Assessment of the phytoremediation capacity of *Vetiveria Zizanioides* for the remediation of crude oil contaminated soils

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Abstract

This study was conducted to evaluate the phytoremediation capacity of *Vetiveria Zizanioides* in crude oil-contaminated soils in Imiringi, Bayelsa State. 2000g sample of soil was collected, homogenised and divided into six equal parts A, B, C, D, E, and F, respectively. Sample B, D and F were artificially contaminated with 200 cm^3 of crude oil each and homogenised again. Samples A, C, and E served as control over B, D and F, respectively. This was followed by series of tests. First, *Agaricus bisporus* was added to Sample C to make it a Myco-rich environment. *A. bisporus* was also added to sample D. *A. bisporus* thrived on C for 4 days while it was observed to almost immediately decompose in D. Furthermore, grown *Pistia stratiotes* (Linn.) was transplanted on both Samples C and D at the same time. *P. stratiotes* (Linn.) on Sample C blossoms while within very few minutes of transplanting, *P. stratiotes* (Linn.) in

Sample D lost its colouration and died within two (2) hours. Moreso, both the *V. zizanioides and Leptochloa caerulescence (Steud.)* were grown and transplanted on samples E and F. Both grew on sample E whereas *L. caerulescence (Steud.)* could not even survive a day on sample F. The death of the *Leptochloa caerulescence (Steud.)* could be attributed to the crude oil contamination. The results of the current study shows that *V. Zizanioides* is promising for the remediation of petroleum hydrocarbon contaminated soils. However, further work is needed to evaluate its potency for one to two vegetation periods; and genuinely crude oil-contaminated soils.

Keywords: Crude oil contamination; *V. Zizanoides* ; Phyto-remediation; Remediation.

Introduction

There are huge numbers of crude oil-impacted sites in the Niger Delta region, where the oil and gas industries in the country sit. Consequently, oil pollution has become a severe challenge in the region. This has attracted crucial ecological and human health concern, thus environmental clean-up using green approach is needed. Hence, remediation becomes imperative as one of the reliable tools to clean-up the impacted environment; leaving no unacceptable risk. Contaminated soils can be remediated biologically or by physiochemical means. However, some technologies are quite uneconomic and can even affect soil functions, and may render soil unproductive for plant growth [1]. Novel and environment friendly methods, including phytoremediation have been investigated as new alternatives [2]. Phytoremediation is the application of plants and associated microbes to reduce the concentration toxic effects on contaminants in the environment. This methodology is perceived as cost-effective, efficient, and green solution to the problem of environmental pollution. However, the challenge of this remediation strategy is that it works well at shallow depths; while oil pollution in Niger Delta has penetrated below 5 m [8]. Recently, the effectiveness of onsite exsitu by remediation enhanced by natural attenuation (RENA) has been assessed; and then proposed as an alternative remediation technique to remediation by RENA [9]. There is a high expectation that onsite exsitu by RENA would add contaminants into the already contaminated soil and the wider environment if the leachate collection system is not properly designed; which is a disadvantage. Thus, biological method of remediation is strongly desired.

Biological method uses plants and microorganisms to get rid of toxic environmental contaminants [10]. This approach is most effective, environment friendly, relatively cost-effective, and has highly gained public acceptance [11].

A number of plants are able to accumulate contaminants in their tissues [12], for instance, *Eleocharis acicularis* is capable of accumulating arsenic (As), copper (Cu), Zinc (Zn), and Lead (Pb) [13]. *Brassicaceae*, *Euphorbiaceae*, *Asteraceae*, *Fabaceae*, *Lamiaceae,* and *Scrophulariceae* are some vital families of plants capable of accumulating heavy metals [14, 15]. *Jatropha curcas*, a plant commonly known as the physic nut, in the family of *Euphorbiaceae* recognised as a fuel [15] has been tested to evaluate their phytoremediation potential in soils by different concentrations of mercury [16]. The authors concluded that *Jatropha curcas* could be useful for the remediation of mercury-contaminated sites. Phytoremediation has been applied for the uptake of vast quantities of heavy metals from soil and storage of these in a removable component [15, 16]. Plants typically cope with contaminants by changing the properties of soil, which conserves soil efficacy and fertility [17].

In Nigeria, biological remediation approach has been implemented in some parts of the Niger Delta area to detoxify and restore ecosystems damaged by oil spills [18, 21]. For instance, *Hibiscus cannabinus*, an annual herbaceous plant has been originally used for pulp production. This species has high rates of absorbency and can be laid down on top of oil-impacted water to absorb oil. In Niger Delta, relatively few studies had been successfully carried out using bioremediation approach [19, 20]. To date, there is no study on phytoremediation using *Vetivera Zizanoides* to remediate crude oil-contaminated soils. In view of the persistence occurrences of oil spill in low land sedimentary environment, there is urgent research need into using a biological means of remediating the huge numbers of crude oil-impacted sites in Niger Delta. Accordingly, the objective of this study was to assess the phytoremediation capacity of *Vetiveria Zizanioides* to remediate soils artificially contaminated with crude oil.

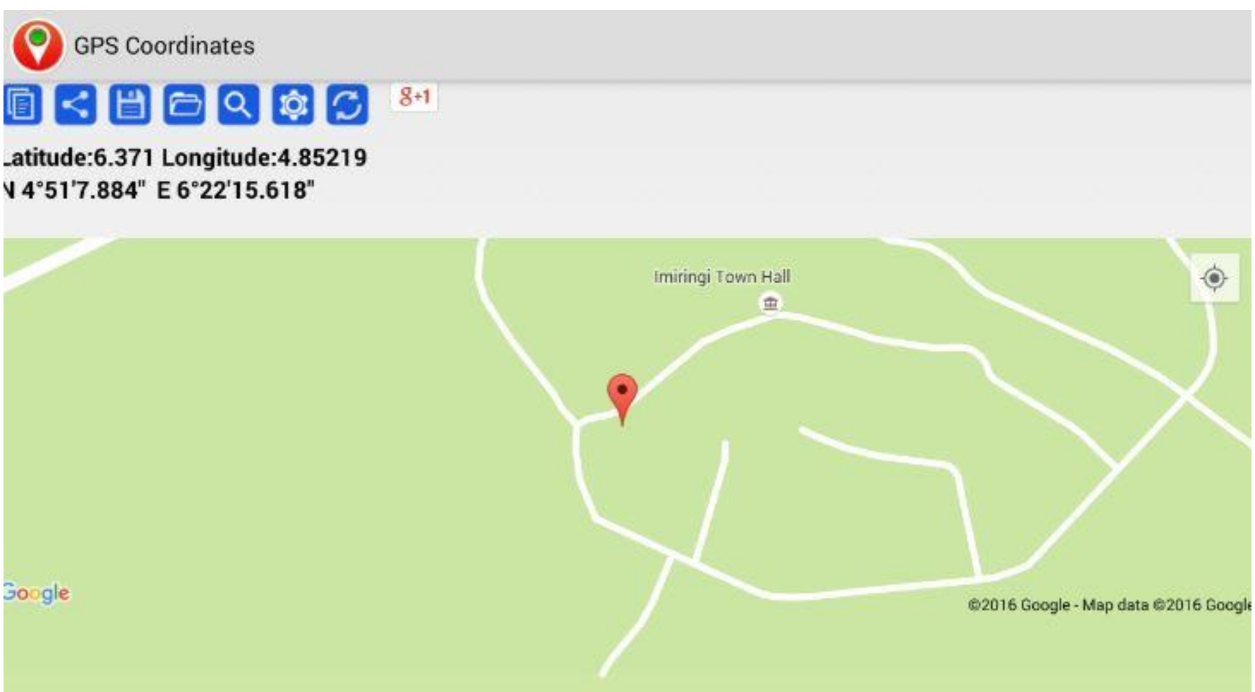

Figure 1 Location of the study area

The study area Imiringi (in Ogbia Local Government Area, LGA), is part of the Niger Delta sedimentary basin of Nigeria. It is situated on the continental margin of the Gulf of Guinea in Equatorial West Africa between latitude 3° and 6° N and longitudes 5° and 8°. It is geographically located within 4°15' North and Latitude 5°23' South also within Longitude 5° 22' West and 6° 45' East. The state is bounded by Delta State on the North, Rivers state on the East and the Atlantic Ocean on the Western and southern parts.

GEOLOGY OF THE STUDY AREA

Bayelsa State is located within the lower delta plain believe to have been formed during the Holocene of the quaternary period by the accumulation of sedimentary deposits. The major geological characteristic of the state is sedimentary alluvium. The entire state is formed of abandoned beach ridges and due to many tributaries of the River Niger in this plain, considerable geological charges still abound. The major soil types in the state are young, shallow, poorly drained soils (inceptisol Aquests) and acid sulphate soils (sulphaquets). There are variations in the soils of Bayelsa state; soil types occupy extensive areas whereas others are of limited extent. However, based on physiographic differences, several soil units could be identified in the state.

Climate and Vegetation

The climate is homointic generous. Rainfall in study area varies from one area to another. The state experiences equatorial type of climate in the Southern part and tropical climate rain towards the northern part. Rainfall occurs generally every month of the year with heavy downpour in July. The climate is topical i.e wet and the dry season. The amount of rainfall is adequate for all year round crop production. The wet season is not less than 340 days. The main monthly temperatures in study area range from 25°C to 31°C. The mean annual temperature is uniform for the entire State. The hottest months are December to April. Relative humidity is high in the state throughout the year which decreases slightly in the dry season. Bayelsa state is composed of four ecological zones. These include: coastal barrier island forest, mangrove forests, freshwater swamp, forests and lowland rain forests. These different types of vegetation are associated with the various soil units in the area, and they constitute part of the Niger Delta complex ecosystems.

METHODOLOGY

This research work utilises plant biotechnology, and environmental method of study to remediate artificially contaminated soils. Both the soil sample and the plant species for the experiment were collected from the same sampling site (oil field). The environmental investigation involves the comparison of the physical and chemical properties of the soil samples in relation to the growth of the subjected plants in the soil. The water used throughout the experiment was collected from the sample location to prevent non-indigenal effect and to promote homogeneity of materials used.

Results and Discussion

PROCEDURE 1

Two kilo grams (2kg) soil was collected from the study area and was divided equally into six (6) different sample containers. Then the samples were labelled **A**, **B**, **C**, **D**, **E**, and **F** respectively. The experiment has three (3) controls: Sample A was used as control over sample B, C was the control for D and E was the control for F. The water sample used throughout the experiment was water collected from the soil sampling environment so as to maintain homogeneity of material and to enhance good result.

PROCEDURE 2

Sample A was maintained as control while B was contaminated with 200 cm^3 of crude oil and homogenised.

Figure 2 PLATE 1 SHOWING MAIZE SEEDLING IN SAMPLE A

Figure 3 PLATE 2 SHOWING CONTAMINATED SAMPLE B

PROCEDURE 3

White Mushroom *Agaricus bisporus* (an edible basidiomycete mushroom) was added to Sample C to make it a Myco-rich environment without being contaminated with crude oil while sample D was contaminated with crude oil (200 cm^3) and homogenised; followed by planting of white mushroom.

Figure 4 PLATE 3 SHOWING MYCO-RICH SAMPLE C

PROCEDURE 4

Sample E was uncontaminated soil sample with Poacea**,** *Vetiveria zizanioides* growing on it and *Leptochloa caerulescence (Steud.)* while sample F was contaminated with crude oil (200 cm^3), homogenised and thereafter *Leptochloa caerulescence (Steud.)* was transplanted on the Sample.

Figure 5 PLATE 4 SHOWING *V. zizanioides* ***(R)*** AND *L. Caerulescence* (STEUD) ***(L)***

OBSERVATION 1

Sample A germinated after five (5) days of seed planting with a hypogeal germination, bearing just a leaf seedling being a monocotyledon plant. This shows a normal germination; and a fertile and unpolluted soil is the reason. Sample B did not germinate, rather died and decayed in the soil. This may be attributed to the presence of crude oil in the soil. This is because crude oil has been previously reported to have altered some of the soil properties leading to poor aeration, immobilisation of soil nutrients, and lowering soil pH which are principally accountable for change(s) in fertility of soil [22].

OBSERVATION 2

Sample C which was made rich by fungi; by the addition of white mushroom *Agaricus bisporus* (an edible basidiomycete mushroom) to test the effect of crude oil on the fungi by comparing the observed result with the contaminated Sample D, which was also made rich with *Agaricus bisporus.* It was discovered that the *Agaricus bisporus* thrived on Sample C for a period of four (4) days before disintegration whereas; disintegration and decomposition process was almost immediately in Sample D. The presence of crude oil in sample D is the only reason and explanation for the quick disintegration and decomposition of *Agaricus bisporus* in sample D.

OBSERVATION 3

Further probing was done to ascertain what was responsible for the death of the white mushroom in Sample D, so, water lettuce, *Pistia stratiotes* (Linn.) was transplanted on both Sample C and D at the same time. The water lettuce, *Pistia stratiotes* (Linn.) transplanted on Sample C blossoms (**PLATE 5**) while within very few minutes of transplanting, water lettuce, *Pistia stratiotes* (Linn.) in Sample D lost its colouration and died (**PLATE 6**) within two (2) hours of contacting the crude oil in Sample D. It was observed that there was a capillarity effect of crude oil on the leaves of water lettuce, *Pistia stratiotes* (Linn.)

Figure 6 PLATE 5 SHOWING BLOSSOMING water lettuce, *Pistia stratiotes* (Linn.)

Figure 7 PLATE 6 SHOWING DECOLOURIZING water lettuce, *Pistia stratiotes* (Linn.)

Figure 8 PLATE 7 SHOWING DEAD, water lettuce, *Pistia stratiotes* (Linn.)

OBSERVATION 4

Sample E was an unpolluted (pristine) soil sample from the same area as others on which two plants are thriving i.e. Poacea**,** *V. Zizanioides* growing and Poacea *L. caerulescence (Steud.).* These two plants are doing well at least in the first three (4) weeks of transplanting. The plant in Sample F, Poacea**,** *L. caerulescence (Steud) did not survive in the first day.*

The presence of crude oil was suspected to be the reason for the death of the Poacea**,** *L. caerulescence (Steud.).*

RESULTS AND DISCUSSION

Table 1: System designs for the experimental set-up

S/N	System description	System code	Result	Remarks
1	Sample A alone	S	Control	Positive
2	Sample B +CO	S + CO	Oil killed	Negative
3	Sample C + WM	S + WM	Untreated	Positive
4	Sample D + CO + WM	S + CO + WM	Oil killed	Negative
5	Sample E + V.z +L.c	S + V.z + L.c	50%:50%	Positive & negative
6	Sample F + CO + L. c	S. CO + L.c	Oil killed	Negative

CO =crude oil, **L.c=** *Leptochloa caerulescence***, V.z=** *Vetiveria zizanioides***, S**=Soil, WM=White Mushroom

The experiment had three controls: (i) soil without crude oil (CO) contamination and treatment (S) (ii) soil without contamination with crude oil (S+ CO) and received no treatment of white mushroom and (iii) soil without contamination with crude oil with the two grass species growing on it: *Vetiveria Zizanioides* and *Leptochloa caerulescence (Steud..)* The different responses to crude oil contamination and its effects are noted in each system. The introduction of crude oil into the sample was followed by homogenization process and watering to provide aeration and moisture respectively. Aeration was thereafter enhanced on weekly basis. No other form of nutrient supplement or amendment was introduced into the system throughout the remediation period of 16 weeks except in sample F that was later treated with crude oil to validate the ability of *V. Zizanioides* to degrade carbon compounds.

Maize plants in Sample A blossoms with a normal growth rate of 17 inches per 48 hours. Therefore the death and decay of sample B is believed not to have come from the soil sample but from the crude oil contamination. White mushroom *Agaricus bisporus* survived before disintegrating due to maturity, while same white mushroom *Agaricus bisporus* could not survive under the presence of crude oil which shows that the negative effect of crude oil has on fungi srvived. Lettuce, *Pistia stratiotes* (Linn.), though, being a free-floating aquatic herb with thick, succulent leaves could not survive the presence of crude oil contamination. Both plants are of the same class and family but they respond to crude oil contamination differently. *Vetiveria Zizanioides* responded positively, that is, crude oil has no deteriorating effect on it; while it destroys Poacea and *Leptochloa caerulescence (Steud.).* Hence the result of the study reveals that *Vetiveria zizanioides* is promising for the remediation of crude oil impacted land sites.

CONCLUSIONS

This study investigated the phytoremediation potential of *V. Zizanioides* in artificially crude oil-contaminated soils. Results from the study showed that: (1) *P. stratiotes* (Linn.) transplanted on Sample C blossoms while it died on Sample D within two hours; (2) *V. zizanioides and L. caerulescence (Steud.)* were grown and transplanted on samples E and F; where both grew on sample E whereas *L. caerulescence (Steud.)* could not survive on sample F. The growth of *V.*

Zizanioides despite the toxicity of the contaminant demonstrates its phytoremediation ability. The result suggests that *V. zizanioides* is a good choice for the phytoremediation of crude oil-impacted soils. However, it should be emphasised that this study was carried out on artificially crude oil-contaminated soils, and has to be conducted on the numerous petroleum-impacted sites in the Niger Delta. Further work should consider longer vegetation period.

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