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Water Star Grass Enhanced Bioremediation of Petroleum Hydrocarbon Polluted Soil

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Abstract

The Niger Delta environment in the south- South region of Nigeria is in dire need of remediation on account of petroleum hydrocarbon pollution. The wide spread pollution of the region is due to the frequent and huge magnitude of oil spillages. The aim of this study is to determine the petroleum hydrocarbon pollution bioremediation enhancement potential of water star grass compost. Water star grass was harvested from invaded land in Yenagoa, then chopped into pieces and the biomass was compost for three months. Different amount of the mature compost was used to treat soil spiked with engine oil in a set of 8 replicates in plastic bioreactors. The pH, electrical conductivity (EC), Total Organic carbon (TOC), Total Nitrogen (TN), Phosphate (P), Potassium (K), total Petroleum hydrocarbon concentrations and hydrocarbon utilizing bacteria and fungi populations in the treated soil sample in each experimental set up Labeled Cont, A, B,C,D,E,F and G, were monitored every two weeks for a period of 5 months. At the end of the 5th month, the results show that Total Petroleum Hydrocarbon (TPH) concentration reduced by 22.96% in the control, 87.88% in set up A, 91.78% in B, 94.15% in C, 94.65% in D, 98.33% in E, 99.11% in F and 99.45 in G. There was also a progressive decline in Total Organic Carbon in each set up in proportion to the TPH removal. It is therefore concluded that water star grass biomass compost is a potential supplement for the bioremediation of petroleum hydrocarbon polluted soil

Keywords: *Water Star Grass, Petroleum Hydrocarbon, Pollution, Enhanced and Bioremediation*

1.0 INTRODUCTION

1.1Background to the study

The Niger Delta environment in the south- South region of the Nigeria is in dire need of remediation on account of petroleum hydrocarbon pollution. The wide spread pollution of the region is due to the frequent and huge magnitude of oil spillages as well as the menace of artisan refineries which effluents and refining residues of the illegal operations are indiscriminately discharge into the environment. According to (Mansi and Ambrose, 2023), oil pollution in soil and water via accidental oil spills and operational leakages or discharges is a major way by which human activities is impairing or stressing the environmental quality. The Bayelsa Oil and environment commission, (2023) report indicates that toxins from hydrocarbon pollution are present at dangerous levels in the soil, water and air across Bayelsa State.
Available literatures reveal that the magnitude of the hydrocarbon pollution in the Niger Delta region and the environmental, Socioeconomic as well as the health effects are enormous. (UNEP (2011) report indicates that crude oil contamination in many sites measured within Ogoni land in the Niger Delta were significantly higher than the EGASPIN intervention level for both soil and groundwater and therefore intervention and risk reduction measures are urgently needed for both soil and groundwater. Ekpali (2022) reported that between 2020 and 2021, Nigeria National Oil Spill Detection and Response Agency (NOSDRA) recorded 822 combined oil spills, totaling 28, 003 barrels of oil spilled into the environment.

According to a report by (Ordinioha and Brisibe, 2013 and Gigi, 2017), oil pollution in the Niger Delta can lead to 60% reduction in household food security, reduce ascorbic acid content of vegetables by 36%, decrease crude protein in cassava by 40% if nothing change about oil pollution in the region. Oil spills, whether natural or human caused, brings devastating short and long term consequences on the environment and human (Gerardo, 2023)

Bioremediation of petroleum-hydrocarbon-polluted soil is considered globally as economic, ecofriendly and efficient process. Biostimulation which is a bioremediation approach that involves the addition of nutrient supplements to the polluted medium to stimulate the growth and metabolic activity of indigenous microorganisms in order to enhance the biodegradation of pollutant has often times proven to be more effective than bioaugmentation for the remediation of aged organic pollutant. Literature records revealed that organic fertilizers are released more slowly and more beneficial to soil microbiomes, hence very useful for bioremediation of polluted soil.
Organic fertilizer from local raw materials would be more economically viable, ecofriendly and safer source of nutrients for biostimulation of petroleum hydrocarbon polluted environment. Water star grass (*Hymenche Amplexicaulis*) could serve as a potential source of biomass for biostimulation of petroleum hydrocarbon pollution bioremediation, considering the length and dense mass of the stem and fibrous roots. The aim of this study is to determine the petroleum Hydrocarbon bioremediation enhancement potential of water star grass compost.

2.0 Materials and method

2.1 Area of the study

The area of this study is Yenagoa. Yenagoa is a Local Government Area and the capital city of Bayelsa State in South- South geopolitical zone of Nigeria. The city is located in the southern part of the country at coordinates $4^{0}55'29''N6^{0}15'51''E$. Yenagoa lies on a coastal flood plain with an average height of about 15mters above sea level (Ohwo, 2014). The city is a riverine settlement. It is made up of fusion of several smaller communities that were settled along the Epie Creek, thereby forming a linear settlement. Fig. 2.1 is the map of Yenagoa the area of the study.

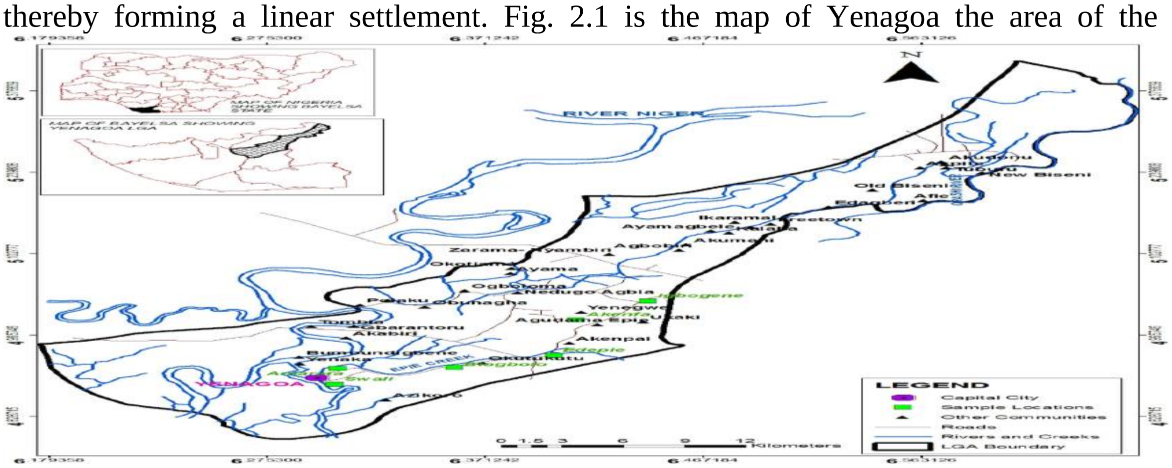

Fig2.1: Map of Yenagoa the area of the study (Source: Ebiegberi and Hyacienth, 2017:)

Under the Kopen-Geiger classification of climate, Yenagoa fall into the Monsoon climate (AM). The temperature of the city ranges between 26 and 29^{O}C throughout the year. The daily temperature of Yenagoa rarely drops to 19^{O}C or go above 38^{O}C. The average annual rainfall amount in Yenagoa is about 2870mm (113.3inches) and receives about 285 rainy days on the 1mm (0.04inches) annual threshold. The city enjoys an average of 2,994 hours of sunshine annually. The daylight varies from 11hours to 12hours 23 minutes daily. (www.wikipedia)

The warmest months in Yenagoa city are February, March and April with daily mean temperature ranging between 28 and 29^{O}C. The coldest months are July. August and September when the daily average temperature range between 25 and 26^{O}C throughout the day. On the average, Yenagoa experiences 329 days above 25^{O}C temperature and 0 day below 0^{O}C temperature.

2.2 Method

The study is undertaken in two phases. The first phase of the study involved the harvesting of Water star grass in bulk quantity from an invaded environment. The water star grass sample was collected. The leaves, stems and roots were separated and then cut into small pieces. The bulk of the biomass was compost for three months. Sample of dried leaves, stems and roots of the water star grass collected were grinded into fine powder form and chemical analysis of total Nitrogen, total Phosphorus, total Potassium, cellulose and lignin content was conducted. The results of the physicochemical analysis of the parts of water star grass are presented in Table 3.1

A bulk quantity of agricultural soil was collected from fallow farm land then air dried. The dried soil was then grinded into fine power form and then sieve with 2.5 pore size sieve. The sieved soil was spiked with engine oil dissolved in gasoline. 1kg of the spiked soil was collected in eight replicates into plastic bioreactors. The bioreactors were labeled Cont, A_{100}, B_{200}, C_{300}, D_{400}, E_{500}, F_{600} and G_{700}, control was not treated with the compost.. The spiked soil serve as prototype of polluted soil. Soil sample in each set up was treated with different quantity of mature water star grass biomass compost. Soil samples were collected from the spiked soils for laboratory analysis of day zero concentration of total petroleum hydrocarbon and polycyclic aromatic hydrocarbon. Hydrocarbon degrading bacteria and fungi in the polluted soil were screened and identified by morphological and biochemical methods

The treated soil samples were sprinkled with water and thoroughly mixed every four days to provide moisture and aeration to the soil for optimum performance of hydrocarbon degrading microbes in the soil. During the study, soil samples were collected from each experimental set up for analysis of total organic carbon, residual TPH and PAHS, soil electrical conductivity and PH were also monitored for a period of five months. Fig 2.2 and 2.3 are photograph water star grass sample collection from an invaded plot of land and the samples collected respectively.

Fig. 2.2: Harvesting of water star grass **Fig.2.3: Harvested water star grass**

2.3 Data analysis

Percentage analysis of TPH degradation in each experimental set up was conducted using descriptive statistics equation (3.1)

$$\% \text{ deg} = \frac{TPHic - TPHct}{TPHic} x\ 100$$

Where % deg is percentage of TPH degradation at the end of the 5th month

TPH_{ic} is initial TPH concentration at day Zero

TPH_{ct} is the TPH concentration at time t (day 140)

3.0 RESULTS AND DISCUSSIONS

3.1 Results

The physicochemical analysis of parts of the water star grass for the purpose of determining the biostimulation potential of the grass has been conducted. Results of the physicochemical analysis are presented in Table 3.1

Table 3.1: Results of physicochemical analysis of water star grass.

S/N	ANALYTICAL PARAMETERS	ANALYTICAL PARTS OF WATER STAR GRASS		
		Grass leaf	Grass stem	Grass root
1	Lignin (%)	6.74	13.42	17.38
2	Cellulose (%)	24.86	36.73	30.59
3	Total Nitrogen (mg/Kg)	2.72	2.18	1.76
4	Total Phosphate (mg/Kg)	1.48	1.17	0.84
5	Total Potassium (mg/Kg)	872.19	913.74	1183.76
6	Total Organic Carbon (mg/Kg)	6.67	8.61	6.15

After composting the water star grass for three months some chemical characteristics of the compost were analyzed. The results of the chemical analysis are presented in Table3.2

Table.3.2: chemical characterization of the water star grass compost

PARAMETERS	SAMPLE (WATER STAR GRASS COMPOST)
pH	8.55
TOC	6.39
TN (%)	5.72
Phosphate (mg/kg)	110.74
Potassium (mg/kg)	272.08

After spiking the soil with the engine dissolved in petrol baseline microbial and physicochemical characteristic of the treated soil was undertaken and the results are presented in Table 4.2.

Table 3.3: chemical characterization of the soil

PARAMETERS	SAMPLE (SOIL)
pH	7.66
EC	415.71
TPH (ppm)	60,163.09
PAHs (ppm)	43,818.57
HUB (cfu/g)	$1.37X10^2$
HUF (sfu/g)	81

The time series analysis of TPH concentrations in the control, Cont, A and B experimental set ups are presented in Fig.3.1

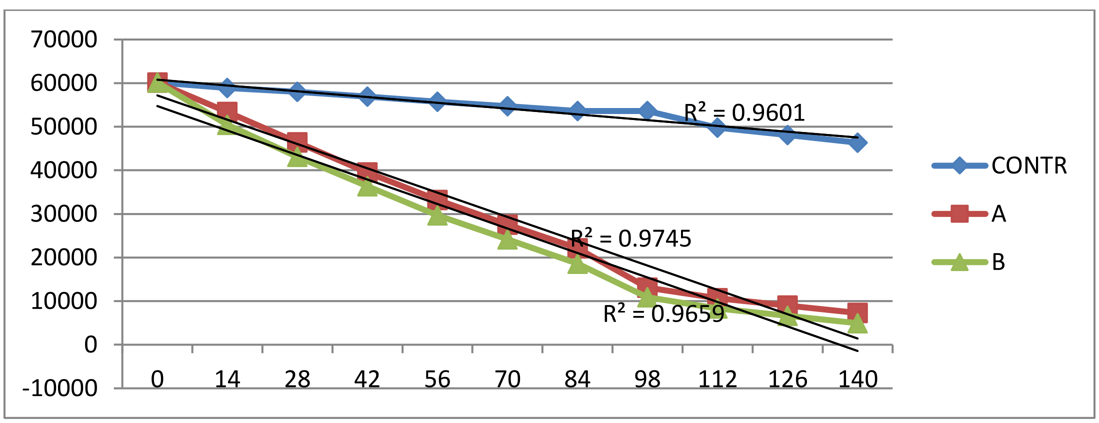

Fig. 3.1: Time series analysis of TPH concentrations in the Cont, A and B experimental set ups

The time series analysis of TPH concentrations in the control, C, D, E, F and G experimental set ups are presented in Fig.3.2

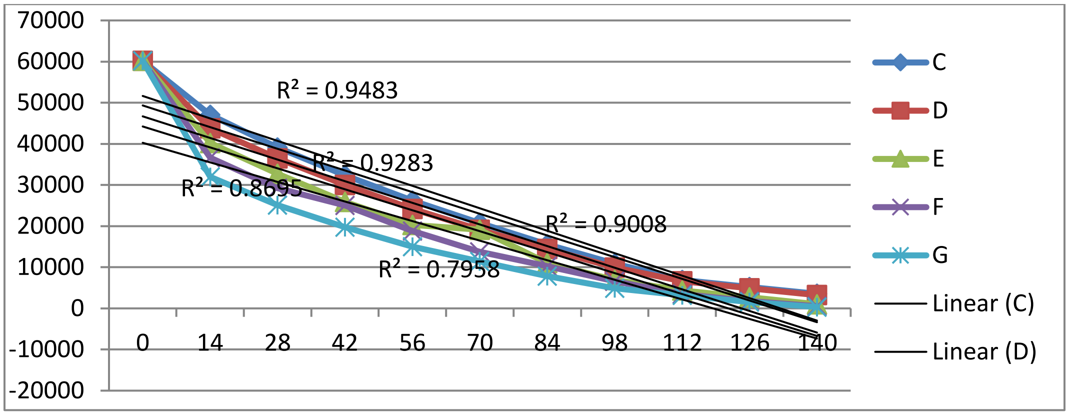

Fig. 3.2: Time series analysis of TPH concentrations in the C, D, E, F and G experimental set ups

Table 3.3: Results of statistical analysis of percentage of TPH degradation in each experimental set up

EXPERIMENTAL SET UP	INITIAL TPH CONCENTRATION AT DAY ZERO (PPM)	FINAL TPH CONCENTRATION AT DAY 140 (PPM)	PERCENTAGE OF TPH REDUCTION (%)
Cont	60,163.09	46348.95	22.96%
A	60,163.09	7291.74	87.88
B	60,163.09	4943.02	91.78
C	60,163.09	3548.23	94.15
D	60,163.09	3220.10	94.65
E	60,163.09	1005.38	98.33
F	60,163.09	532.90	99.11
G	60,163.09	329.28	99.45

The result of change in Total organic carbon concentration in each experimental set up during the study is presented graphically in Fig. 3.3

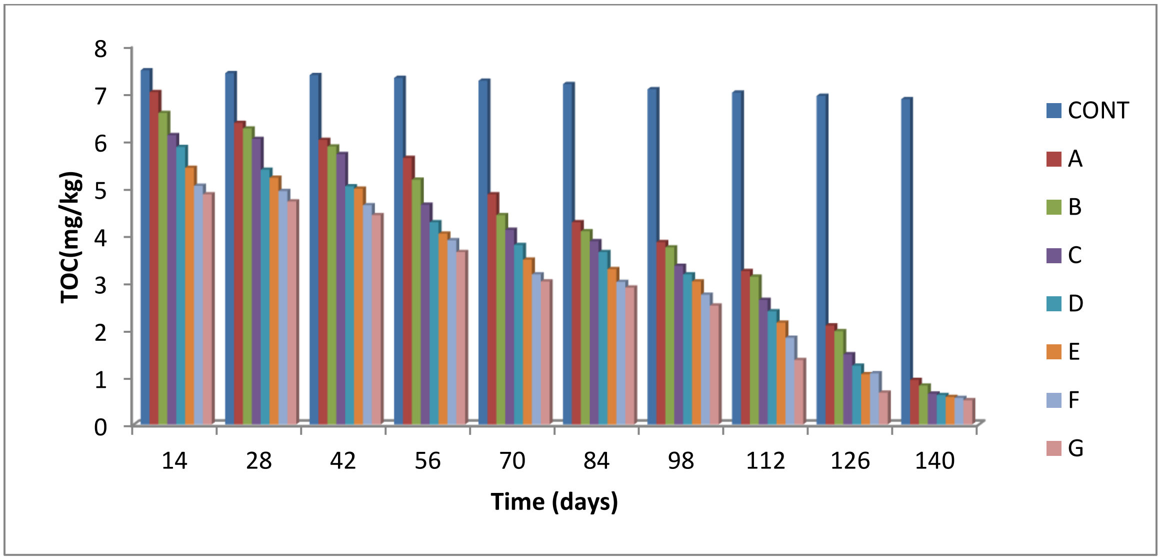

Fig. 3.3: Graph of TOC concentration (mg/kg) against time (days)

3.2 Discussions

Nigeria faces an enormous task of cleaning up the Niger Delta environment which has been severely polluted by oil spillage. Bioremediation has been identified globally as very effective, economical, and sustainable hydrocarbon remediation technology. Therefore the economical and simplicity advantage of bioremediation can be exploited to clean up the oil pollution in the Niger Delta region. Bioremediation has been defined as "the act of adding materials to contaminated environments to cause an acceleration of the natural biodegradation processes" (USEPA, 2006). Abu and Ogiji (1996) described bioremediation as technology that holds a lot of promise for both the developed and developing nations. Bioremediation is influenced by many factors of which the availability of hydrocarbon degrading microorganisms and nutrient are dominant factors. Different materials have been studied as possible source of nutrients for enhancement of biodegradation of crude oil pollution. These materials include inorganic fertilizer, kitchen sewage, organic compost, poultry dropping, cow dung, saw dust

In this study, the potential of water star grass compost in the enhancement of bioremediation of petroleum hydrocarbon polluted soil has been investigated. Total petroleum hydrocarbon (TPH) concentration was monitored throughout the study and the time series of TPH reduction presented in Fig 3.1 and Fig 3.2 while the initial and final TPH concentration in each set up are presented in Table 3.3. The results showed that TPH concentration reduced from 60163.09ppm to 46348.95ppm representing 22. 96% reduction in the control. Set up A, TPH reduced from 60163.09 to 7291.74ppm (87.88%) reduction. In B TPH reduced from 60163.09ppm to 4943.02ppm (91.78%). In set C, TPH reduced from 60163.09 to 3548.23 (94.15%) reduction. In D, TPH reduced from 60163.09 to 3220.10ppm (94.65%). In E, TPH reduced from 60163.09 T0 1005.38PPM (98.33%). In F there was a reduction from 60163.09 to 532.90ppm representing (99.11) reduction, while in set up G, TPH concentration reduced from 60163.09 to 329.28pp (99.45%) at the end the 5th month.

Iheoma *et al.,* (2015) recorded 99% TPH degradation with two times application of CNB bioremediation product. Adams *et al.,* (2014) reported 85% TPH removal in bioremediation project using Poultry litter as treatment. Jorgensen *et al.,* (2000), also implemented bioremediation of petroleum hydrocarbon contaminated soil using composting biopiles and recorded 70% TPH degradation. The difference in TPH degradation between the control and the test samples recorded in this study is attributed to the influence of the water star grass compost treatment on petroleum hydrocarbon biodegradation rate. The increase in microbial population observed in the treatment vessels is an indication that biodegradation was the predominant process of TPH removal in the experiment.

Among the 17 Poly Aromatic Hydrocarbon (PAHs) compounds listed by United States Environmental Protection Agency (USEPA) as chemical of concerned 15 were detected in the polluted soil. PAHs concentration drops from initial level of 43,818.57 to 46348.95ppm in the control.. PAHs concentration reduces from 43,818.57ppm to 10558.37ppm inset upl A at the end of the study period. Setups (treatment options) B, C, D, E, F and G recorded reduction from 43,818.57 to 8343,43ppm, 43,818.57 to 4932.16ppm, from 43,818.57 to 4444.65ppm, from 43,818.57 to 3583.33ppm, 43,818.57 to 1909.87ppm and from 43,818.57 to 962.06ppm respectively. In a bioremediation study conducted by Ambrosoli *et al.,* (2005), reported that approximately 30 – 60% of PAHs concentration reduction was achieved in a denitrifying condition with consortium of microorganisms isolated from contaminated soil. Iheoma *et al.,* (2015) researched on bioremediation of crude oil polluted soil in the Niger Delta and reported 100% reduction of Five PAHs identified in the polluted soil using CNB bioremediation product in two times application. The result in this study is in line with the result of Iheoma *et al.,* (2015).

Total organic carbon (TOC) of the soil sample in each set up was also monitored during the study. Soil organic carbon is mainly generated from decayed organisms (Wang *et al.,* 2013). Microorganisms derive carbon and energy from organic. Crude oil pollution also contributes to increase in soil total organic carbon. Monitoring results of TOC in the study, showed that TOC has a concentration of 7.48 mg/Kg, 7.02 mg/Kg, 6.58 mg/Kg, 6.11 mg/Kg, 5.86 mg/Kg, 5.42 mg/Kg, 5.04 mg/Kg and 4.86 mg/Kg in the Control, set up A, B, C, D, E, F and G respectively at day 14 but reduced to 1.09mg/kg, 0.94mg/kg,, 0.82mg/kg, 0.75mg/kg, 0.71mg/kg, 0.67mg/kg,, 0.61mg/kg and 0.58mg/kg respectively, at the end of the study. Wang *et al.,* (2010 and 2013) also reported that TPH increase soil TOC. This follows that crude oil degradation will cause TOC decrease. The drop in TOC recorded in this study is corroborated by the general decline in TPH and line with (Odokuma and Okey, 2005).

4.0 CONCLUSION AND RECOMMENDATIONS

4.1Conclusion

Bioremediation is recognized as efficient, economical and environmentally friendly pollution treatment technology. This technology takes advantage of the natural ability of microorganisms such as bacteria, fungi biodegrade organic pollutant to smaller harmless molecules.. In this study water star grass biomass compost was added to petroleum hydrocarbon polluted soil as a supplement to enhance natural attenuation. Based on the results obtained, the following conclusions have been drawn

Analysis of the percentage of total petroleum hydrocarbon degradation during the study revealed that the minimum compost e treatment of 100g per kilogram of polluted soil achieved 87.88% TPH removal, 500g of the the water star grass compost achieved 98.33% of TPH removal. 700g per kilogram of polluted soil achieved 99.45% of TPH removal. While only 22. 96% of TPH removal was achieved in the control set up. It is therefore concluded that water star grass biomass compost is a potential supplement for the bioremediation of petroleum hydrocarbon polluted soil

4.2 Recommendations

Based on the results obtained from this research, the following recommendations have been made;

i. The potential of water star grass should be exploited for the bioremediation of polluted soil as beneficial approach for the management and control of the stubborn grass.
ii. Further pilot field study using water star grass biomass compost to enhanced bioremediation of crude oil polluted soil is recommended.

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