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Impact of Spent PMS on Biodiversity of Plant Species around Fuel Stations in Port Harcourt

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Abstract

The environmental impact of spent Premium Motor Spirit (PMS) on plant species diversity is an area of growing concern, particularly in urban regions like Port Harcourt. This study aimed to assess the impact of spent PMS on plant species diversity and abundance across three different stations in Port Harcourt, with a specific focus on species richness and the Shannon Diversity Index. Among these, Station 3 served as the control site, providing a baseline for comparison. Biodiversity was evaluated at all three stations using quadrat sampling to measure species richness, evenness, and overall diversity. Key indices such as the Shannon Diversity Index (H'), Simpson's Index, and species richness (S) were calculated to quantify biodiversity. Hutcheson t-tests were performed to determine the statistical significance of differences in diversity between the stations.The findings revealed significant variations in species diversity across the stations. Station 2 exhibited the highest species richness (12 species) and the highest Shannon Index (H' = 2.297), indicating a more balanced and diverse ecosystem. In contrast, Station 1, exposed to higher PMS contamination, had the lowest species richness (6 species) and the lowest Shannon Index (H' = 1.683), suggesting a more degraded environment. Station 3, the control station, had a moderate species richness (9 species) and a Shannon Index (H' = 2.030), providing a comparative baseline that underscored the impact of PMS at the other stations. Statistical analysis confirmed significant differences in plant diversity between Station 1 and Station 3 ($t = 2.5355$, $p < 0.05$) and between Station 2 and Station 3 ($t = 3.6509$, $p < 0.001$).This study highlights the adverse effects of PMS contamination on plant species diversity, particularly at Station 1, where reduced diversity and higher species dominance were observed. Immediate remediation measures are recommended at the more severely impacted sites, particularly Station 1, to restore soil quality and support the recovery of plant biodiversity. Additionally, further research into the specific mechanisms of PMS impact and the potential for phytoremediation using native species is crucial for developing effective environmental management strategies.

Keywords: Spent PMS, Biodiversity, species, richness, evenness.

Introduction

Fuel stations, as centres for the distribution and dispensing of petroleum products, are potential sources of soil and groundwater contamination (Itodo *et al*., 2013). The leakage or spillage of PMS, coupled with improper waste management practices, can lead to the accumulation of harmful hydrocarbons in the surrounding environment (Okafor *et al*., 2017).

Plant species, as primary producers in terrestrial ecosystems, are particularly vulnerable to the toxic effects of petroleum hydrocarbons (Ibrahim *et al*., 2014). Exposure to these contaminants can inhibit germination, reduce growth, and alter physiological processes, ultimately leading to decreased biodiversity (Oguzie *et al*., 2012).

The Niger Delta region, a vast wetland ecosystem, is renowned for its rich biodiversity, supporting a diverse array of flora and fauna (Nwilo *et al*., 2010). Mangrove forests, freshwater swamps, and rainforests characterize the region, providing critical habitats for numerous species. However, the region has also been subjected to significant anthropogenic pressures, including oil exploration and production, leading to environmental degradation and habitat loss (UNEP, 2006).

Port Harcourt, the capital of Rivers State, is a major urban centre within the Niger Delta. Its rapid industrialization and population growth have contributed to increased pollution and environmental challenges. The city's reliance on fossil fuels for energy has led to the proliferation of fuel stations, which can pose significant risks to the surrounding environment if not properly managed.Given the ecological significance of the Niger Delta and the potential impacts of fuel stations on plant biodiversity, there is a clear need for comprehensive studies to assess the extent of contamination and its effects on plant communities. Understanding the relationship between spent PMS, soil quality, and plant diversity is essential for developing effective remediation and prevention strategies.

Materials and Methods

Study Location:

The sampling areas includesConoil Fuel Station Uniport, Choba (Lat: 4.898505, Longitude: 6.917073) as station 1, AP Fuel Station, East-West Road, Obio/Akpor, Rivers State (Latitude: 4.894179, Long: 6.913990) as station 2 and University of Port Harcourt Main Campus (Lat: 4.898573, Long: 6.916663) as station 3. This geographical coordinate is located in the Niger Delta area of Nigeria. This area experiences two distinct seasons; the dry season and the wet season, which span from November to March and April to October respectively. The climatic condition of the area is characterized by temperature range of 36^{o}C – 45^{o}C for daily and annual range.

Sampling Method

A systematic sampling method was adopted. A transect line was laid across a mapped-out area of 20 meters by 20 meters and a quadrant of 1 meter by 1 meter was placed in the marked point on the line. Sampling was done at 1 meter interval all the way down the line, giving a total of 10 quadrants at each site. The dominant plant species in the study area were characterized into Station 1, Station 2 and Station 3 by counting, and identified using Handbook of West African Weeds (IITA) (Akobundu & Agyakwa, 1987)to obtain phytosociological data.

Determination of Specie Composition and Type

Plant species within the sample plot were observed, photographed, collected and taken to plant herbarium for identification.

Vegetation Analysis

Parameters such as specie composition, specie richness, specie population, species diversity and specie evenness were observed and calculated.

Species Richness (Taxa_S)

This is the total number of different species observed in a sample. It's a simple measure of biodiversity, indicating the variety of species present (Magurran, 2004).Species richness data was collected on the sample site (Station 1, Station 2, and Station 3). Species richness data was obtained by taxonomical identification of the different species found in the various stations by physical count. Specie richness is determined using Margalef Index. It is expressed as: =

$$\frac{S-1}{ln(N)}$$

Where:

- S is the total number of species observed.
- N is the total number of individuals observed.

Individuals

The total number of individuals across all species in the sample. This gives an idea of the population size and can be used to calculate other indices (Kent & Coker, 1992).

Dominance_D

This index measures the degree to which one or a few species dominate the community.(Simpson, 1949). A high dominance value indicates that a few species are very abundant, while most others are rare (Simpson, 1949). It is calculated as

D = \sum (p_i^2).

Where: p_i is the proportional abundance of species i

Simpson_1-D

Simpson's Index of Diversity measures the probability that two individuals randomly selected from a sample will belong to different species (Simpson, 1949). Values range from 0 to 1, where higher values indicate greater diversity (Simpson, 1949).

It is calculated as =

D = Σ [n_i(n_i-1)] / [N(N-1)]

Where:

- D is the Simpson's diversity index
- n_i is the number of individuals of species i
- N is the total number of individuals of all species.

Shannon_H

Shannon-Wiener Diversity Index. It accounts for both species richness and evenness (Shannon, 1948). Higher values indicate more diverse and evenly distributed species (Shannon, 1948). It is calculated as =

H' = -Σ (p_i * ln(p_i))

Where:

- H' is the Shannon diversity index
- p_i is the proportion of species i relative to the total number of species
- S is the total number of species.

Evenness_e^H/S

This measures how evenly individuals are distributed across different species(Pielou, 1966). Values closer to 1 indicate a more even distribution of species (Pielou, 1966). The formular is

E = H'/ ln(S)

Where:

- E is the evenness
- H' is the Shannon diversity index
- S is the total number of species.

Brillouin Index

The Brillouin Index is a measure of diversity similar to Shannon but is used when all individuals are counted, and there is no sampling error. It is particularly useful for comparing samples where the total population size differs (Brillouin, 1956). It is calculated as

H = (1/N) log (N!/II N,!)

Where:
- N is the total number of individuals
- n_i is the number of individuals of species i

Menhinick Index

This index measures species richness relative to the total number of individuals(Menhinick, 1964). Higher values indicate higher species richness relative to the number of individuals (Menhinick, 1964). It is calculated as

$$S / \sqrt{(n)}$$

Where:
- S is the total number of identified groups
- n is the total number of counted individuals

Margalef Index

Margalef's Index is another measure of species richness, calculated (Margalef, 1958). Higher values suggest a greater number of species relative to the number of individuals (Margalef, 1958). It is calculated as =

$$(S - 1) / \ln(N)$$

Where:
- S is the total number of species
- N is the total number of individuals.

Equitability_J

Pielou's Equitability Index is a measure of species evenness(Pielou, 1966). Values range from 0 to 1, with higher values indicating more equitable distribution among species (Pielou, 1966). It is calculated as

$$J = H'/\ln(S)$$

Where:
- H' is the Shannon index
- S is species richness

Fisher_alpha

Fisher's Alpha is a parameter of the log-series distribution that relates species richness to the number of individuals in a community (Fisher *et al*., 1943). Higher values suggest greater species diversity (Fisher *et al*., 1943). It is calculated as =

$$S = a^*\ln (1+ n / a)$$

Where:
- S is number of taxa
- n is number of individuals
- a is the Fisher's alpha.

Berger-Parker Index

This index is a measure of dominance, calculated as the proportion of the most abundant species in the sample(Berger & Parker, 1970). Lower values indicate less dominance by a single species and therefore greater diversity (Berger & Parker, 1970). It is calculated as

$$BPI = Nm / n$$

Where:
- BPI is the Berger-Parker Index
- Nm is the number of individuals in the most abundant species
- n is the number of individuals in the sample

Statistical Analysis

The data generated was subjected to ecological statistical analysis using PAST 4.03. While further validation of significant difference between stations were estimated using Hutcheson t-test.

Results

Floristic Composition

Visual observation of the species diversity from the various sample locations showed some dominant weed species which includes *Kyllinga erecta, Tridax procumbens and Cyperus difformis* in the three study locations. Station 1 recorded a total number of 159 species, Station 2 recorded the highest species diversity at 268 species. However, Station 3 which served as the control site recorded the lowest species diversity at 83 species.

Table 1: Species Diversity and Abundance in Three sample stations

S/N	Species	Station 1	Station 2	Station 3
1	*Kyllinga erecta*	44	17	5
2	*Tridax procumbens*	23	34	14
3	*Cyperus difformis*	38	53	21
4	*Euphorbia hyssopifolia*	27	32	7
5	*Eclipta alba*	19	8	6
6	*Commelina erecta*	0	20	6
7	*Alternanthera sessillis*	8	0	0
8	*Phyllanthus amarus*	0	36	10
9	*Portulaca oleracea*	0	0	12
10	*Boerhavia coccinea*	0	18	0
11	*Cleome viscosa*	0	21	0
12	*Spilanthes filicaulis*	0	0	0
13	*Cyperus esculenta*	0	18	0
14	*Euphorbia hirta*	0	8	2
15	*Nelsonia canescens*	0	3	0
Total number of Species		**6**	**12**	**9**
Total number of Individuals		**159**	**268**	**83**

Biodiversity Indices Results for Three Sampling Stations: Species Diversity and Abundance

Results for Table 2 showed diversity indices results for the three study locations. Species Taxa recorded highest values (12) followed by the control station (9). However, the lowest was recorded in the Station 1. Results from Individuals recorded highest in Station 2 at 268 followed by Station 1 at 159, while the lowest was recorded at the control station. Results from other biodiversity indices showed slight significant differences in the three stations on Dominance, Shannon_H, Menhinick, and Margalef.

Table 2: Biodiversity Indices Results for Three Sampling Stations: Species Diversity and Abundance

	Station1	Station2	Station3
Taxa_S	6	12	9
Individuals	159	268	83
Dominance_D	0.2003	0.1142	0.1497
Simpson_1-D	0.7997	0.8858	0.8503
Shannon_H	1.683	2.297	2.03
Evenness_e^H/S	0.8966	0.8285	0.8459
Brillouin	1.61	2.205	1.856
Menhinick	0.4758	0.733	0.9879
Margalef	0.9864	1.967	1.81
Equitability_J	0.9391	0.9243	0.9238
Fisher_alpha	1.233	2.579	2.566
Berger-Parker	0.2767	0.1978	0.253

Validation of Shannon Index Results

Table 3 and Table 4 shows the validation of Shannon Index results across different stations based on the data collected. The results include the calculation of Dominance (D), Variance, t-values, degrees of freedom (df), and p-values, with conclusions drawn using Hutcheson t-test.

Based on the results for comparison of Shannon index between station 1 and station 3, t (2.5355) > 0.2003, therefore the diversity of plant species in Station 1 is significantly different at $p < 0.001$ compared to Station 3. While in Station 2 and Station 3, since t (3.6509) > 2.2967, the diversity of plant species in Station 2 is therefore significantly different at $p < 0.001$ compared to Station 3.

Table 3: Comparison of Shannon Index between Station 1 and Station 3

Parameter	Station 1	Station 3
Dominance (D)	0.20027	0.14966
Variance	0.00012505	0.00027337
t-value	2.5355	
Degrees of freedom (df)	158.94	
p-value (p(same))	0.012193	

Table 4: Comparison of Shannon Index between Station 2 and Station 3

Parameter	Station 2	Station 3
Shannon Index (H)	2.2967	2.0299
Variance	0.0011996	0.0041413
t-value	3.6509	
Degrees of freedom (df)	134.55	
p-value (p(same))	0.00037301	

Species Richness (S) Across Three Sampling Stations

The graph in Fig 1 is a line graph representing the species richness (S) across three different stations (Station 1, Station 2, and Station 3). Station 1 has the lowest species richness, with S = 6, Station 2 shows the highest species richness, with S = 12, and Station 3 being the control has a moderate species richness, with S = 9.The graph indicates that Station 2 has the most diverse plant species, as it has the highest species richness (number of different species present).Station 1 has the least diversity in species, which may suggest it is a more disturbed or less favourable environment for species diversity.Station 3 falls between the two, with species richness lower than Station 2 but higher than Station 1.

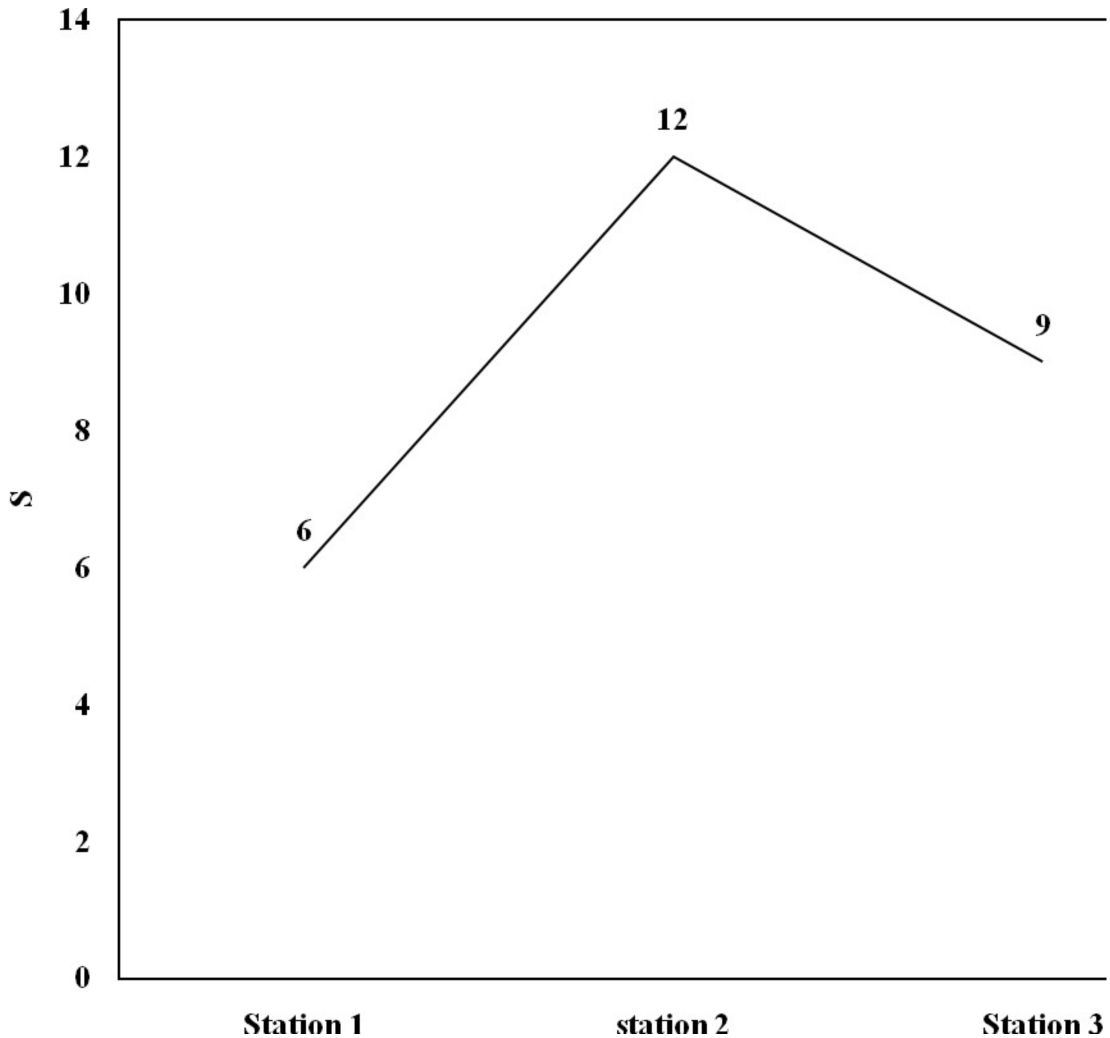

Fig 1: Graph of Species Richness (S) Across Three Sampling Stations

Discussion

Magurran (2004) reported that species evenness measures the number of species present. Hill (1973) disposes that a community with high species evenness is often considered ecologically stable and resilient, as changes in the abundance of one species are less likely to have a disproportionate impact on the overall ecosystem. Species is one of the simplest and most commonly used metrics for assessing biodiversity (Magurran 2004).

However, man-made activities have posed a threat to the native species diversity by stalling or disrupting the normal growth. Anthropogenic activities can introduce contaminants or pollutants into the soil which includes petroleum hydrocarbons and other materials that affect the normal soil chemistry (Smith *et al,* 2006).

A total of 159 plant species were recorded at Station 1, while 268 species were recorded in Sample Station 2. The control location recorded the lowest plant species 83. This is in line with Ogdudu (2021) who recorded that Fuel Stations influenced the growth and yield of native plants that are hyperaccumulators.

This study also agrees with (Wei *et al*., 2005) who noted that excluder plants can normally survive in contaminated soil containing high levels of heavy metals, and the contents of heavy metals accumulated in aboveground parts and roots of such plants.

Conclusion

This study aimed to assess the impact of spent Premium Motor Spirit (PMS) on plant species diversity and abundance across three different stations in Port Harcourt. The research utilized several biodiversity indices, with a particular focus on the Shannon Diversity Index, to quantify species richness, evenness, and overall biodiversity in the contaminated sites.The findings revealed significant variations in plant species diversity among the three stations. Station 2 exhibited the highest species richness (12 species) and abundance, indicating a relatively more favourable environment for a diverse range of plant species.Station 1, with the lowest species richness (6 species), suggested that environmental conditions at this site were less conducive to supporting a wide variety of species, possibly due to higher levels of contamination.Station 3, with moderate species richness (9 species), recorded lower species diversity as compared to the other two stations, indicating a stable and moderate diverse ecosystem.

The Shannon Index calculations further corroborated these observations, with Station 2 showing the highest diversity, followed by Station 3, and Station 1. These results indicated that Station 2 has the most balanced and diverse plant community, as compared to the other two stations. Hutcheson t-tests confirmed that the differences in Shannon Diversity Index between Station 1 and Station 3 and between Station 2 and Station 3 were statistically significant, highlighting the impact of PMS on species diversity.

The significant reduction in species diversity at Station 1 may be attributed to the adverse effects of PMS pollution, which likely impairs soil quality and plant growth, leading to the dominance of a few resilient species and the decline or absence of more sensitive ones.The relatively higher diversity at Station 2 is an implication that this site either experiences less contamination or has better ecological resilience, allowing for the coexistence of a wider range of species.

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