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Application of phytoremediation technique in the treatment of produced water using *eichornea crassipes*

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Abstract
This paper reports on a study carried out to determine the effectiveness of using a hyper accumulating plant like *Eichorneacrassipes* (water hyacinth) to reduce toxicity of produced water gotten from an oil field of the Niger Delta region of Nigeria. Results from the phytoremediation experiment showed that the concentration of biological oxygen demand (BOD), chemical oxygen demand (COD), and oil/grease were reduced from initial concentrations of 10.6mg/l, 150 mg/l and 7.70 mg/l to 7.25mg/l, 106.25 mg/l and 8.35mg/l respectively. Heavy metals like iron (Fe), zinc (Zn), Magnesium (Mg), nickel (Ni), copper (Cu), and lead (Pb) were reduced from initial concentrations of 3.00 mg/l, 3.40 mg/l, 1.22 mg/l, 1.40 mg/l, 0.06 mg/l, and 0.030 mg/l to 2.18, 2.09, 0.82, 0.25, 0.015, and 0.009 mg/l, respectively. A comparison of the system's effluent characteristics with effluent discharge limits in Nigeria, show that for inland, near-shore and offshore disposals, the effluent can be discharged into these environments with minimum public hazards. It is recommended that every company should carryout proper detoxification of produced water before disposal, while regulatory agencies such as DPR, FEPA, etc., must ensure proper monitoring and enforcement of effluent standards.

Keywords: Phytoremediation; Pollutants; Water hyacinth; Produced water; Disposal standards; Public health.

1. Introduction

Phytoremediation refers to the natural ability of certain plants called hyper accumulators to degrade or render harmless contaminants in soils, water or air. These contaminants include metals, pesticides solvents and crude oil and its derivatives. A plant in said to be a hyper-accumulator if it can concentrate the pollutant in a minimum percentage which varies according to the pollutant involved [1, 2]. Miller [3] explained that phyto-remediation may be applied whenever soil or static water environment has become polluted or suffering ongoing chronic pollution. According to Adler [4] plants absorb contaminants through the root system and store them in the root biomassand /or transport them up into the stems or leaves.

Hamallin [5] reports that in the case oforganic pollutions such as pesticides, solvents, industrial chemical, certain plants such as cannas render these substances nontoxic by their metabolism. However, Meagher [6] explains that metal pollutants in industrial process water and in underground water are most

commonly removed by precipitation or flocculation followed by sedimentation and disposal of the result sludge.

Produced water is waste water formed during the process of petroleum production from underground reservoirs. Produced water properties and volume from one location can vary over time [7]. Produced water contains various toxic organic and inorganic compounds, some of which are naturally occurring in the water while others are related to chemicals that have been added for cleaning and other purposes. Therefore Yael [8] suggested that the disposal of untreated effluent into the environment should be strictly forbidden or regulated by agencies of government. Hence this study was initiated to investigate the suitability of using a hyper-accumulator like *Eichorneacrassipes* (water hyacinth) in the treatment of produced water from an oil field in AkwaIbom State, Nigeria. Other investigators have reported about the good attributes of water hyacinth in nutrient removal [9-12].

The present study through experiments, analyzes the quality the resulting effluent from produced water treatment using water hyacinth with a view to determine whether they can be displayed to the aquatic environment.

2. Brief descruption of the study aera

The study area in Okuorioil field of Addax,AkwaIbom State. The water hyacinth was gotten from a stream in Ogoni, Rivers State, Niger Delta region of Nigeria. The Niger Delta region lies between latitudes 4° 15' N and 6° 30' N and longitudes 5°.00' E and 8° 00 E.The area falls within the tropical rain forest vegetation belt of the country. Annual rainfall ranges from 2400-2700 mm while the average temperature is 27°C.

3. Materials and methods

3.1 Sample collection

Produced water sample was obtained from Okuori oil field, while water hyacinth plant *(eichroueacrassipes*) was obtained from a stream in Ogoniland, Rivers State.

3.2 The experiments

The produced water was put into a carefully washed basin of produced water. The water hyacinth plants were then placed in the basin containing the produced water and then the water and plant were left to stand for four weeks. Tests were carried out after one week interval to obtain reading for each week. All samples were subject to physic – chemical analysis.

3.3 Physico-chemical parameters

The samples were analyzed according to the standard method for the examination of water and waste water (APHA) [13, 14] for the following parameters: iron (Fe), Zinc (Zn), Magnesium (Mg), Nickel (Ni),Copper (Cu), and Lead (Pb) using a spectrometer machine. A formula by Talini and Anderson [15] was used to compute the chemical oxygen demand (COD). Other parameters determined include biological oxygen demand (BOD), pH, and oil /Grease [16].

4. Results and discussions

Test data on the performance indicator of the phytoremediation experiment are given in Tables 1 and 2. Results were analyzed and presented graphically in Figures 1 to 10.

It was observed that pH was increasing throughout the experiment showing a 10.39% increase atthe end of the end of the experiment as shown in Table 2. This was probably due to the total decomposition of the plant throughout the duration of the experiment. The concentrations of lead and copper were reduced from 0.03 and 0.06 mg/l to 0.007 and 0.008 mg/l respectively after the first 2 weeks of the experiment which showed a percentage reduction of 90% of copper and 83% of lead as seen in Figures 2 and 9 respectively.

The reduction of Nickel concentration was significant in that by the first week of the experiment there was a 29.29% reduction, gradually increasing to a 99.64% reduction by the fourth week, as shown in Figures 1 and 7.

The concentration of COD after the fourth week however decreased by as shown in Figures 4 and 5. The BOD reduced by 52.83% as shown in Table 2, Figures 3 and 8. The significant reduction may have been due to the uptake of nutrients by the plant.

Table 1. Show the experiment results of the practical on weekly intervals

	Introducing the plant					
Parameters	Before introducing plant	After 1 week	After 2 weeks	After 3 weeks	After 4 weeks	Mean values over 4 weeks
pH	7.70	7.90	8.49	8.50	8.50	8.35 ± 0.45
BOD (mg/l)*	10.60	9.00	8.00	7.00	5.00	7.25 ± 1.75
COD (mg/l)	1500	150	135	80	60	106.25 ± 43.75
Oil/Grease content (mg/l)	2.51	1.00	0.04	0.03	0.03	0,28 ± 0.73
Iron (mg/l)	3.00	2.70	2.31	2.00	1.72	2.18 ± 0.52
Zinc (mg/l)	3.40	2.32	2.27	2.00	1.75	2.09 ± 0.24
Magnesium (mg/l)	1.22	1.17	1.05	1.00	0.05	0.82 ± 0.35
Nickel (mg/l)	1.400	0.990	0.008	0.006	0.005	0.25 ± 0.74
Copper (mg/l)	0.060	0.040	0.008	0.006	0.006	0.015 ± 0.025
Lead (mg/l)	0.030	0.020	0.007	0.005	0.004	0.009 ± 0.011

Note: *mg/l – milligram per liter; COD – chemical oxygen demand;BOD – biological oxygen demand

Table 2. Showing percentage differences in parameters

Parameters	**0 Week**	**1 Week**	**2 Weeks**	**3 Weeks**	**4 Weeks**
pH	7.70	7.90	8.49	8.50	8.50
Δ pH	0.00	0.20	0.79	0.80	0.80
pH % increase	0.00	2.597	10.260	10.390	10.390
BOD	10.60	9.00	8.00	7.00	5.00
Δ BOD	0.00	1.60	2.50	3.60	5.60
BOD % gone	0.00	15.09	23.59	33.96	52.83
COD	1500	150	135	80	60
Δ COD	0.00	1350	1365	1420	1440
COD % gone	0.00	90	91	94.67	96.67
OIL/GREASE	2.51	1.00	0.04	0.03	0.03
Δ OIL/GREASE	0.00	1.51	2.47	2.48	2.48
OIL/GREASE % gone	0.00	60.16	98.41	98.80	98.80
IRON	3.00	2.70	2.31	2.00	1.72
Δ IRON	0.00	0.30	0.69	1.00	1.28
IRON % gone	0.00	10.00	23.00	33.33	42.67
ZINC	3.40	2.32	2.27	2.00	1.75
Δ ZINC	0.00	1.08	1.13	1.40	1.65
ZINC % gone	0.00	31.76	33.29	41.18	48.55
MAGNESIUM	1.22	1.17	1.05	1.00	0.05
Δ MAGNESIUM	0.00	0.05	0.17	0.22	1.17
MAGNESIUM % gone	0.00	4.10	13.93	18.03	95.90
NICKEL	1.40	0.99	0.008	0.006	0.005
Δ NICKEL	0.00	0.410	1.392	1.394	1.395
NICKEL % gone	0.00	29.29	99.43	99.57	99.64
COPPER	0.060	0.040	0.008	0.006	0.006
Δ COPPER	0.00	0.020	0.052	0.059	0.054
COPPER % gone	0.00	33.33	86.67	90.00	90.00
LEAD	0.010	0.009	0.008	0.006	0.005
Δ LEAD	0.00	0.010	0.022	0.029	0.025
LEAD % gone	0.00	33.33	73.33	80.00	83.33

Magnesium concentration and Oil/grease content of the water were 0.05 and 0.03 respectively, which results to about 95.9% decrease in magnesium and a 98.8% decrease in oil/grease content of effluent water as can be seen in Figures 1 and 3.

Zinc and Iron were reduced to 48.53% and 42.67% respectively at the end of the experiment as shown in Figures 1 and 10.

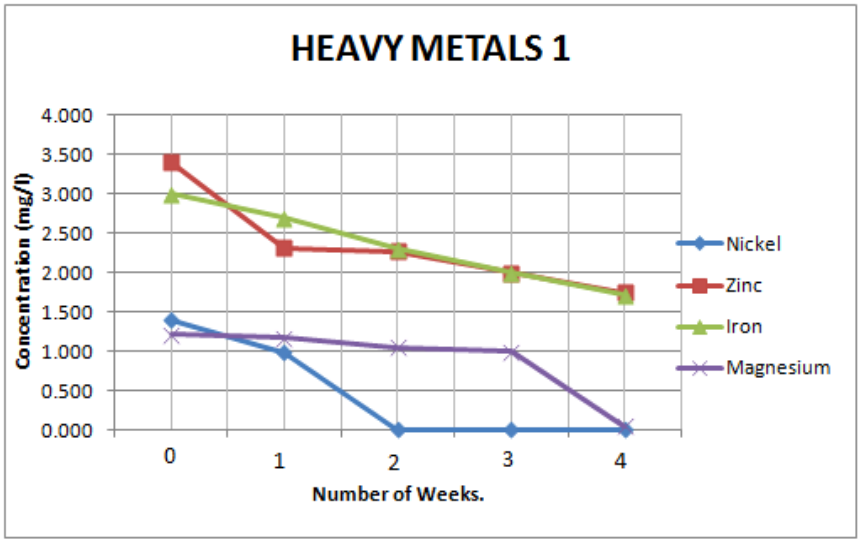

Figure 1. Plotshowing heavy metal concentrations of (Nickel, Zinc, iron & Magnesium)

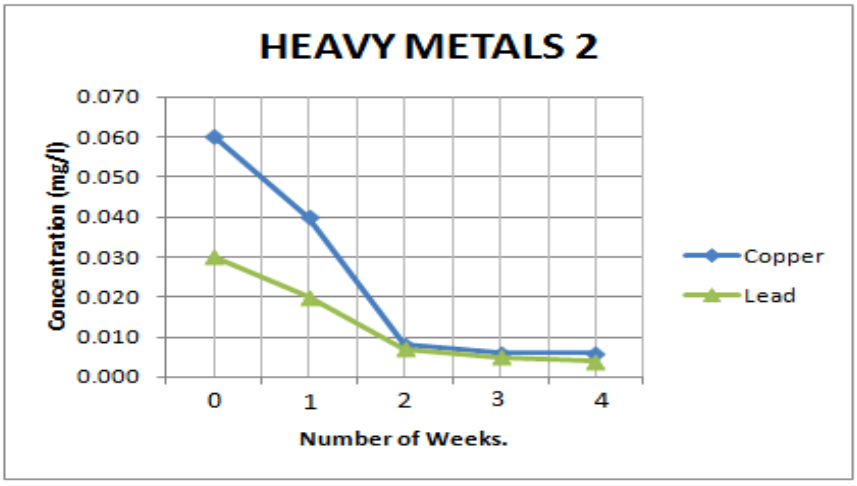

Figure 2. Plot showing other heavy metals (Copper & Lead)

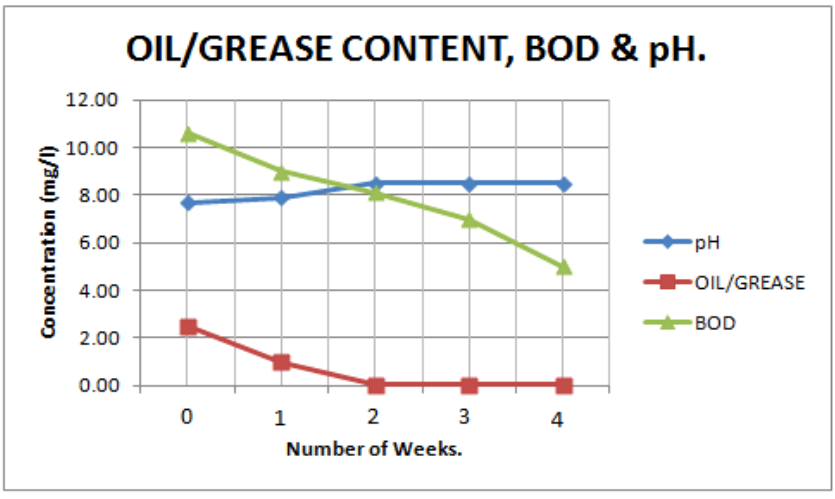

Figure 3. Plotshowing Oil / Grease content, BOD & pH

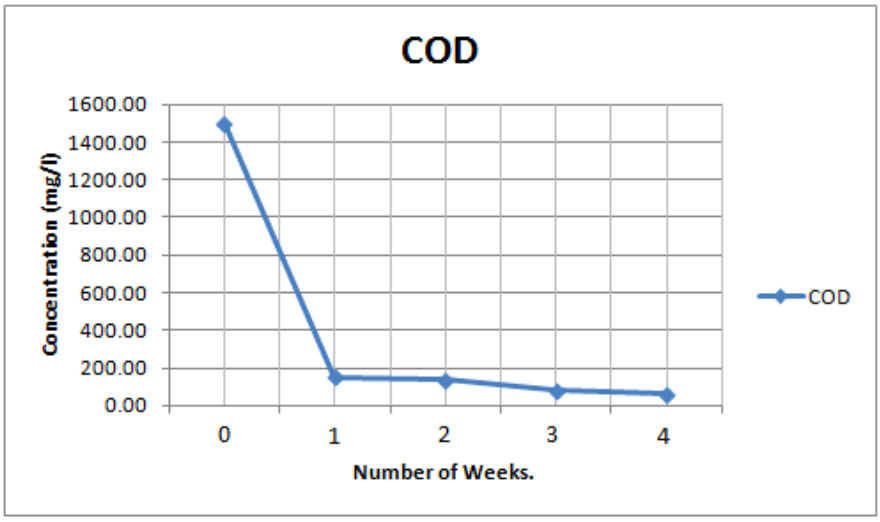

Figure 4. Plotshowing COD concentration

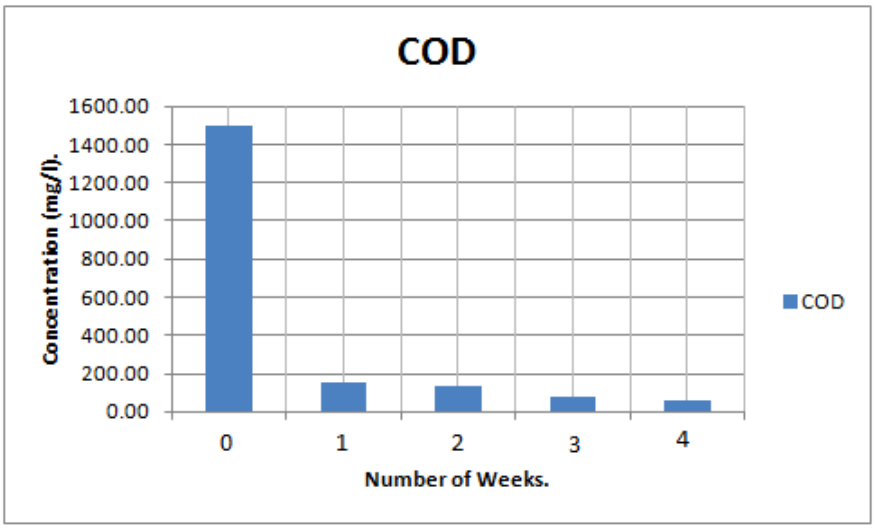

Figure 5. Bar chart showing COD concentration

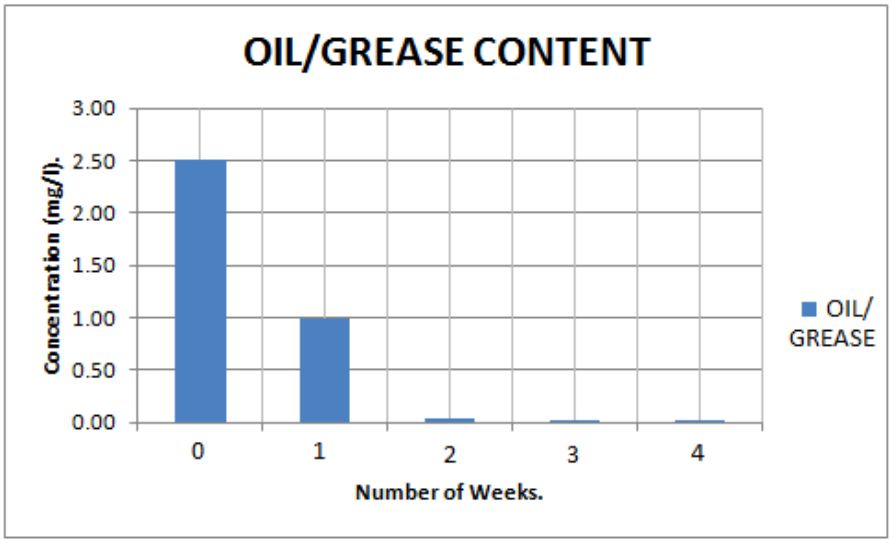

Figure 6. Bar chart showing Oil /Grease concentration

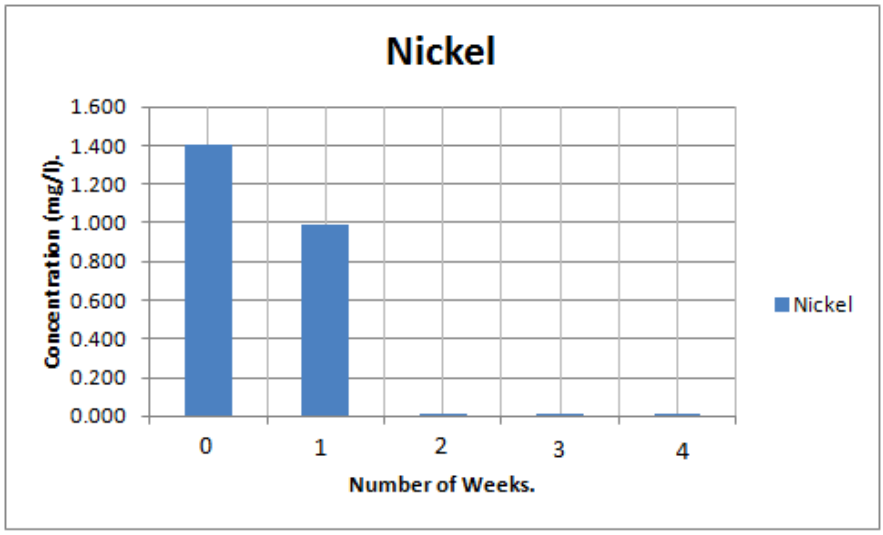

Figure 7. Bar chart showing Nickel concentrations

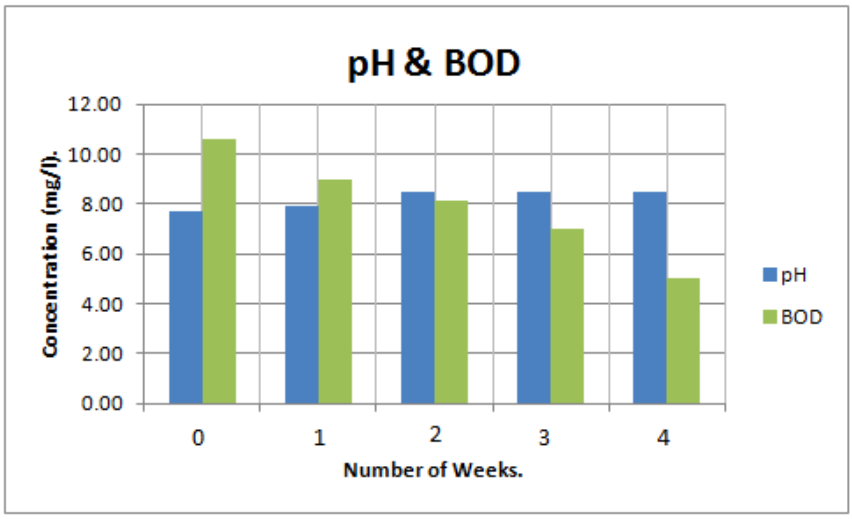

Figure 8. Bar chart showing pH and BOD concentrations

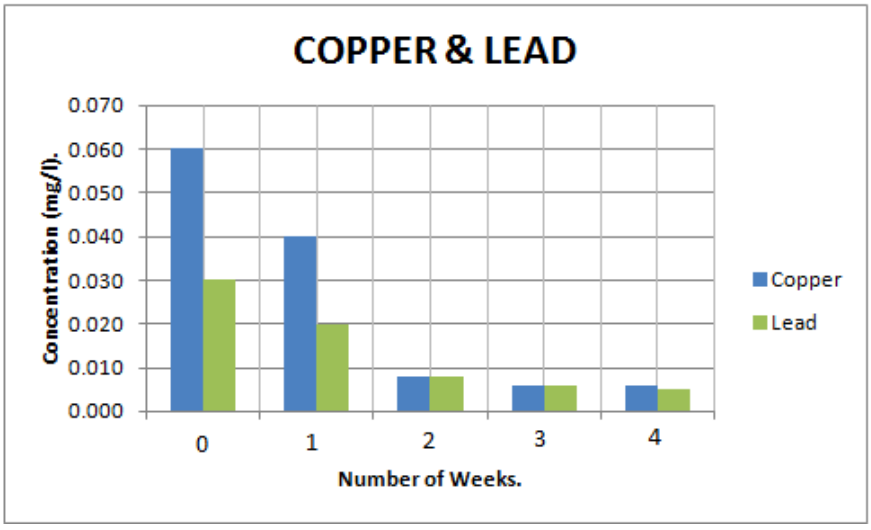

Figure 9. Bar chart showing Cooper & Lead concentrations

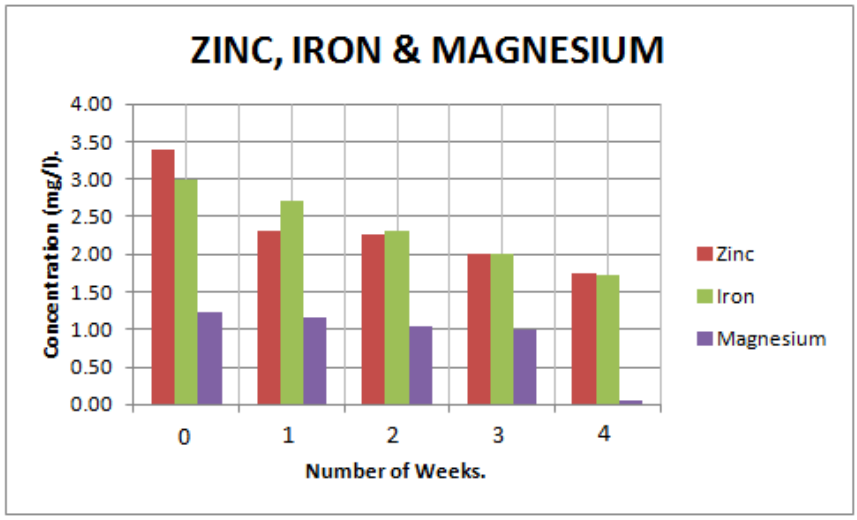

Figure 10. Bar chart showing Zinc, Iron and Magnesium concentrations

5. Conclusion and recommendations

Phytoremediation, as applied in this work, has proved to be a sustainable and inexpensive process, and is fast emerging as a viable alternative to conventional remediation methods and would be most suitable for a developing country like Nigeria. Its advantages in this work included its low cost, environmental friendliness, simplicity of operation and reducible volume of secondary waste.

To be able to manage produced water problems in Nigeria mostly in the Niger delta the following should be recommended:

1. Every company should have a DPR representative who monitors the rules and regulation of waste water management in that company to ensure standards are adhered to.
2. Further testing and experimentation should be carried out to identify promising plant species to carry out phytoremediation technique.
3. More sensitization programs should be carried out to educate companies on how to manage produced water discharged intoenvironment for safe disposal.

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