (*Eichhornia crassipes*).

2. Materials and Methods

2.1 Collection of experimental plant

Water hyacinth (*Eichhornia crassipes*) obtained from Ekpan River in Warri, Delta state, were thoroughly washed with tap water to remove any soil/sediment particles attached to the plant surfaces. The plants were placed in 60liters capacity tanks.

2.2 Experimental Setup

Fifty (50) litres of compost leachate from Fomas Venture Nigeria Ltd, Delta state,~~;~~ managers of organic waste from Shell Petroleum Development Company~~;~~ was collected, filtered using a very fine mesh (2.0mm) and transferred into a 60 litres capacity tank with Water hyacinth (*Eichhornia crassipes*) as bio-purificator. The experiment was carried out under natural condition for 112 days without aeration. Before and after the experiment began, the untreated leachate and plant sample were collected and analyzed; in other to monitor the pollution removal process.

2.3 Water and plant analysis

Acceptable standard methods and instrumentations were followed during sample collection procedures [26]. During each sampling, water samples for physicochemical analyses were collected into thoroughly cleaned 1liter polyethylene bottles and tightly closed. Each bottle was rinsed with the appropriate sample before the final sample collection. The samples were placed in a cooler box and then taken to the laboratory for analyses. For dissolved oxygen (DO) determinations, separate samples were collected in 300 ml plain glass bottles and the samples fixed using the azide modification of Winkler's method [26]. Samples for biochemical oxygen demand (BOD) were collected into dark glass bottles for incubation and subsequent DO determination. Also vegetative parts of the plants consisting of the leaf, stem and root were collected in sterile bags, sealed, labelled appropriately and taken to the laboratory for digestion as described by USEPA [27].

In the laboratory pH, total dissolved solids, electrical conductivity, dissolved oxygen, biochemical oxygen demand (BOD_5), chemical oxygen demand (COD), colour, chloride, sodium, magnesium, sulphate, nitrate, phosphate, lead, iron, zinc, cadmium and copper were determined according to procedures outlined in the Standard Methods for the Examination of Water and Wastewater [26]. pH was measured using a HACH digital meter, total dissolved solid was determined using a TDS meter (Model 4076), electrical conductivity was measured using Cybersan 510 conductivity meter. Titrimetric method was used in the determination of chemical oxygen demand (COD), chloride, sodium and magnesium. Sulphate, nitrate and phosphate were determined spectrophotometrically at 380nm, 470nm and 680nm respectively. Heavy metals such as lead, iron, zinc, cadmium and copper in the water sample were determined using Atomic Absorption Spectrophotometer (Buck Scientific Model-210) at 217.0nm, 248.0nm, 213.9nm, 228.8nm and 324.8nm respectively. Microbiological parameters monitored included total bacterial count, total fungi count and total faecal coliform counts, which were carried out according to Standard methods [26].

3. Result and Discussion

A summary of the results of physical, chemical and microbial analyses of both untreated and treated effluents are presented in Table 1. These values were placed alongside WHO guideline values [28]. The heavy metals concentration in Water hyacinth before and after treatment is also shown in Figure 1 and 2.

The mean pH in untreated leachate which was slightly alkaline (7.95) was slightly reduced after treatment by 5.41%. Similar report has been made by Mahmood *et al.* [22] and Dipu *et al.* [23] when they carried out laboratory scale studies on water hyacinth for biotreatment of textile wastewater; and phytoremediation of dairy effluent by constructed wetland technology respectively. According to them, Water hyacinth can convert alkaline pH into neutral. Mahmood *et al.* [22] stated that the reduction in pH is due to absorption of nutrients or by simultaneous release of H^+ ions with the uptake of metal ions. The reduction in pH favors microbial action to degrade biochemical oxygen demand (BOD) and chemical oxygen demand (COD) in the wastewater.

Total dissolved and suspended solids in the untreated leachate were higher than WHO limit. This may be because the organic waste was grinded (which is usually one of the composting process) in order to increase surface area for increased bacterial activity; and might have led to increased dissolved and suspended solid in the leachate. The high concentration of total dissolved and suspended solid noted in the untreated leachate was reduced by 91.00% and 71.12% respectively after treatment; and the reduction well below maximum acceptable limit [28]. Borges *et al.* [24]; Jamuna and Noorjahan [29] reported that water hyacinth significantly reduced the total dissolved and suspended solid after 20 days and 96 hours respectively. My findings were however in contrast to the report of Lissy and Madhu [25]. According to them the increase in TDS and TSS was due to the presence of clay or other fine particles present in the plant roots after the treatment. Excessive concentration of suspended and dissolved solids might be harmful to aquatic life, because they decrease water quality, inhibit photosynthetic processes and eventually lead to increase of bottom sediments and decrease of water depth [30].

Conductivity of water is a numerical expression of the ability of an aqueous solution to carry an electric current. This ability is a function of the presence of ions, their total concentration, mobility, valency and the temperature of measurement. Example of such ions is chloride. High conductivity has been reported in water with high chloride content [31]. Higher value of conductivity and chloride found in the untreated leachate may be as a result of common salt which is used extensively in cooking all types of food and it is also present in naturally occurring food in limited quantity [31]. However after treatment, electrical

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conductivity was reduced by 18.17% below the initial concentration. This may be as a result of reduction the concentration of Chloride alongside sodium, magnesium, sulphate, nitrate, phosphorus were reduced by 98.71%, 96.94%, 97.17%, 98.89%, 95.71% and 97.50% respectively after treatment period. Borges *et al*. [24] obtained EC reduction by 18.1% in 5 days when they studied the performance of constructed wetland system for the treatment of water from the Corumbatai River.

The DO level in the untreated leachate was completely absent (0.00 ± 0.00mg/l) in the untreated leachate; and so cannot sustain aquatic productivity WHO [31]. This could be attributed to high level of microbial activities consequent of high concentrations of degradable organic and inorganic matters which resulted in a tendency to be more oxygen demanding. Roghanian *et al*. [32] reported a similar finding when they studied the effects of composted municipal waste and its leachate on some soil chemical properties and corn plant responses. After treatment for 112days, dissolved oxygen was increased to 1.50mg/l representing 24% increase. Similar trend has been reported by Dar *et al.* [33] and Shah *et al*. [34] when they studied Sewage treatment potential of water hyacinth (*Eichhornia crassipes*); and water hyacinth (*Eichhornia crassipes*) as a remediation tool for dye-effluent pollution respectively. According to Reddy [35], the presence of plants in wastewater depletes dissolved CO_2 during the period of photosynthetic activity and an increase in DO of water, thus creates aerobic conditions in wastewater.

BOD and COD represent the amount of oxygen required for the biological and chemical decomposition of either organic or inorganic matter respectively under aerobic condition at a standardized temperature in surface water (e.g. lakes and rivers) or leachate [31]. High BOD (35.19mg/l) and COD (87.31mg/l) value as recorded in untreated leachate is an indication of high level of pollution which could result in high biodegradation activity by microbes. However, high biological and chemical oxygen demand in the leachate was reduced by 69.05% and 68.81 respectively after treatment. The reports of Gamage and Yapa [36] and Kulatillake and Yapa [37] on BOD and COD reduction efficiency using water hyacinth were consistent with my findings. Gamage and Yapa (2001) used water hyacinth in textile mill and monitored for a period of one year. They observed BOD and COD removal was 75% and 81.4% respectively whereas Kulatillake and Yapa [37] reported 99% BOD and 80% COD removal for rubber factory effluents. According to Reddy [35], the presence of plants in wastewater depletes dissolved CO_2 during the period of photosynthetic activity and an increase in DO of water, thus creates aerobic conditions in wastewater which favors the aerobic bacterial activity to reduce the BOD and COD [22]. Colour may be the first indication of a hazardous situation. In the untreated leachate, colour which was 21.00 Pt.Co. was higher than WHO limit of 15 Pt.Co. High value of colour reported in the untreated leachate may be due to the presence of coloured organic matter (primarily humic and fulvic acids) associated with the humus fraction of soil. Colour is strongly influenced by the presence of iron, other metals, and contamination of the water source with industrial effluents [31]. However, after treatment for 112days, colour was reduced by 90.48% improving the colour of the leachate.

Table 1: Physical, chemical and microbial changes in leachate treated using water hyacinth

	Before treatment	After treatment	% treatment	WHO, 2011
pH	7.95	7.52	5.41	6.5-9
TDS (mg/l)	5920.00	533.00	91.00	1000
TSS (mg/l)	33.27	9.61	71.12	-
EC (µs/cm)	9570.00	7780.00	18.70	-
DO (mg/l)	**0.00**	**1.20**	0.00	5
BOD_5 (mg/l)	35.19	10.89	69.05	28-30
COD (mg/l)	87.31	27.23	68.81	-
Colour (Pt.Co)	21.00	2.00	90.48	15
Cl (mg/l)	2876.00	163.24	94.32	400
Na (mg/l)	17.34	1.67	90.37	50
Mg (mg/l)	3.18	0.21	93.40	150
SO_2 (mg/l)	192.43	21.04	89.07	400
NO_2 (mg/l)	**2.10**	**40.00**		50
P (mg/l)	5.19	0.47	90.94	-
Pb (mg/l)	1.71	0.02	98.83	0.01
Fe (mg/l)	38.22	0.61	98.40	1.0
Zn (mg/l)	4.10	0.74	81.95	5
Cd (mg/l)	0.24	0.00	100.00	0.003
Cu (mg/l)	0.02	0.02	0.00	2.0
TFC × 10^3 (cfu/ml)	13.82	1.19	91.39	100
TBC × 10^7 (cfu/ml)	15.02	2.03	86.48	100
TC ×10 (MPN/100ml)	33.23	4.17	87.45	0

Lead, iron, zinc, cadmium and copper are toxic heavy metals in the body when present beyond required level. It can bind with important enzymes and inactivate them. It can also displace biologically important metals, such as Calcium, Zinc and Magnesium, interfering with a variety of the body's chemical reactions [38]. Lead, iron and cadmium in untreated leachate were above WHO [28] acceptable limit. The organic waste used for composting activity in this facility is usually from petroleum processing facilities which may be the major source of these heavy metals. However; after treatment, lead, iron, zinc, cadmium and copper were reduced by 98.83%, 98.40%, 81.95%, 100.00%, and 0% respectively, bringing it to concentration within acceptable limit [28]. Mishra *et al*. [15] used hyacinth for coal mining effluent for the removal of heavy metals and observed 70.5±4.4%, 69.1±3.9%, 76.9±1.4%, 66.4±3.45%, 65.3±2.4% and 55.4±2.9% for Fe, Cr, Cu, Cd, Zn and Ni, respectively was removed. Similarly Mishra and Tripathi [39]; Haider *et al.* [40]; Chigbo *et al.* [41] and Liao and Chang [42] reported that water hyacinth has successfully been used to clean up lead, iron and cadmium contaminated water systems.

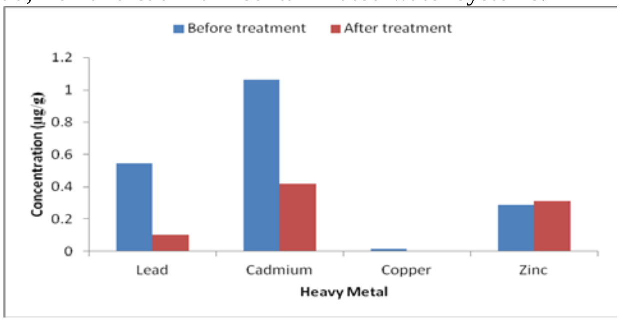

Figure 1: Changes in the heavy metals concentration of water hyacinth before and after treatment of compost leachate

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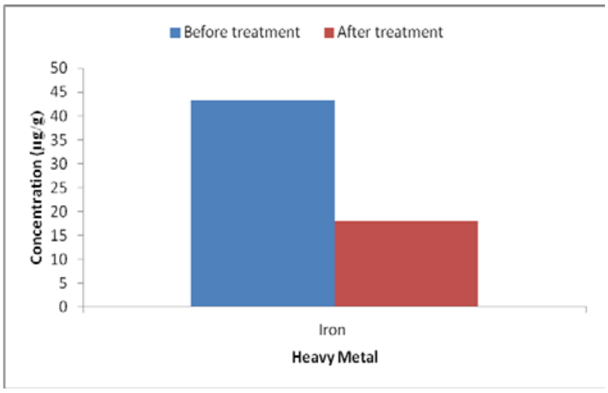

Figure 2: Changes in iron concentration of water hyacinth before and after treatment of compost leachate

The presence of faecal contamination in the untreated leachate is an indication that a potential health risk exists for an individual exposed to this leachate. This may be as a result of high organic matter and essential nutrients supporting the growth of microorganism [43][44]. Chukwu, *et al.* [45] stated that the presence of faecal contamination indicates the presence of waste from warm blooded animals. Water hyacinth; after 112 days, reduced total coliform count by 96.45. However, the feacal coliform count after treatment was still above WHO limit. The persistence of total coliform after the treatment period shows that it may persist in the environment longer as earlier reported by Anderson *et al.* [46]. The World Health Organization identifies the greatest human health risk of microbial contamination as being through the consumption of water contaminated by human or animal faeces [28].

The concentration of heavy metals in plants used in the treatment of compost leachate reduced after 112 days in all treatments. This may imply that these plants are able to excrete or convert the metals to forms other than metals since the concentration of heavy metals decreases at the end of the purification period. Raskin *et al.* [47] stated that Plants are able to convert metals that are toxic to them into other forms which are less harmful to them. This makes it safe for consumption by livestock.

4. Conclusion

This study has provided an insight into the dynamics of the physical, chemical and biological compounds that are likely to be of concern with regards to the protection of the water environment from discharge of compost leachate. It has shown that water hyacinth under investigation exhibits quite distinct responses to the treatment of compost leachate. In other to effectively manage this waste, compost leachate should be recirculated as a wetting agent in further composting processes instead of using fresh unpolluted water. This however increases the amount of leachate produced. In situations where recirculation is not possible, other arrangements should be made for on-site treatment of the leachate before discharge into the environment. Using water hyacinth for bio-purification has been reported to be effective in the treatment of this leachate. The methods from this research can be adopted as a suitable method which is economic to construct, requires little maintenance and increases the biodiversity.

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Author Profile

Ibezute A.C. received the B.Sc. degree in Animal and Environmental Biology; M.Sc. in Environmental Quality Management from the University of Benin, Benin City, Nigeria. At present, He is pursuing a Ph.D. in Environmental Quality Management from the same University. He is currently Lecturer in Federal University of Petroleum Resources, Effurun, Delta State, Nigeria.

Tawari-Fufeyin P. is presently working as professor at University of Benin, Benin City, Edo State Nigeria. She has mentored so many students; and has supervised several B.Sc., M.Sc. and Ph.D. students. She is currently supervising over five Ph.D. and ten M.SC students. She has published across several research journal both locally and internationally.

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