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ASSESSMENT OF PHYSICOCHEMICAL PARAMETERS AND POLYCYCLIC AROMATIC HYDROCARBONS IN SOIL AND WATER OF SELECTED AGROCHEMICAL FACILITIES IN SOUTHWEST NIGERIA

BY

Damilola Tope Ogundele[1], AbdulKareem Abiola Olatunji[1], Olusola David Ogundele[2] & Damilola Jumoke Ogunleye[1]
[1]Department of Chemistry and Industrial Chemistry, Kwara State University, Malete, Nigeria
[2]Department of Chemical Sciences, Achievers University Owo, Ondo State, Nigeria

Abstract

The study encompasses an assessment of physicochemical characteristics and the detection of the 16 polycyclic aromatic hydrocarbons (PAHs) in soil and water samples within the Iragbiji, Kelebe, Onne, and Ore study areas. The soil and water samples underwent preparation and extraction procedures according to standardized protocols, followed by analysis for the 16 priority PAHs utilizing Gas Chromatography-Mass Spectrophotometer (GC-MS). Results revealed that 90% of all physicochemical parameters remained within prescribed standard limits, encompassing pH, EC, TDS, TA, TH, TOC, OM, and K among others. 50% of the water samples tested fall within the range (QWI < 25) of excellent water quality and are good for domestic, irrigation and industrial purposes. The average PAHs level varied from a minimum value of (0.03 to 0.11) mg/L in all the study sites. The soil and water samples exhibited a greater impact from High Molecular Weight PAHs compared to Low Molecular Weight PAHs. Specifically, the Onne (C) site demonstrated a strong correlation coefficient ($R^2 = 0.729$) across all sample sites. Conversely, the Ore (D) site displayed a statistically significant difference ($p < 0.05$) among the sites. Overall, this study indicated that the sampling sites bore a low health risk burden, thus suggesting the likelihood of low to moderate adverse health effects.

Keywords: PAHs, Physicochemical Parameter, Water Quality Index, Correlation matrices and coefficient.

Introduction

The buildup of pollutants in water and soil is attributed to the rapid pace of industrialization, modern agricultural practices, and other human activities. These factors have contributed to the indiscriminate discharge of various pollutants into the environment, among which polycyclic aromatic hydrocarbons (PAHs) are prominent (Balabanova *et al.,* 2014; Mojiri *et al.,* 2019). These pollutants give rise to environmental challenges such as toxicity and chemical accumulation throughout biodiversity. Consequently, they pose significant threats to both the environment and human well-being (Tatem *et al.,* 1987). They enter into the environment via agriculture, domestic and industrial effluents discharge among others routes. The quality of soil and water depends on physicochemical properties and processes which effects on soil and water to operate efficiently as a component of ecosystem (Tale and Ingole, 2015). Soil physicochemical properties deteriorate to the change in land use especially from agriculture (Jha and Singh, 1991).

Water is a vital resource for agriculture, industries and other human activities. The disposal of effluents due to human negligence in the water bodies mostly contribute to the poor quality of water. Alterations in soil and water physicochemical properties can result in long-term soil infertility, impeding normal plant growth for extended periods (Sumithra *et al.,* 2013). These parameters include: pH, temperature, turbidity, COD, TDS, acidity, alkalinity, conductivity, and other functions. Several studies have underscored the importance of soil physico-chemical properties on water quality. The role of several parameters can't be neglected for maintaining and sustaining a healthy environment and aquatic ecosystems (Ahmad *et al.,* 2015). Therefore, there is need for investigations and monitoring physicochemical properties and concentrations of PAHs pollutant level in soil and water, this will elucidate assessing their influence on environment and human well-being. Therefore, this study seeks to investigate the physicochemical parameters and polycyclic aromatic hydrocarbons in soil and water located at Iragbji, Kelebe, Onne and Ore agrochemicals industries in southwest of Nigeria, to ascertain the level of contaminations on environment.

Materials and Methods

The Study Area

The study covered four major sites on the basis of the potential effects of anthropogenic activities such as agricultural and industrial activities. The sampling points were geo-located with a global positioning system (GPS) to ensure consistency. (Table.1) and employed in generating the geographical information using GPS (geographical positioning system).

Sample Collection

Water samples were collected from shallow points, approximately 10-15 cm deep, using clean water bottles equipped with Teflon-lined tops to mitigate photochemical degradation. Employing gloves, the samples were hand-collected by submerging the bottles beneath the water surface. Soil sampling involved retrieving samples from the topsoil layer, approximately 15 cm deep, along the riverbanks using a pre-cleaned stainless-steel shovel. Multiple spots within each site were sampled, and soil samples from each site were carefully wrapped in aluminium foil. This procedure was repeated for the remaining sites. Each sample were labelled and securely moved to the laboratory for further analysis. A total of three samples were collected and labelled for each site.

Table 1: GPS location of the sampled area

LOCATION	LONGITUDE	LATITUDE
Iragbji(A)	4.64^{o} E	7.80^{o} N
Kelebe(B)	4.59^{o} E	7.80^{o} N
Onne(C)	7.12^{O} E	4.73^{o} N

Measurement of Physicochemical Parameters

The physicochemical parameters analyzed encompassed a comprehensive range, including pH, electrical conductivity (EC), total dissolved solids (TDS), total hardness, turbidity, total alkalinity, total nitrogen, total organic carbon, phosphate, organic matter and potassium,. Measurement of pH, EC, and TDS was conducted using a pH/TDS/EC meter for accuracy and consistence.

PAH Analytical Procedure

Extraction of PAH from Water and Soil Samples

The extraction of water samples was done by liquid–liquid extraction method. 5 mL of the samples were treated with 5g of sodium sulphate to salt out the aqueous phase to the organic phase, this was followed by 60 mL of dichloromethane (DCM), shaken for thirty minutes, and allowed to separate for thirty minutes. The lower organic layer was placed into a clean and dry 250 mL conical flask. 5 g of each soil sample was weighed and homogenously mixed with 5 g of anhydrous sodium sulphate. The mixtures were transferred to pre-cleaned extraction tubes, and 40 mL of dichloromethane was added. The tubes were tightly sealed and left to stand for 30 minutes. Then, they were

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vigorously shaken for additional 30 minutes. After allowing the particles to settle, the solvent layers were filtered using filter papers

The extraction process for both (water and soil) were repeated using 25 mL of dichloromethane (DCM), and the combined extracts were concentrated using a rotary evaporator (Buchi Rotavapor R-114). The concentrated extract was then exchanged with 10 mL of n-hexane and re-concentrated to 1 mL for further purification. The extract was then passed through a silica gel column using a 40 mL DCM/hexane eluent, and the resulting eluate was evaporated and re-dissolved in 1 mL of hexane. The purified extract was subsequently analyzed for the presence of 16 representative polycyclic aromatic hydrocarbons (PAHs) using gas chromatography-mass spectrometry (GC/MS) on a Shimadzu QP 2010 model instrument.

Calibration Procedure

A working solution of 75 mg/L was prepared from the stock solution procured from Accu Standard (US). Calibration solutions of (0.125, 0.5, 1.0, 2.5 and 5) mg/L were prepared by a 5-point serial dilution of the working solution and used to calibrate the responses of the GC-MSD.

Statistical Analysis

The mean, standard deviation, R^2 correlation coefficient, and correlation matrix coefficient were used to determine the relationships in concentration of PAHs in this study, as well as also their significant difference, at 95% confidence level ($p \leq 0.05$). Similarly, water quality Index analysis were carried-out, graphs and tables were used to illustrate the concentration of the heavy metals and PAHs.

Water Quality Index (WQI)

The Water Quality Index (WQI) of the water samples was determined using a method previously employed by (Smoke and Smoking, 2004) and (Masih and Lal, 2014). WQI is commonly used for the evaluation and detection of water contamination and possible level of uses (Table 2). In this study, eight (8) water physicochemical parameters were selected based on theirs directly contributes to the degradation of water quality, making it unsafe for human consumption. The relative value of each parameter was calculated using the formula:

$$Qi = C_i/S_i \times 100 \quad (1)$$

Where:

- Q_i = quality grading,
- C_i = the concentration level of each parameter, and
- S_i = the standard value for the physicochemical parameter.

$$Wi = \frac{wi}{\sum_{i=1}^{n} wi} \quad (2)$$

Where:

- W_i = relative weight,
- w_i = weight of parameter, and
- n = the total number of each physicochemical parameters.

WQI is the auto-sum of all sub-indices for each sample, in Eqn. 3 and 4, respectively.

$$SI_i = Wi \times Qi \quad (3)$$

$$WQI = \sum SI_{i-n} \quad (4)$$

Where:

- SI_i = the sub-index parameter,

- Q_i = the quality rating based on concentration parameter and
- n = the number of parameters.

Table 2: WQI classification scheme for water sample and possible ranges of use (Pei-Yue *et al.*, 2010)

WQI	Quality water	Levels of use
0 – 25	Excellent	Drinking, irrigation and industrial
25 – 50	Good	Domestic, irrigation and industrial
50 – 75	Fair	Irrigation and industrial
75 – 100	Poor	Irrigation
> 100	Very poor	Restricted use for irrigation

Results and Discussions

Physicochemical Parameters of Water and Soil

The results of the physicochemical parameters determined in this study include; pH, electrical conductivity, and total dissolved solids of soil and water are given in (Table 3 & 4) respectively.

pH

The pH of water ranged from (6.2 to 7.55) in the study sites as presented in (Table 3). Site B has the highest pH value, its pH was 7.55, this indicate that the water was little bit alkaline which can also affect nutrient availability (Pei-Yue *et al.*, 2010). Site A has the lowest value of 6.2. this value was comparable with (Ojekunle *et al.*, 2020) report, where they carried-out the evaluation of the physicochemical properties of groundwater within designated industrial areas in Ogun State, Nigeria. The pH values were within the WHO and USEPA recommended guideline for water courses standards of 6.5 to 8.5 (WHO, 2002; USEPA, 2005). Water with a slight acidity can impact how readily available nutrients are to plants and aquatic life, this pH range is generally favourable for most crops. Meanwhile, the pH of soil ranged from (6.47 to 7.68) as presented in (Table 4). The highest pH value was obtained in site A and site B has the lowest among the study sites for soil samples, this indicate that the water is little bit alkaline for site B, which can also affect nutrient availability. Soil pH should be monitored and control over time to ensure it remains within the desired range for the crops being grown (Wright and Kravaris, 2001).

Total Dissolved Solids (TDS)

The total dissolved solids (TDS) of the water samples ranged from (27 mg/L in site A, to 52.5 mg/L in site B to 90 mg/L in site D and 624 mg/L in site C (Table 4). Sites A, C and D have TDS values below 1000 mg/L and can thus be classified as freshwater (Adebayo *et al.*, 2015). The result correlates with comparable work by (Adeolu *et al.*, 2011)). This is generally acceptable for agricultural use as lower TDS levels suggest cleaner water with fewer impurities.

Table 3: Results obtained from physicochemical analysis of Soil samples

Parameter	Sample Locations			
	A(Iragbiji)	B(Kelebe)	C(Onne)	D(Ore)
PH	*7.680*	6.470	6.510	6.51
Total nitrogen %	0.253	0.230	0.261	0.120
Electrical conductivity µs/cm	43.500	34.700	47.800	31.20
Total organic carbon %	1.745	1.536	1.846	1.350
Phosphate (mg/kg)	0.104	0.100	0.094	0.04

Organic matter %	3.017	2.656	3.192	2.334
Potassium (mg/kg)	2.413	2.284	2.386	1.368

The source of this water may be relatively pristine, or it might have undergone effective filtration (Bhatla *et al.*, 2018). The TDS of 624 mg/L for the water in site B indicates a significantly higher concentration of total dissolved solids. The result was similar to a study conducted by (Miima *et al.*, 2011) showed higher values (542.47 to 1538.50 mg/L) than what was reported in the work by (Gebreyohannes *et al.*, 2015) in Elala River, Ethiopia showed TDS values ranging between (700 to 1328 mg/L) which were equally higher.

Total Hardness

The presence of calcium and magnesium in water is a measure of total hardness in water samples as presented in (table 4). Total hardness results ranged from (12.6 mg/L to 42 mg/L to 63 mg/L), which were in the category of Slightly to Hard Class (17.1–60 mg/L). The highest value of total hardness were obtained in site B and D. This may be a result of the geological characteristics of the area with high concentrations of calcium and magnesium naturally present in water.

Potassium

The concentration of potassium ranged from (1.368 mg/kg, 2.143 mg/kg, 2.284 mg/kg and 2.386 mg/kg in site D, A, B and C respectively, as presented in (Table 3). This level falls within the usual range (Bhatla *et al.*, 2018). In comparison, site D has a little higher potassium level, of 1.368 mg/kg, while site C has the highest value of 2.284 mg/kg.

Table 4: Results obtained from physicochemical analysis of Water samples

Parameter	Sample Locations			
	A (Iragbiji)	B (Kelebe)	C (Onne)	D (Ore)
PH	6.200	7.550	7.100	7.10
Total dissolved solids (mg/l)	27.000	52.500	624.000	90
Total hardness (mg/l)	42.000	63.000	12.600	63
Electrical conductivity µs/cm	52.600	10.700	114.400	18.40
Turbidity (NTU)	6.140	8.601	14.400	3.74
Total alkalinity (mg/l)	0.200	0.240	0.320	0.40

Electrical Conductivity (EC)

Electrical Conductivity (EC), measure the total dissolved solids, indicates the presence of ions in water, providing a valuable indicator of water quality. The value ranged from (10 µs/cm to 18.40 µs/cm) as presented in (Table 4). EC of site A, was 10 µs/cm, compared to other sites. This suggests a relatively low concentration of dissolved ions, a low EC value indicate lower salinity, which is generally suitable for agricultural use (Adeosun *et al.*, 2016). Meanwhile the EC of site D shows a slightly higher concentrations of dissolved ions this could be related to agricultural practices in the area. For soil sample, the EC values ranged from (31.20 to 47.8 µs/cm) as presented in (Table 3). Site C and A have EC of 47.8 µs/cm and 43.5 µs/cm respectively, which indicates moderate electrical conductivity in the soil. Site D has a EC value of 31.2 µs/cm, which was slightly lower compared to site A and C. Variations in soil EC can be attributed to differences in soil composition, drainage, and land management practices. The values of EC in all the study sites fall below the permissible standard of 1000 µS/cm conducted by (NSDWQ, 2007).

Turbidity

The turbidity values ranged from (3.74 NTU to 14.40 NTU) as presented in (Table 4). Site D has lowest turbidity value of 3.74 NTU, this value was within WHO standards of 5 NTU. This indicates a relatively clear water with low suspended particle content, which is generally suitable for agricultural use as it reduces the risk of clogging irrigation systems (Adeosun *et al.*, 2016). While the values in other sites were relatively high above WHO standards of 5 NTU. Site C has turbidity value of 14.40 NTU compare to other sites. The presence of higher turbidity may be due to factors such as soil erosion or land management practices in the area (Sadashivaiah *et al.*, 2008).

Total Alkalinity

The total alkalinity of 0.4 mg/L in the water of site D suggests a moderate high alkalinity level compared to site C (0.32 mg/L), A (0.20 mg/L) and site B (0.24 mg/L) as presented in (Table 4). These values are less than the WHO standard of 120 mg/L. Low alkalinity can lead to pH instability and potentially affect aquatic life. It's essential to monitor and manage alkalinity to ensure the health of aquatic ecosystems.

Total Organic Carbon

The soil in site C sample has a relatively high TOC content of 1.846%, indicating a rich source of organic matter. An adequate amount of organic matter is indicated in the soil of the site A sample, reasonably high TOC content of 1.745%. The soil in site D sample has a TOC content of 1.360%, as presented in (Table 3) which is slightly lower than the soil in site B samples. These results are similar to a study at the Eleme petrochemical jetting port site (Brooijmans *et al.,* 2009).

Phosphate

The Phosphate values in the soil samples ranged from (0.094 mg/kg), (0.100 mg/kg) and (0.104 mg/kg) for site C, B and A respectively, as presented in (Table 3). These low concentration values may be as a result of less human activities that would serve as common sources of phosphate contamination. High soil phosphate levels can cause PAHs to bind to soil particles more tightly, reducing their mobility and the likelihood that they will leach into groundwater (Webster *et al.,* 2003).

Correlation Matrices of Physicochemical Parameter

Table 5 and 6, shows the correlative potential of physicochemical parameter of water and soil in all the study sites, as seen, in the (table 6) a positive correlation PC is represented with blue colour and negative correlation NC with red colour, the PC revealed a presence of strong (≥ 0.70 PC ≤ 1.00), fair (≥ 0.30 PC ≤ 0.69) and weak (≥ 0.00 PC ≤ 0.29) correlations (Ojaniyi *et al.*, 2021). The EC and TOC show a strong positive correlation with other parameters except Phosphates, there was a fairly positive correlation between pH and other parameter phosphate (0.7852) and K (0.6834) and a fairly positive correlation between T.N (0.2969) > TOC (0.2256) > O.M (0.2248). Also there's a positive correlation among the other parameter such as OM and potassium are expected because of their interdependence in water-soil system (Ganiyu *et al.*, 2018). Negative correlation exist between Phosphate and TN, EC, TOC and OM parameters as showed in (table 6). The correlation matrix of water parameter shows a positive correlation among the study parameters except for TDS with pH parameter in the study (table 5). The correlation matrix conducted showed produce a positive regression and agrees with similar result reported by (Badmus *et al.,* 2014).

Table 5. Correlation matrices for the physicochemical parameter for the water samples in all the sites

	pH	*EC*	*TDS*	*Turbidity*	*TA*
pH	1				
EC	0.225202	1			
TDS	-0.21485	0.903176	1		
Turbidity	0.465773	0.967066	0.76417	1	
TA	0.5	0.95638	0.738378	0.999236	1

EC= Electrical conductivity TDS= Total dissolve solid TA = Total Acidity

Table 6. Correlation matrices for the physicochemical parameter for the soil samples in all the sites

	pH	*T.N*	*EC*	*TOC*	*PO4-*	*O.M*	*K*
pH	1						
T.N	0.296972	1					
EC	0.222997	0.997065	1				
TOC	0.225635	0.997269	0.999996	1			
PO4-	0.785272	-0.35802	-0.42845	-0.426	1		
O.M	0.224893	0.997212	0.999998	1	-0.42669	1	
K	0.683428	0.900043	0.864038	0.865397	0.084685	0.865015	1

TN= total nitrogen, EC= Elctrical conductivity, TOC = Total Organic Carbon, O.M= Organic Matter, K = potassium

Water Quality Index (WQI)

The water quality in this study sites was classified using the WQI classification scheme (Table 2 and Figure 1.). Out of all the study sites, site D and A shows an excellent (D =11.22 and A =12.59, WQI < 25) water quality based on the WQI classification scheme signifying that the water can be used for irrigation, domestic and industrial purposes and drinking. While site B and C have a WQI of 26.17 and 39.58 respectively, which are below the (WQI < 50) suggesting that site B and C water samples can only be used for industrial and irrigation purposes and not for drinking (Table 2). However, 50% of the water samples tested fall within the range (QWI < 25) of excellent water quality (Table 2 and Figure. 1). The water samples are good for domestic, industrial and irrigation purposes which is similar compared to the reports by (Hammani, *et al.*, 2022) where they assess the physicochemical properties of groundwater for irrigation Purposes from Difa , Area of Gombe State , Nigeria. The results suggest that the studied water samples are suitable for consumption and irrigation purposes.

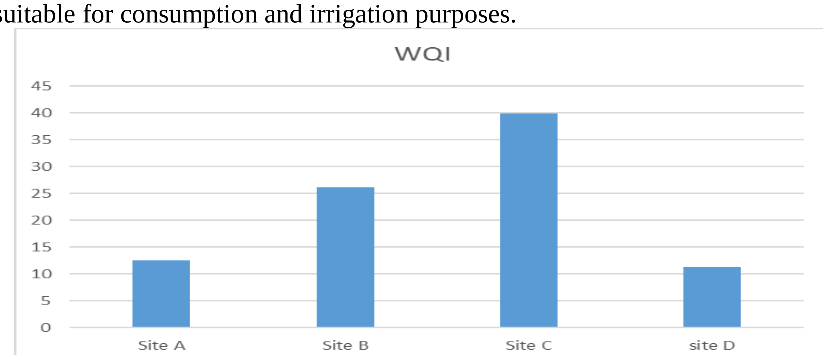

Figure 1: WQI of the water samples in all the sites

Concentrations of PAHs in Soil and water

The concentrations of the 16 priority PAH components (mg/kg) in the soil and water samples collected from Kelebe, Onne and Ore site are presented in (Table 7). The 16 priority PAHs recommended by WHO and USEPA were found present in all the study sites except for anthracene, fluoranthene, benzo (a) anthracene, chrysene and indeno (1,2,3-cd) perylene which were either non-existent or below detection limit. The average PAHs level varied from a minimum of 0.03 mg/L to a maximum of 0.11 mg/L. The PAH compounds are of particular concern due to their potential health and environmental impacts. Notably, benzo(a)pyrene exhibited a relatively high concentration of 0.10 mg/L in soil of Kelebe site, indicating a significant presence in the sample. Also, Fluorene has highest 0.09 mg/L concentration in Kelebe water sample. Albeit at relatively low concentrations Benzo(a)anthracene showed a notable presence, suggesting its contribution to the PAH composition in Onne soil samples, while for Ore site all the compounds are detected in the soil except Benzo(b)fluoranthene. Dibenzo(ah)anthracene and Flurorene are not detected in the water sample of Ore site. Additionally, some compounds, such as benzo(b)fluoranthene and indeno (1,2,3 cd) pyrene, were not detected (N.D.), suggesting variations in the presence of specific PAHs in Kelebe. Generally, the PAHs in soil and water of both sites are lower than WHO standard of 4 mg/kg. According to the European Commission's classification system, soil contamination levels are categorized based on the concentration of the 16-priority polycyclic aromatic hydrocarbons (PAHs). This system defines four contamination levels: no contamination (< 0.20 mg/kg), weak contamination (0.20-0.60 mg/kg), moderate contamination (0.60-1.0 mg/kg), and heavy contamination (> 1.0 mg/kg) (Ubong et al., 2023). Based on this classification, the soil and water samples from this study's sites exhibit moderate contamination levels, falling within the 0.60-1.0 mg/kg range. The lower molecular weight PAHs (LMW PAHs) were generally present in lower concentration in all the sites except the water samples in Kelebe site.

The highest molecular weight PAHs (HMW PAHs) has the highest concentration in all the samples with Ore soil and water samples have the highest total concentration of 0.67 and 0.56 mg/L. This observation is in agreement to the results obtained by (Balogun-Birro, 2015, who found that higher molecular weight PAHs were more dominant in the soil sample investigated. The R^2 and p-value were used to compared and determined the correlation coefficient and significant difference of the PAHs concentration in Kelebe, Onne and Ore sample sites, the result showed that there were significant differences of ($R^2 = 0.551$; p-value = 0.01 $p < 0.05$), ($R^2 = 0.729$; p-value = 0.0403 $p < 0.05$) and ($R^2 = 0.039$; p-value = 0.446 $p < 0.05$) for Kelebe, Onne and Ore sites respectively.

Table 7: Analytical Characteristics of the Target Compounds obtained from soil and water sample in Kelebe, Onne & Ore.

S/N	Target Compound	Kelebe site		Onne site		Ore site	
		Soil (mg/L)	Water (mg/L)	Soil (mg/L)	Water (mg/L)	Soil (mg/L)	Water (mg/L)
1	Naphthalene	0.03	0.06	0.03	0.03	0.03	0.05
2	Acenaphthylene	N.D.	0.07	N.D.	N.D.	0.07	0.07
3	Acenaphthene	N.D.	0.07	N.D.	N.D.	0.07	0.07
4	Fluorene	N.D.	0.09	N.D.	N.D.	0.07	N.D.
5	Phenanthrene	0.07	0.07	N.D.	N.D.	0.07	0.07
6	Anthracene	0.07	0.07	N.D.	N.D.	0.07	0.07
7	Fluoranthene	0.07	0.07	0.07	N.D.	0.07	0.07
8	Pyrene	0.07	0.07	N.D.	N.D.	0.07	0.07
9	Benzo(a)anthracene	0.07	0.07	0.07	N.D.	0.07	0.07
10	Chrysene	0.07	0.07	0.07	N.D.	0.07	0.07

11	Benzo(b)fluoranthene	ND	N.D.	N.D.	N.D.	N.D.	0.07
12	Benzo(k)fluoranthene	0.07	N.D.	N.D.	0.07	0.07	0.07
13	Benzo(a)pyrene	0.10	0.07	N.D.	0.07	0.07	0.08
14	Indeno(1,2,3 cd)pyrene	N.D.	N.D.	N.D.	N.D.	0.07	0 07
15	Dibenzo(ah)anthracene	0.00	N.D.	0.00	0.00	0.07	ND
16	Benzo(ghi)perylene	N.D.	N.D.	N.D.	0.07	0.11	0.06
	Total PAHs	0.62	0.71	0.24	0.24	1.05	0.89
	ΣLMW PAHs	0.1	0.43	0.03	0.03	0.38	0.33
	ΣHMW PAHs	0.52	0.28	0.21	0.21	0.67	0.56

Onne site show a strong correlation coefficient of ($R^2 = 0.729$) in all the sample sites, while Ore shows a good significant difference of ($p < 0.05$), in all the sample sites. Which was efficient similar comparable to the report by (Fakhri *et al.*, 2018).

Conclusion

The results in this study revealed significant variations in physicochemical parameters across the study sites, with 90% of parameters such as pH, EC, TDS, TA, TH, TOC, OM and K,, among others falling within standard limits. Approximately 50% of the water samples tested exhibited excellent water quality, with Quantitative Water Index (QWI) values less than 25, which are suitable for domestic, irrigation, and industrial purposes. The average PAH levels ranged from 0.03 mg/L to 0.11 mg/L across all study sites, well below the WHO standard of 4 mg/kg and classified as moderate contamination according to the European Commission classification system. High Molecular Weight PAHs (HMW PAHs) demonstrated the highest concentrations in all samples, with Ore soil and water samples exhibiting the highest total concentrations of 0.67 and 0.56 mg/L, respectively. This method of assessing soil and water contamination through physicochemical analysis and PAH detection provides valuable insights for pollution assessors in Nigeria and beyond.

Recommendations

Based on the findings, it is recommended:

1. The selected agrochemical should carried-out physicochemical parameters such as pH, EC, TDS, TA, TH, TOC, OM and K among others, before discharging to the environment.

2. The selected agrochemicals industries in (Iragbji, Kelebe, Onne and Ore) Nigeria should ascertain the level of contaminations on environment before and after the discharged of effluents.

3. Also, the quality of water assessment should be done by the agrochemicals industries at regularly interval in the study areas. In order to ascertain the impact of effluents discharged into the water bodies around the study area.

4. The soil and water in the study areas should be conserved to maintain and sustain ecological benefits.

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