Assessment of Show Star Grass (*Melampodium Paludosum)* for Phytoremediation of Motor Oil Contaminated Soil

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Abstract

Environmental pollution by petroleum and petroleum based products is a serious concern in pollution studies because of their structural complexity, slow biodegradation, bio- magnification potential and the serious health hazards associated with their release into the environment. Petroleum and allied products may enter the soil environment from ruptured pipelines, from land disposal of refinery products, petroleum wastes, leaking storage tanks, accidental spill and sometimes outright sabotage. Physical, chemical and thermal methods are already being used to remediate oil contaminated sites but their enormous costs, adverse effects on the environment and low efficiencies associated with these techniques limit their use and availability hence the use of biological methods like phytoremediation are being evaluated as alternative for the removal of pollutants because of their cost and safety of implementation.In this study, we investigate the potential of show stat grass (*Melampodium Palusodum*) a leguminous plant species which grows in tropical Nigeria for phytoremediation of laterite soil contaminated with motor oil. Our results indicate the following: that Show star grass (*Melampodium palusodum*) can grow, sustain growth and can survive in a motor oil contaminated laterite soil environment and can tolerate motor contaminated laterite soil at a concentration of 75.46 mg/g. Also, at a concentration of 75.46 mg/g in motor oil contaminated laterite soil environment, show star grass will stabilize and grow steadily after 8 weeks and enhances the degradation of motor oil in the contaminated laterite soil. Our results further indicate that Show star grass (*Melampodium palusodum*) reduced the initial TPH content in the contaminated soil from 75.46mg/g to 49.822 mg/g in two weeks after plant stabilization to 30.07 mg/g after 16 weeks of plant stabilization.

From the plot of TPH remaining in the soil against time, a polynomial model fit of the form:

$y = - 0.0675x^2 +0.0879x + 47.754$ is developed from which it is predicted that it will take about 28 weeks after the stabilization of the plants to reduce the total petroleum hydrocarbon (TPH) content in the contaminated soil to zero. The study revealed that the amount of hydrocarbon removed per plant from the contaminated soil ranges from 4.273mg/g after 2 weeks to 7.564 mg/g after 16 weeks of testing with corresponding removal efficiency ranging from 33.97% to 60.14% and hence it is concluded that Show star grass (*Melampodium palusodum*) has potential phytoremediation application in motor oil contaminated laterite soil.

Keywords: Phytoremediation, Show star grass, Motor oil, Laterite soil, Contamination.

1. Introduction

With the commercial exploration of petroleum products in Nigeria since 1958 (Okoh, 2003), petroleum has become the main stay of the Nigerian economy with the petroleum exploration, exploitation and distribution activities leading to the pollution of land and waterways in the Niger Delta region of the country where oil exploration and exploitation are carried out (Njoku *et al,* 2009) . The agricultural lands in the area have become less productive (Dabbs, 1996) and the creeks and fishing water have become more or less dead (Okpokwasili and Odokuma, 1990).

Environmental pollution has become a global problem affecting both developed and developing countries (Suresh and Ravishankar, 2004) and it has assumed global concern since it is a threat to the well being of all life forms including humans. Hydrocarbons are widespread in the environment; their major source is petroleum but they are also formed by synthetic processes and by biological processes by bacteria and plants (Weisman, 1998). Petroleum and petroleum products enter soil from ruptured crude oil pipelines, land disposal of refinery products, petroleum wastes, leaking storage tanks and accidental spill (Schwab and Bank, 1999; Schroder *et al.,* 2002).Petroleum hydrocarbons found in the environment usually originate from crude oil distillates like gasoline, lubricating oils and other petroleum products used by humans for a variety of activities like fuelling of vehicles, natural gas, motor oil has been on the increase due to industrialization that has resulted in increased consumption of petroleum products resulting in increased contamination of sites with petroleum and petroleum by- products (Bauman, 1991). According to Kathi and Khan (2011), petroleum and its products are of specific concern in pollution studies because of their structural complexity, slow biodegradability, biomagnification potential and the serious health hazards associated with their release into the environment.

The loss of occupations by native inhabitants of the Niger Delta region of Nigeria who are predominantly subsistent farmers and fishermen due to the pollution of land and waterways by oil exploration, exploitation and distribution activities has caused and is still causing restiveness in the region. Contaminated land has elevated concentrations of chemicals or other substances derived from man's use of land and soil contaminants influence human health, surface and ground water quality, the nature and viability of ecosystems, condition of buildings and other materials within the ground as well as the visual amenity of an area (Vegter *et al.,* 2002).This therefore calls for urgent and cost effective measures for the remediation of the contaminated lands and waterways in the Nigerian environment. Various physical, chemical and thermal processes or methods are already being used to remediate oil contaminated sites (Frick *et.al*., 1999; Gao and Zhu, 2003) but the enormous costs, adverse effects on the environment and low efficiencies associated with these remediation techniques present limitations to their availability and usage. It is reported in the literature (e.g. Gao and Zhu, 2003) that organic pollutants derived from treated soils are seldom thoroughly removed or degraded from the environment and thus still threaten human health and that the cost of these remediation methods are usually as high as US$ 100 – 300 per m^3 of soil hence limiting their application in developing countries like Nigeria. Hence in recent times, biological techniques like phytoremediation are being evaluated as alternative option for removal of environmental pollutants e.g. from sites contaminated with petroleum (Njoku *et.al*, 2003) due to its low cost and safety of implementation (Suza *et al.,* 2006). Phytoremediation is the use of plants and their associated microorganism to degrade, contain or render harmless contaminants in soil or groundwater (Cummingham *et al*., 1996; Merkl, 2005). It is a cost effective alternative for remediation of recalcitrant hydrocarbon contaminated soils (Salt *et al.,* 1998). Plants can provide a favourable environment for bioremediation and also reduce runoff and leaching from the contaminated site (Schnoor *et al.,* 1995). Phytoremediation has been shown to be effective for different kinds of pollutants e.g heavy metals, radio nuclides and broad range of organic pollutants (Schroder *et al*., 2002). The application of plants for remediation of soil contaminated with petroleum hydrocarbon is one of the promising cost and environmental effective approaches and for successful phytoremediation both plant and microorganism must survive and grow in the hydrocarbon contaminated soil.

Various plants with their associated microorganisms have been found to increase the removal of petroleum hydrocarbons from contaminated soil (Aprill and Sims 1999, Qiu *et al.,* 1997). According to Siciliano and Germida (1998b), plants to be used for phytoremediation should be appropriate for the climatic and soil conditions of the contaminated sites and such plants should also have the ability to tolerate conditions of stress. Of the various plants identified in the literature for their potential to facilitate the phytoremediation of sites contaminated with petroleum hydrocarbons, grasses and legumes were singled out for their potential in this regard (Aprill and Sims,1990; Gunther *et al.,*1996). Grasses are said to make superior vehicles for phytoremediation because they have extensive fibrous system and in particular grass root systems have maximum root surface area (per m^3 of soil) of any plant and may penetrate up to 3m (Aprill and Sims, 1990) while legumes are thought to have advantage over non- leguminous plants in phytoremediation because of their ability to fix nitrogen that is, legumes do not have to compete with microorganism and other plants for limited supply of available soil nitrogen at contaminated sites. Additional research work is needed to improve the natural capabilities of plants to perform remediation functions and to investigate other plants with potential phytoremediation applications.

The main goal of this investigation therefore, was to evaluate the potential of show stat grass (*Melampodium Palusodum*) a leguminous plant species which grows in tropical Nigeria for phytoremediation of laterite soil contaminated with motor oil. The study is significant in the sense that only few researches have been carried out on phytoremediation in the tropics even when conditions in the tropics favours the technique (Merkl *et al.,* 2005a). There is need therefore to investigate other plants with potential phytoremediation applications (Kumar et al., 2005) especially with respect to laterite soils contaminated with petroleum hydrocarbons. Laterite is a soil type found in the Niger Delta region in Nigeria (Leton and Omotosho, 2004) where pollution due to oil activities is high (Njoku *et al.,* 2009). The specific objectives of the study were:

- Characterize the soil and motor oil to be used for the study
- To ascertain the ability of show star grass to grow , sustain growth and survive in motor oil contaminated laterite soil
- Evaluate the potential of show star grass to stimulate biodegradation process of petroleum hydrocarbons in the soil
- Determine the amount of hydrocarbon removed from the soil with time and hence calculate the efficiencies of removal and on the basis of which determine the suitability of show star grass for use in phytoremediation of motor oil contaminated laterite soil.

2. Materials and methods

This study was carried out in two phases namely: (i) Field work and (ii) Laboratory work.

2.*1Field work*

The field work involved the collection of soil samples, soil preparation and obtaining and transplanting of the plants (show star grass). The soil used for the study was a sandy loam obtained from an agricultural land in Ugbowo Quarters, Benin City in Nigeria a site where the likelihood of previous petroleum hydrocarbon contamination was very remote. Soil samples were collected from both surface and subsurface. The subsurface soil was collected at a depth of 30 – 35 cm. The motor oil used for contaminating the soil was obtained from a motor / lubricating oil retail outlet in Benin City. The plant (Show star grass – *melampodium palusodum*) used for the study was obtained from a botanical garden in Benin City. The plant species are native to tropical subtropical regions. They can grow to a height of 1m in well drained soils but can equally grow in rocky soil and are moderately to highly drought and heat resistant. The plant is readily available in the Niger Delta region of Nigeria

Soil preparation was done in order to simulate a polluted land; 12kg of the air dried soil was fertilized with 10% (w/w) organic fertilizer. Three replicates of 3kg of the soil were each contaminated with 200ml of motor oil and the balance 3kg of the soil was left uncontaminated. The contaminated soil replicates and uncontaminated soil were each placed in a plastic bowl with a height column of about 35cm.The soils in the four bowls were watered and left for two day to absorb moisture. Eighteen young plants of show star grass obtained from a research garden near the University of Benin in Benin City were transplanted (6 each) into the 3 bowls with contaminated soil and the bowls housed the grasses throughout the duration of the experiments. The bowl with the uncontaminated soil was left with no plants and it thus served as control. The 4 bowls were stationed in the research garden under normal environmental conditions

2.2 Laboratory Experiments

The laboratory experiments for this study were carried out at two laboratories in Benin City. They are Civil Engineering Laboratory, University of Benin, Benin City and Franej Laboratory, Benin City. The following laboratory works were carried out in the laboratories:

i. Characterization of motor oil sample
ii. Characterization of the soil
iii. Total Petroleum Hydrocarbon analyses of the soil samples

2.2.1 Characterization of motor oil

The motor oil used for the study was characterized for following properties: density, specific gravity, kinematic viscosity, moisture content, flash point, temperature, and pH. The ASTM specifications/procedures were adopted. The results are given in Table1

2.2.2 Characterization of soil

The soil used for the study was characterized for the following properties using the indicated test procedures/ specifications:

i. Specific gravity [BS1377]
ii. Organic matter content [BS1377]
iii. Total Nitrogen content [IUPAC]
iv. Total phosphorus content [ASTM]
v. Total potassium content[ASTM]
vi. pH(soil) [ASTM]
vii. Sieve Analysis (BS1377)

The results are presented in Table2.

2.2.3 Total Petroleum Hydrocarbon Analyses

After an initial eight weeks period allowed for the growth and stabilization of the plants in the contaminated soil environment, soil samples were collected randomly from each of the three bowls at the top and below and then mixed and the labeled and taken to the laboratory for determination of the total petroleum hydrocarbon content (TPH) remaining in the soil in each bowl. The mean value of the TPH content remaining in the soil was recorded. The procedures were subsequently repeated every two week for a period of 16 weeks. The TPH content of the soil was determined using ASTM test procedures. However, the initial TPH of the soil was taken immediately after contaminating the soil with motor oil.

2.2.3.1 Amount of Hydrocarbon removed from the soil

The amount of hydrocarbon removed from the soil was estimated using the equation (Raghuvanshi *et al,* 2004):

$$q = \frac{C_o - C_e}{m} \qquad (1)$$

Where q = amount of hydrocarbon removed from the soil (mg/g)

C_o is the initial concentration of hydrocarbon in the soil (mg/g)

C_e is equilibrium concentration of hydrocarbon in the soil (mg/g)

2.2.3.1 *Efficiency of removal of hydrocarbon from the soil*

The efficiency of removal of hydrocarbon from the soil was estimated using the equation (Badmus *et al.,* 2007):

$$\in = \left(\frac{C_o - C_e}{C_o}\right)100 \qquad (2)$$

Where $\in$ = efficiency of removal of hydrocarbon from soil (%)

C_o = initial concentration of hydrocarbon in the soil (mg/g)

C_e = equilibrium concentration of hydrocarbon in soil (mg/g)

3. Results and discussion

The physico- chemical properties of the motor oil and soil samples are presented in Table 1 and Table 2.

Table 1: Properties of the motor oil used for contamination of the soil

Parameters	Results
Density(g/cm3)	0.878
Dynamic viscosity(g/cms)	2.37×10^{-5}
Kinematic viscosity (cm^2/s)	2.70×10^{-5}
Specific gravity	1.444
Flash point (^{o} C)	136
Temperature (^{o} C)	35
pH	5.71
Moisture content	1

Table 2: Physico- chemical properties of the laterite soil used for the study

Parameters	Results
Coarse sand (%)	1.18
Medium sand (%)	1.28
Fine sand (%)	85.01
Fine silt (%)	2.61
Fine gravel (%)	0.01
Clay (%)	10.02
Organic matter content (%)	5.6
Total Nitrogen content (%)	0.14
Total Phosphorus content (%)	4.25
Total Potassium content (mg/100mg Soil)	0.76
pH	7.98
Specific gravity	2.5

From the mechanical analysis of the soil as given in Table 2 (sand 85.01%, silt 2.61%, and clay 10.02%) the laterite soil texture is determined as loamy sand using the diagram provided in Harry and Nyle (1962). This soil texture type affects the phytoremediation process as it influences the bioavailability of the contaminant (Fricks et al, 1999). For example, clay is capable of binding molecules more than silt and sand resulting in the bioavailability of contaminants being lower in soils with high clay contents. As shown in Table 2 the soil has high organic matter content of 5.6% (> 5%) which leads to strong adsorption and therefore low bioavailability (Otten *et al.,* 1997). Adequate soil nutrients are required to support the growth of plants and their associated micro organisms during phytoremediation when the plant/microbe community is under stress from the contaminants especially as petroleum hydrocarbons greatly reduce availability of plant nutrient in soil (Xu and Johnson, 1997) due to the fact that petroleum hydrocarbons have high carbon content but are poor suppliers of nitrogen and phosphorus and as soil microorganisms degrade the hydrocarbons, they use up or immobilize available nutrients(N and P) creating nutrient deficiencies in the contaminated soil. Nutrient deficiencies which arise due to petroleum hydrocarbon contamination of soil may however be offset by application of fertilizer (Fricks *et al.,* 1999), addition of cow dung (Njoku *et al*., 2009) to the soil.

Observation during the initial growth period of the plant in the contaminated soil environment showed initially weak growth of the plant at the early period in the contaminated environment (first three weeks) but after eight weeks of transplanting to the contaminated environment the show star grass indicated steady growth. This indicates that show star grass can grow, sustain growth and survive in the contaminated soil environment and is therefore a good candidate for phytoremediation. This agrees with the position of Wenzel *et al* (1999) that plants to be used for phytoremediation must tolerate the pollutants at the concentration present in the contaminated environment.

The weak growth observed at the early stages could be attributed to the inhibited water and nutrient uptake due to the hydrophobic character of motor oil. The results of TPH analyses of the soil carried out on 2 weekly bases after the initial eight week growth period in the contaminated soil environment are presented in Table 3. The table shows the TPH (mg/g) content remaining in the soil, amount of hydrocarbon removed from the soil per plant and the efficiency of removal of hydrocarbon from the contaminated soil.

Table 3: Results of phytoremediation experiments and hydrocarbon removal efficiency computation

Time (weeks) [After initial 8 weeks plant growth/stabilization Period]	TPH(mg/g) content (mean) remaining in show grassed soil	Amount of hydrocarbon removed from show star grassed soil q (mg/g) (per plant)	Efficiency of removal of hydrocarbon from show star grassed soil ∈ (%)
2	49.822	4.273	33.976
4	45.064	5.066	40.281
6	44.183	5.213	41.449
8	43.508	5.325	42.343
10	42.788	5.445	43.788
12	40.885	5.763	45.819
14	36.982	6.413	50.991
16	30.079	7.564	60.139

Initial concentration of TPH in the contaminated soil (C_0) = 75.46 mg/g

From Table 3, it can be seen that the show star grass reduced the initial content of TPH in the contaminated soil from 75.46mg/g to 49.822 mg/g in two weeks after plant stabilization and to 30.07 mg/g after 16 weeks of plant stabilization. From the plot of TPH remaining in the soil against time shown in figure 1, a polynomial model fit is developed ($y = - 0.0675x^2 +0.0879x + 47.754$). From the model equation it is predicted that it will take about 28 weeks after the stabilization of the plants to reduce the total petroleum hydrocarbon (TPH) content in the contaminated soil to zero. This period may however be reduced if the plant density is increased. The degradation of the motor oil in the contaminated soil by show star grass plant may have occurred due to one of the many mechanisms of phytoremediation which include; phytodegradation, phytovolatilization, phytotransformation, phytostabilization and rhizofiltration (Gao and Zhu, 2003). This suggests that the ability of the show star grass to effect phytoremediation of the hydrocarbon contaminated soil is likely due to its capacity to enhance microbial activity in the rhizosphere (Anderson *et al.,* 1993) and activities of the detoxifying enzymes of the plant themselves (Newman and Reynolds,2004). The efficiency of this process is often associated with the high number of degrader microorganisms and their degradative activities in the rhizosphere of plants (Muratova *et al.*, 2003). The production of root exudates and plant materials which serve as source of carbon, nitrogen and phosphorus for petroleum degrading microbes (Alexander, 1997) is particularly important in this process especially as nitrogen fixed in the soil by legumes (e.g. show star grass) tends to reduce plant/microbes competition for nitrogen and thereby increasing plant growth exudates production and thereby increasing the ability of the plants to increase the degradation of the contaminants (Njoku *et al.,* 2009).

It is also shown in table 3 that the amount of hydrocarbon removed per plant from the contaminated soil ranges from 4.273mg/g after 2 weeks to 7.564 mg/g after 16 weeks of testing with corresponding removal efficiency ranging from 33.97% to 60.14%. This is a steady increase in the rate of degradation of hydrocarbon present in the soil with time as given in Figure 3

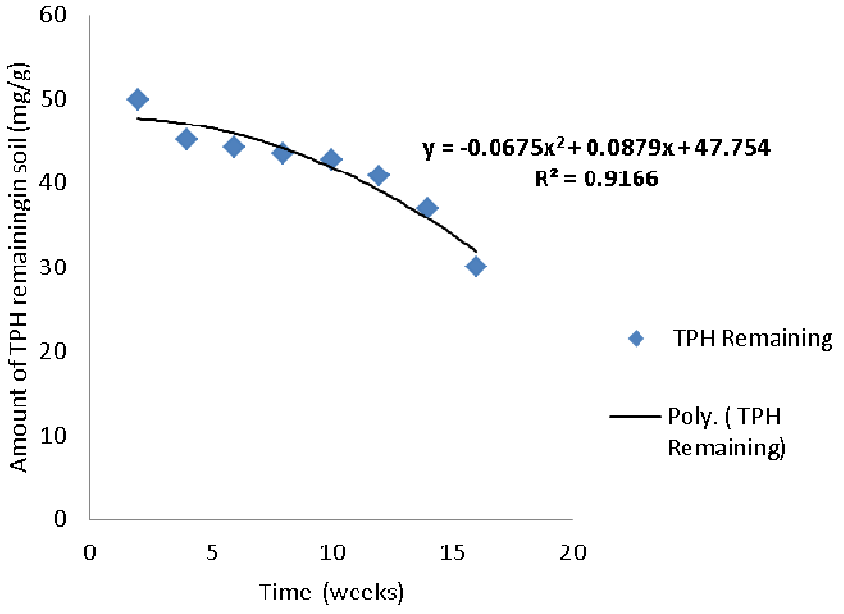

Fig 1: Plot of amount of TPH remaining in soil with time

From the model equation; $y = - 0.0675x^2 + 0.0879x + 47.754$, it is predicted that it will take about 28weeks after the stabilization of the plants for it to reduce the total petroleum hydrocarbon (TPH) content in the contaminated soil to zero.

4. Conclusions

From the study the following conclusions are made:

- Show star grass (*Melampodium palusodum*) can grow, sustain growth and can survive in a motor oil contaminated laterite soil environment.
- Show star grass (*Melampodium palusodum*) can tolerate motor oil contaminated laterite soil at a concentration of 75.46 mg/g.

- At a concentration of 75.46 mg/g in motor oil contaminated laterite soil environment, Show star grass (*Melampodium palusodum*) will stabilize and grow steadily after 8 weeks.
- Show star grass (*Melampodium palusodum*) enhances the degradation of motor oil in the contaminated laterite soil. The degradation of the motor oil in the contaminated soil may have occurred due to one of the many mechanisms of phytoremediation which include; phytodegradation, phytovolatilization, phyto extraction, phytotransformation, phytostabilization and rhizofiltration (Gao and Zhu, 2003).
  Show star grass (*Melampodium palusodum*) reduced the initial TPH content in the contaminated soil from 75.46mg/g to 49.822 mg/g in two weeks after plant stabilization to 30.07 mg/g after 16 weeks of plant stabilization.
- From the plot of TPH remaining in the soil against time, a polynomial model fit of the form: $y = -0.0675x^2 + 0.0879x + 47.754$ is developed.
- From the model equation it is predicted that it will take about 28 weeks after the stabilization of the plants to reduce the total petroleum hydrocarbon (TPH) content in the contaminated soil to zero.
- The amount of hydrocarbon removed per plant from the contaminated soil ranges from 4.273mg/g after 2 weeks to 7.564 mg/g after 16 weeks of testing with corresponding removal efficiency ranging from 33.97% to 60.14%.
- Show star grass (*Melampodium palusodum*) can thus be used for the phytoremediation of petroleum hydrocarbon contaminated soil.

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