EFFECTIVENESS OF MAGATHYRSUS MAXIMUM IN THE PHYTOREMEDIATION OF CRUDE OIL CONTAMINATED SOIL

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ABSTRACT

The effectiveness of Magathyrsus maximum in the phytoremediation of crude oil contaminated soil was examined in this paper. This was done by examining two soil samples labeled B1 and B2 for eighteen-week period. Sample B1 contained crude oil; serving as the control and sample B2 contained Magathyrsus maximus, crude oil and cow dung manure. The experiment involved mixing 70g of crude oil thoroughly with 4000g of loamy soil in plastic containers. Soil samples were collected using a hand trowel and analyzed at the beginning and end of the investigation. At the conclusion of the eighteen-week period, there were no significant changes for sample B1. Significant changes were observed in various soil parameters for sample B2. The pH values increased from 5.750±0.034 to 6.990±0.041, while electrical conductivity (EC) values decreased from 427 dS/m to 261 dS/m. Moisture content (MC) values increased from 17.3 ± 0.016% to 26.3 ± 0.057%, and bulk density decreased from 1.386 ± 0.004 g/cm^3 to 1.349 ± 0.025 g/cm^3. Total nitrogen content (TNC) values decreased from 0.131 ± 0.316% to 0.101 ± 0.701%, available phosphorus (AP) values decreased from 11.610 ± 0.097 mg/kg to 4.000 ± 0.054 mg/kg, and total organic carbon (TOC) values decreased from 3.990 ± 0.082% to 1.920 ± 0.035%. However, total organic matter (TOM) values increased from 1.101 ± 0.017% to 1.267 ± 0.048%, and total hydrocarbon content (THC) values decreased from 89.280 ± 0.108 mg/kg to 7.900 ± 0.082 mg/kg. The findings indicate that Magathyrsus maximum demonstrates potential for remediating crude oil-contaminated soil based on the observed changes in soil parameters.

Keywords: Effectiveness, Phytoremediation, Crude Oil, Soil, Contamination and Magathyrsus Maximus (Guinea Grass)

1. INTRODUCTION

Soil plays a pivotal role as a fundamental and indispensable natural asset, serving as a crucial intermediary among environmental elements such as air, bedrock, water, and biota. Through their complex interrelations, these components collectively fulfill vital requirements, including the provision of sustenance like food, fuel, and fiber to support diverse organisms. Petroleum contamination of soil has become a notable environmental issue worldwide, attracting considerable public awareness in recent decades (Fanaei et al. (2020)). Human activities, including agriculture, industrial operations, and bunkering, are the primary contributors to the release of hydrocarbons into the environment (Fanaei et al. (2020)).

In Nigeria, particularly in the South-South region where oil exploration is prevalent, the occurrence of crude oil pollution is increasing. As the extent of soil affected by petroleum hydrocarbons continues to grow, efforts have been made to tackle and remediate the overall contamination caused by petroleum hydrocarbons in soil. Occurrences like spills, leaks, and other environmental factors associated with petroleum products present hazards to human health (Ogah & Ozioma (2021)).

In recent years, biological methods have gained preference over chemical and physical techniques for remediation due to their cost-effectiveness and their ability to prevent the buildup of contaminants (Osman et al. (2020)). Research suggests that certain plants can remediate soils contaminated with crude oil through a process called phytoremediation (Njoku et al. (2009)).

Phytoremediation, as outlined by Truu et al. (2015) is a technology that relies on the cooperative actions of plants and their associated microbial communities to degrade, remove, modify, or immobilize harmful compounds present in soils, sediments, and increasingly in polluted groundwater and wetlands. This cost-effective and passive method has the capability to target both organic and inorganic contaminants without the limitations associated with traditional remediation techniques.

2. MATERIALS AND METHOD

2.1. STUDY AREA

The research was conducted at the demonstration farm of HighCast International Academy, situated at 6, Logos/Holiness Avenue, off NTA-Rumuokwuta road, Mgbuoba, Port Harcourt, Rivers State. Mgbuoba is a locality within the Obio/Akpor Local Government Area of Rivers State, positioned at latitude 4.8421° N and longitude 6.9692° E.

2.2. SAMPLE COLLECTION AND PREPARATION

The crude oil used in the study, characterized as light sweet crude with 36.3 oAPI and 0.16 wt% sulfur, was sourced from The Port Harcourt Refining Company (PHRC) in Port Harcourt, Rivers State, Nigeria (Enekwe et al. (2012)). Magathyrsus maximus (Guinea grass) samples were harvested from the demonstration farm of HighCast International Academy. Additionally, uncontaminated loamy soil samples were gathered from the same demonstration farm in Mgbuoba, Port Harcourt, using a hand trowel at a depth of 12 cm on a single day. These soil samples were then air-dried for two days to remove moisture, sieved through a 2 mm mesh, and stored in polyethylene bags at room temperature.

2.3. PHYTOREMEDIATION STUDIES

Seventy grams (70g) of crude oil was thoroughly mixed with 4000 grams of loamy soil in plastic containers, with the contamination process also conducted in plastic containers. The soil samples were then left for two days to allow the crude oil to settle properly. In sample B2, cow dung manure was added to enhance plant growth and facilitate the remediation process, while in sample B1 (the control), no cow dung manure was added. Magathyrsus maximus (Guinea grass) was transplanted into sample B2. To prevent contamination from insects, the samples were kept in a greenhouse and regularly watered to maintain moisture levels. The phytoremediation process was allowed to proceed for a total period of eighteen weeks.

2.4. ANALYSIS OF PHYSICOCHEMICAL PROPERTIES OF SOIL

Soil physicochemical properties were assessed before and after contamination to evaluate the impact of phytoremediation on soil quality. These properties included pH, total hydrocarbon content, total organic carbon, total nitrogen content, phosphorus content, moisture content, bulk density, electrical conductivity, and total organic matter. Soil samples were collected from each container using a hand trowel and stored in clean plastic containers for analysis. Sampling was conducted every two weeks. The pH of the soil samples was determined using a glass electrode pH meter. Nitrogen content was determined using the modified Kjeldahl method. Organic carbon and organic matter were measured using the chromic acid wet oxidation method. Available phosphorus was assessed using the colorimetric Molybdenum blue procedure. The amount of crude oil in the soil samples was determined by sieving air-dried soils through a 1mm mesh.

3. RESULTS AND DISCUSSION

3.1. PHYSICOCHEMICAL PROPERTIES OF THE SOIL USED FOR THE STUDY

Table 1 illustrates the changes in soil physicochemical properties before and after exposure to crude oil contamination. The pH decreased from 6.090 ± 0.130 to 5.750 ± 0.034, likely due to the acidic nature of crude oil, which is known to lower soil pH upon contamination, as observed by Ogboghodo et al. (2004). This finding aligns with previous studies (Akubugwo et al. (2009); Nwaogu & Onyeze, 2010; Egharevba et al. (2017)) reporting similar pH values. Furthermore, the introduction of crude oil resulted in an increase in organic carbon content from 1.920 ± 0.014% to 3.990 ± 0.002%. Nitrogen content decreased from 0.175 ± 0.101% to 0.131 ± 0.316%, possibly due to the inhibition of nitrogen-fixing bacteria and other microorganisms involved in organic decomposition by crude oil contamination, resulting in reduced soil nitrogen levels (Wang et al. (2013)). Notably, hydrocarbon levels increased from 0.140 ± 0.006 mg/kg to 89.280 ± 0.008 mg/kg, consistent with the predominant presence of hydrocarbons in crude oil (Ogboghodo et al. (2004)) corroborating earlier findings by Egharevba et al. (2017) on elevated hydrocarbon concentrations in crude oil-contaminated soil. The phosphorus levels also rose from 8.420 ± 0.216 ppm to 11.610 ± 0.097 ppm. Phosphorus exhibits its highest solubility around a pH of 6.5, indicating that the nutrient becomes more accessible up to this pH threshold (Egharevba et al. (2017)). Therefore, the decrease in soil pH resulting from crude oil contamination may have contributed to the increased availability of phosphorus in the soil. This effect could stem from the breakdown of organic matter present in crude oil, releasing phosphorus into the soil. The electrical conductivity (EC) experienced a significant increase from 271.000 ± 1.300 µS/cm to 427.000 ± 0.780 µS/cm post-contamination. This elevation suggests a higher concentration of ions in the soil, potentially impacting soil salinity and nutrient availability. Following contamination, the moisture content decreased from 31.000 ± 0.401% to 17.300 ± 0.016%. This decrease might be attributed to the hydrophobic nature of crude oil compounds, which repel water, thereby reducing the soil's moisture retention capacity. Moreover, the bulk density increased from 1.218 ± 0.011 g/cm^3 to 11.386 ± 0.010 g/cm^3 post-contamination. Crude oil can infiltrate the soil matrix, filling pore spaces and compacting soil particles, leading to a reduction in soil volume and an increase in bulk density. Total organic matter decreased from 2.463±0.032% to 1.101±0.017% after contamination. The decrease may be as a result of activities of some microorganisms such pseudomonas aeruginosapresent, bacillus and rhodococcus in the soil which are capable of utilizing organic matter, including components of crude oil, as a source of energy. As they metabolize these organic compounds, they break them down into simpler forms, thereby reducing the overall organic matter content of the soil.

Table 1

Table 1 Physicochemical Properties of Soil Used for the Study Before and After

Soil Indicators	Before	After
pH	6.090 ±0.130	5.750±0.034
EC(Electrical Conductivity)	271.000±1.300	427.000±0.780
MC (Moisture Content)	31.000±0.401	17.300±0.016
BD (Bulk Density)	1.218±0.011	1.386±0.010
TN (Total Nitrogen)	0.175±0.101	0.131±0.006
AP (Available Phosphorus)	8.42.000±0.216	11.61±0.097
TOC (Total Organic Carbon)	1.920±0.014	3.990±0.002
TOM (Total Organic Matter)	2.463±0.032	1.101±0.017
HC (Hydrocarbon Content)	0.140±0.006	89.280±0.008

TNC, TOC, TOM and MC are expressed in %, AP and HC in mg/kg, BD in g/cm3, PC in ppm, EC in dS/m, CEC in cmol/kg, pH has no unit

3.2. SOIL PH

Figure 1 demonstrates the pH variation in soil samples over time. Initially, all samples displayed acidity following contamination at week 0. However, throughout the 18-week observation period, a gradual rise in pH was observed in samples B2. In contrast, the control sample (B1) maintained relatively stable pH values throughout the experiment, indicating minimal remediation in the absence of plant presence. The pH values for B2 increased from 5.750 ± 0.034 to 6.990 ± 0.041 (a 1.24 increase). This observation is consistent with previous research findings, such as those of Ebere et al. (2011) who noted a similar trend in the remediation of crude oil-polluted soil, where pH increased from 5.21 to 7.1. Comparable results were also reported by Egharevba et al. (2017), with pH levels transitioning from acidic (4.27) to near-neutral (6.07 to 6.59) following treatment with specific plant species. Similarly, Akram & Deka (2021) and Chukwuma et al. (2019) documented similar pH shifts in their respective studies, indicating a shift from acidic levels to more favorable ranges for plant growth, in line with the guidelines established by the Federal Environmental Protection Agency (FEPA), which recommend an optimal pH range of 5.5-7 for plant growth. Overall, the observed pH increase over the 18-week period suggests successful mitigation of acidic conditions in the soil, progressing towards a more neutral range conducive to plant growth.

Figure 1

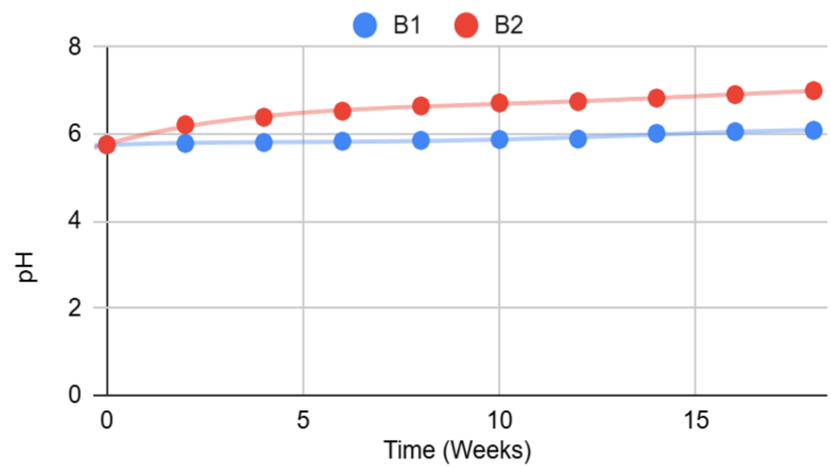

Figure 1 Variation of Soil pH with time

3.3. SOIL ELECTRICAL CONDUCTIVITY (EC)

Throughout the 18-week investigation period, the electrical conductivity (EC) of the control sample (B1) exhibited minimal variation, with a slight decrease from 427 dS/m to 413 dS/m, indicating stability. The EC values for sample B2 dereased 427 dS/m to 261 dS/m. This decrease in EC can be attributed to the natural salt-absorbing and filtering properties of M. maximus. It's likely that the plants absorbed and mitigated the salt content in the soil, leading to a reduction in EC. These findings are consistent with Akram & Deka (2021)who observed similar EC reductions post-treatment with specific plant species. They also align with previous reports such as Okoro et al. (2011) and Anacletus et al. (2017), who documented varying EC values in different soil conditions.

Figure 2

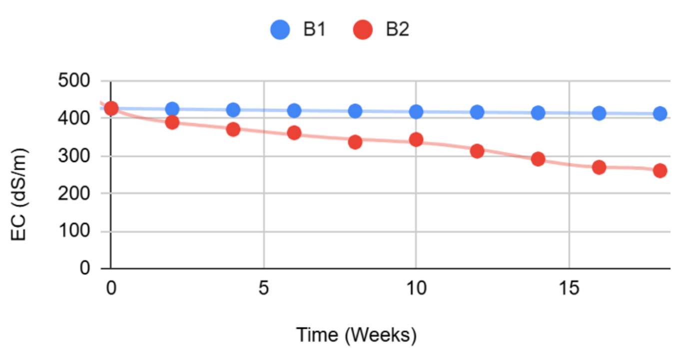

Figure 2 Variation of Soil electrical Conductivity with time

3.4. SOIL MOISTURE CONTENT (MC)

Figure 3 illustrates the moisture content (MC) variations in soil samples over time. By the end of the 18-week investigation period, the control sample B1 remained relatively constant, showing a slight increase from 17.300 ± 0.016% to

19.400 ± 0.024%, indicating a 2.1% increment. This slight rise in moisture content is likely influenced by natural environmental factors.

In contrast, the sample containing plants (B2) demonstrated significant increases in MC, elevating from 17.3 ± 0.016% to 26.3 ± 0.057%. The presence of plants in the contaminated soil likely enhanced its water retention capacity and facilitated the breakdown of contaminants through the rhizosphere effect. Furthermore, microbial activity in the soil contributed to pollutant degradation and an increase in moisture content. The observed rise in moisture content can be attributed to various factors, including contaminant breakdown, microbial activity, and the impact of different plant combinations on soil conditions. The presence of plants is believed to have improved soil water retention capacity, aided in contaminant breakdown, and promoted soil moisture retention. These findings are consistent with previous research, such as that by Essien & John (2010), which reported significantly lower moisture content in polluted soil compared to unpolluted soil, highlighting how high crude oil concentrations can impede water and oxygen penetration by blocking soil pores and reducing pore spaces. Additionally, studies by Osuji & Onojake (2006), Nwazue (2011), and Egharevba et al. (2017)support the observed increase in moisture content in treated soils, suggesting that the reduction in hydrocarbon content resulting from crude oil contamination may lead to improved water permeability and subsequently higher moisture content.

Figure 3

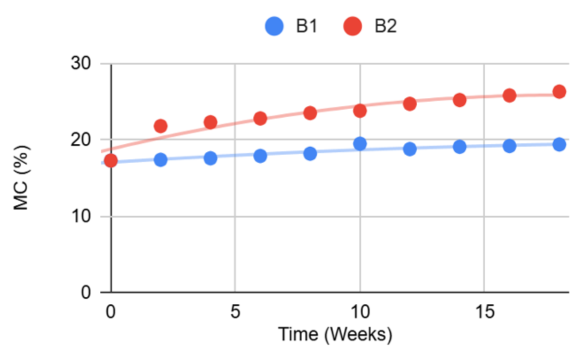

Figure 3 Variation of Soil Moisture Content With time

3.5. BULK DENSITY (BD)

Figure 4 presents the bulk density (BD) measurements of soil samples following the 18-week investigation period. The control sample, B1, demonstrated minimal change, with a slight decrease from 1.386 ± 0.004 g/cm^3 to 1.375 ± 0.008 g/cm^3. This slight reduction in bulk density could be attributed to natural processes such as erosion and water drainage through the soil layers. Samples B2 also showed minimal decreases bulk density but greater than that of B1, declining from 1.386 ± 0.004 g/cm^3 to 1.349 ± 0.025 g/cm^3. The presence of plants promoted microbial activity, leading to the breakdown of contaminants and enhancement of soil structure. The observed decrease in bulk density suggests improved soil structure, increased porosity, and reduced compaction, attributable to the influence of plant roots and associated microbial activity. It is noted that crude oil in soil can impact physical properties such as bulk density, moisture content, soil air, water holding capacity, and porosity. This aligns with prior research by Ekemube et al. (2022) and Kayode et al. (2009), which indicated that crude oil in soil can obstruct pore spaces, impair soil aeration, porosity, bulk density, and water infiltration ability, potentially impeding plant growth and productivity.

Figure 4

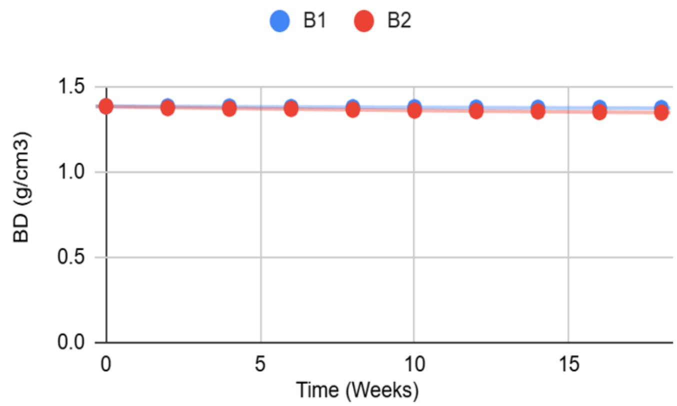

Figure 4 Variation of Bulk Density Treated with Time

3.6. TOTAL NITROGEN CONTENT (TNC)

Figure 5 depicts the changes in total nitrogen content (TNC) of soil samples over the course of the 18-week investigation period. At the conclusion of the study, sample B1 (Control) experienced a slight increase from 0.131 ± 0.316% to 0.178 ± 0.109%, indicating a rise of 0.047%. This suggests minimal to no remediation activity in the control sample. In contrast, the total nitrogen content of sample B2 initially increased from 0.131 ± 0.316% to 0.101 ± 0.701%, following which it decreased. The initial rise in nitrogen content may be attributed to the addition of animal dung manure upon soil contamination with crude oil at the beginning of the investigation period (Egharevba et al. (2017)). The subsequent decline in nitrogen content in polluted samples could be due to the immobilization of nutrients and minerals by crude oil, indicating a decrease in nitrogen pollutants in the soil. The reduction in TNC variation may be influenced by the ability of plants to uptake and metabolize nitrogen compounds from contaminated soil (Egharevba et al. (2017)). Additionally, factors such as soil type, initial nitrogen levels, and environmental conditions can also impact the effectiveness of phytoremediation.

Figure 5

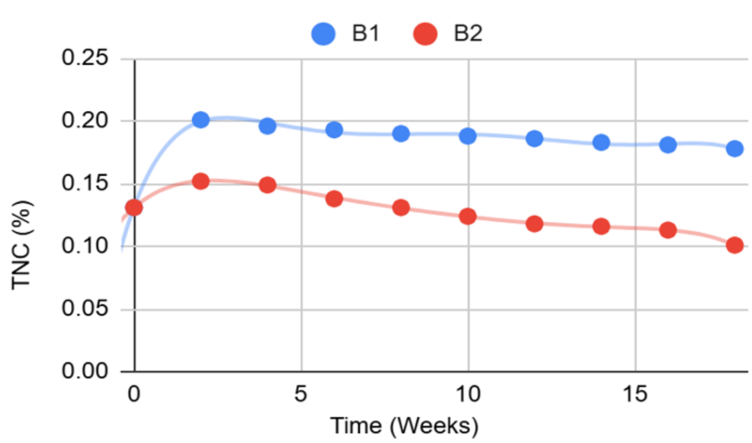

Figure 5 Variation of total Nitrogen Content with time

3.7. AVAILABLE PHOSPHORUS (AP)

Figure 6 illustrates the available phosphorus (AP) levels in soil samples. At the conclusion of the investigation, sample B1 (Control) showed a decrease from 11.610 ± 0.097 mg/kg to 8.160 ± 0.034 mg/kg, likely influenced by natural processes or external factors. In contrast, the AP values for samples B2 decreased from 11.610 ± 0.097 mg/kg to 4.000 ± 0.054 mg/kg. These variations may result from plant uptake and accumulation of phosphorus, soil-plant interactions, and microbial activity affecting phosphorus availability. Environmental factors such as temperature, moisture, and soil composition can also influence nutrient dynamics. These findings align with previous research by Egharevba et al. (2017), which reported a reduction in phosphorus content of soil samples. Lower available phosphorus concentrations in polluted soil may be attributed to microbial utilization of petroleum hydrocarbons as a carbon source, leading to the consumption of available phosphorus during hydrocarbon degradation (Wang et al. (2009)). The notably lower available phosphorus levels in polluted soil compared to unpolluted soil before planting are likely due to crude oil contamination. This is consistent with prior studies associating crude oil contamination with decreased soil available phosphorus (Okolo et al. (2005); Wang et al. (2013)). This finding corresponds with studies linking decreased soil available phosphorus to plant-mediated phosphorus utilization during phytoremediation processes (Ch'ng et al. (2014)).

Figure 6

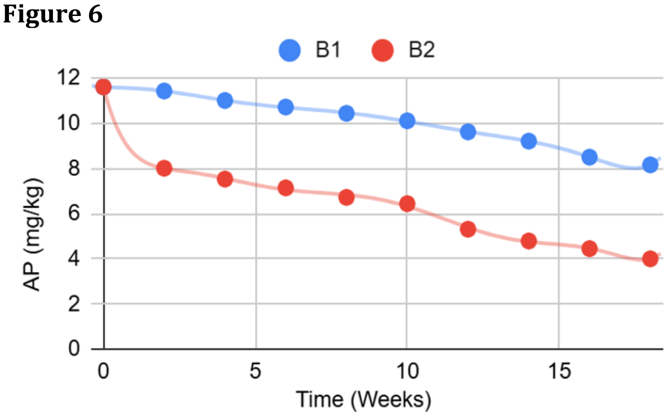

Figure 6 Variation of Available Phosphorus with time

3.8. TOTAL ORGANIC CARBON (TOC)

Figure 7 illustrates the total organic carbon (TOC) levels in soil samples. At the end of the study, sample B1 (Control) demonstrated a decrease from 3.990 ± 0.082% to 3.580 ± 0.005% (a 2.07% decrease), B2 decreased from 3.990 ± 0.082% to 1.920 ± 0.035%. These findings are consistent with those of Akram and Deka (2021) who observed an initial TOC level of 18.75% in an oil-contaminated soil sample, with values decreasing by 8.15% and 9.58%, respectively, after treatment. Similarly, Egharevba et al. (2017) reported a reduction from an initial value of 4.22% to 2.01% and 2.11% for the investigated samples. The higher organic carbon content observed in polluted soil compared to unpolluted soil is in line with previous reports by Abdulsalam et al. (2012). The decrease in organic carbon content of treated soils over time is consistent with findings by Okoro & Adoki (2014), who observed similar changes in total organic carbon during the bioremediation of crude oil-impacted soil. This reduction likely reflects the breakdown and degradation of organic carbon compounds by microbial activity and plant-mediated processes during remediation process.

Figure 7

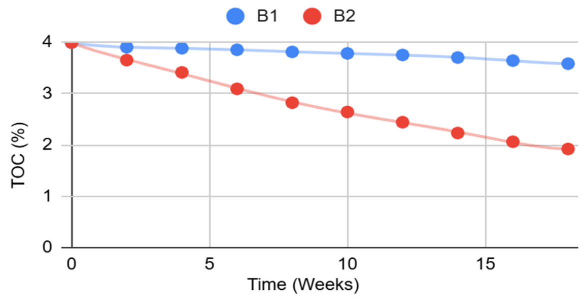

Figure 7 Variation of total Organic carbon with time

3.9. TOTAL ORGANIC MATTER (TOM)

Figure 8 depicts the total organic matter (TOM) levels in soil samples treated with plants. At the conclusion of the 18-week investigation period, sample B1 (Control) showed a slight increase from 1.101 ± 0.017% to 1.113 ± 0.019%. The TOM values for samples B2 increased from 1.101 ± 0.017% to 1.267 ± 0.048%. Organic matter content serves as an indicator of soil fertility and pollution levels. It influences nutrient mineralization, as carbon content directly relates to organic carbon content in the soil, affecting oxygen levels and microbial metabolism. The observed increase in organic matter during soil remediation in the crude oil-treated soils suggests that the selected plants possess significant metabolic and absorption abilities, with efficient transport networks that selectively uptake contaminants present in the soil. This finding is consistent with the research of Jude and Tanee (2016), who reported an increase in total organic matter and carbon in polluted amended soil. However, these results differ from those of Ayotamuno et al. (2006) and Njoku et al. (2012) who observed a reduction in organic matter content in vegetated soils compared to non-vegetated soils, possibly due to organic matter removal by plants. The decrease in organic matter content over time may indicate significant decomposition of petroleum hydrocarbons, facilitated by various decomposition factors, as reported by Okoro et al. (2011), similar to findings by Njoku et al. (2012).

Figure 8

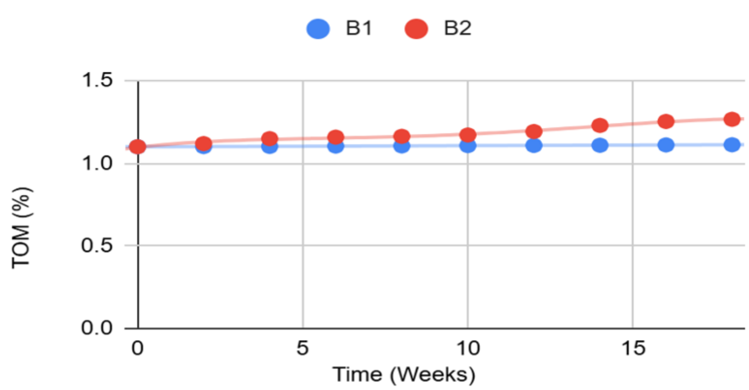

Figure 8 Variation of total Organic Matter with time

3.10. TOTAL HYDROCARBON CONTENT (THC)

Figure 9 displays the total hydrocarbon content (THC) of soil samples. Following the 18-week investigation period, sample B1 (Control) exhibited a slight decrease from 89.2800 ± 0.108 mg/kg to 88.300 ± 0.086 mg/kg. The THC values for samples B2 decreased from 89.280 ± 0.108 mg/kg to 7.900 ± 0.082 mg/kg. The percentage reduction in total hydrocarbon content observed in this study is consistent with the findings of Tanee & Albert (2011), who reported a decrease in total hydrocarbon content in crude oil-polluted soil. Similarly, Sunday and Aboh (2012) and Nwaichi et al. (2015) reported significant decreases in petroleum hydrocarbon content. Egharevba et al. (2017) observed a reduction of 60.8% and 45.89% in hydrocarbon content of polluted soil samples after treatment, while Chukwuma et al. (2019) recorded a decrease from 17962.11 ± 1000.00 mg/kg to 100.82 ± 46.31 mg/kg after treatment with F. ferruginea. These findings suggest effective remediation of soil contaminated with hydrocarbons, further supporting the potential of phytoremediation as a sustainable and eco-friendly approach to soil remediation.

Figure 9

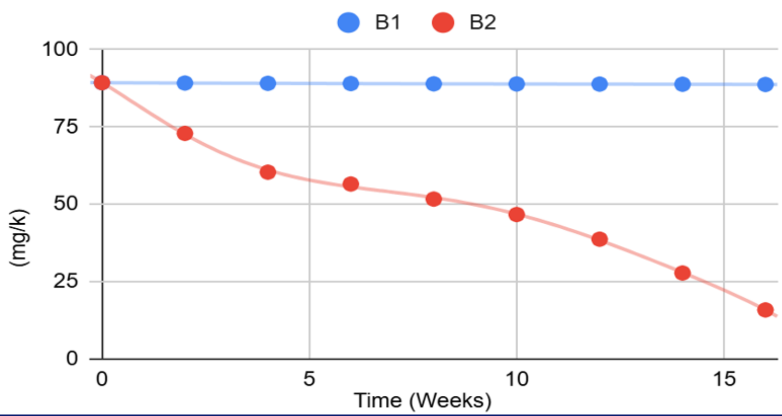

Figure 9 Variation of total Hydrocarbon Content with time

4. CONCLUSION AND RECOMMENDATIONS

4.1. CONCLUSION

It can be concluded from the study that Magathyrsus maximum have the potential to remediate crude oil contaminated soil as the investigated plant was able to remediate and clean-up the contaminated soil. The investigation also showed that time played an important role in remediation process. The rate of remediation was highest in the eighteenth week for all the parameters that were investigated.

4.2. RECOMMENDATION

The effectiveness of Magathyrsus maximum should be utilized in cleaning up crude oil contaminated soil; also, since time is of essence, the rate of remediation should be properly monitored with time.

CONFLICT OF INTERESTS

None.

ACKNOWLEDGMENTS

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