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Assessment of Physicochemical Properties of Wastewater from Waste Stabilization Pond of a Refinery and Petrochemical Industry, Kaduna State, Nigeria

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ABSTRACT: The wastewater released by refineries and petrochemical industries frequently contain a range of substances categorized as physical and chemical pollutants. The objective of this study was to assess the physicochemical properties of wastewater from waste stabilization pond of a refinery and petrochemical industry, Kaduna, Nigeria using appropriate standard methods. Results obtained showed that the wastewater had an average pH (8.18), temperature (26.29ºC), dissolved oxygen (0.86 mg/L), total dissolved solids (195.33mg/L), electrical conductivity (159.71µs/cm) and chloride (40.08mg/L) which were in compliance with the limit set by the Federal Ministry of Environment, Nigeria. However, chemical oxygen demand (65.85mg/L), biological oxygen demand (32.32 mg/L), oil and grease (231.97mg/L), nitrate (16.95mg/L), turbidity (5.37NTU), phosphate (10.06mg/L) and sulphate (140.36mg/L) where found to exceed the permissible limit. The mean concentrations of arsenic (4.59mg/L), nickel (0.15mg/L), iron (0.62mg/L), lead (0.67mg/L), cadmium (0.04mg/L) and chromium (0.29mg/L) were higher than the acceptable limits. However, cobalt (0.16mg/L), zinc (0.30mg/L), manganese (0.56mg/L), copper (0.13mg/L) and magnesium (1.65mg/L) contents were within the acceptable limits. These results point the need for adequate treatment of wastewater from petrochemical and related industries using appropriate wastewater treatment technologies. Continuous release of this wastewater into the environment poses great threat to both the environment and public health.

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Refinery and petrochemical industries generate wastewater characterized by the presence of large quantity of organic and inorganic compounds; polycyclic and aromatic hydrocarbons (PAH), phenols, metal derivatives, sulphides, surface active substances, napthalylenic acids and other chemicals (Dauda *et al.,* 2021) considered harmful to the receiving environment as well as on human lives if not adequately treated to safe levels before discharge. Wastewater stabilization pond (WSP) are ponds designed or built for wastewater treatment, removal or reduction of organic contents and pathogens. These industries employ different treatment technologies including physical, chemical and biological or their combination in wastewater treatment. However, these techniques have their limitations and most at times inefficient in adequately removing the contaminants from the wastewater (Ezeonuegbu, 2021). The wastewater when discharge into land and rivers such as; River Rido in the case of Kaduna Refining and Petrochemical Company (KRPC), end up polluting these environments and pose significant threat to the ecosystem. Wastewater discharge constitutes significantly to water pollution, because they contain

various contaminants and possibly toxic substances which results in water impurity (Anyahara *et al.,* 2020). River Rido, like other freshwater bodies, serves as a vital water resource utilized for various domestic and industrial purposes. These include drinking, irrigation, fishing, laundry, bathing, and supporting industrial activities. However, the discharge of industrial effluent from KRPC into this water body stands as a significant contributor to environmental pollution. This pollution leads to the degradation of the environment, not only in the immediate community but potentially in numerous other communities, particularly in developing countries. Additionally, this pollution puts considerable strain on the aquatic ecosystem and its diverse organisms (Dauda *et al.,* 2021). The assessment of physicochemical properties of petrochemical wastewater is crucial for environmental protection, regulatory compliance, treatment system design, resource utilization, risk assessment, and process optimization. It helps industries to manage their wastewater effectively, reduce environmental risks, and move towards more sustainable practices. Most importantly, the assessment of physicochemical properties of petrochemical wastewater is of utmost importance because it influences the characteristics and quality of the receiving environment such as water bodies and lands in terms of pollution and also paints a picture of the type and abundance of organisms found and the activities of such organisms in such environment. For example, Phytoplankton are of utmost importance in various ecological processes, including primary production, nutrient cycling, and food web dynamics. Due to their high sensitivity and responsiveness to environmental changes, they are commonly utilized as indicators to assess pollution levels in different water bodies. Specifically, in freshwater environments, alterations in the phytoplankton community can have significant impacts on fish production and overall water productivity. When pollutants disrupt the plankton community, it not only affects their structure and stability but also disrupts the functioning of the entire ecological system. The phytoplankton population of freshwater response to parameters like temperature, dissolved oxygen, pH and nutrient concentration of the medium and these parameters are influenced by the inflow of effluents and decomposition of waste materials (Anyahara *et al.,* 2021). Hence, the objective of this study was to assess the physicochemical properties of wastewater from waste stabilization pond of a refinery and petrochemical industry, Kaduna, Nigeria.

MATERIALS AND METHODS

Study site: A Refining and Petrochemical Company located in Kaduna State, Nigeria was the choice of this study. An introduction letter stating the purpose of research, signed by the Head of Department, Microbiology, Ahmadu Bello University was presented to the Refining and Petrochemical Company. The letter was duly signed and acknowledged by the company for its intended purpose and there was no conflict of interest between the institution and the company.

Collection and handling of wastewater samples: Samples of wastewater were collected from the waste stabilization pond of the refining and petrochemical industry. Samples were collected in sterile amber sample bottles by carefully dipping the bottles into a well-mixed section of the pond. After sample collection, outer surfaces of sample bottles were rinsed with sterile distilled water and transported in ice box to the laboratory for physicochemical analysis.

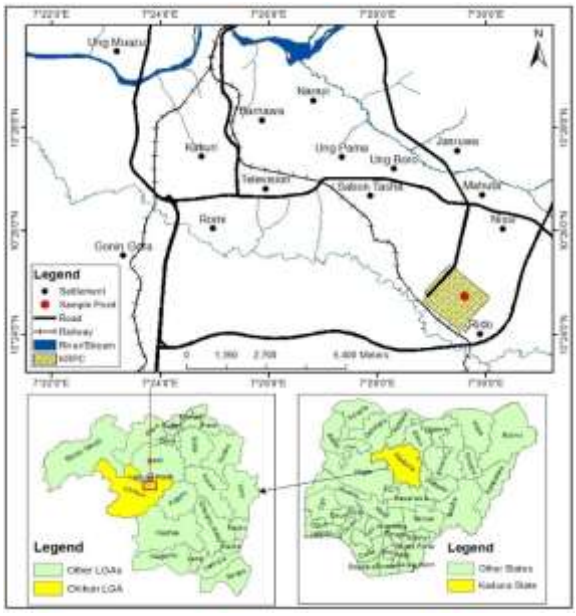

Fig 1: Map of Nigeria showing Kaduna state, the study site and sampling site
Source: Google map, 2022, digitized in GIS Laboratory, Department of Geography, Ahmadu Bello University, Zaria

Determination of physicochemical properties of the wastewater: Physicochemical analysis was carried out in accordance with the standard procedures for wastewater assessment guidelines by APHA (1998). The physicochemical parameters determined were; pH, temperature, electrical conductivity, turbidity, dissolved oxygen, total dissolved solids, biological oxygen demand, chemical oxygen demand, oil and grease, chloride, nitrate, phosphate, sulphate and metals. The pH, temperature, electrical conductivity, dissolved oxygen and total dissolve solids of the wastewater were determined at the point of sample collection using a multi-analyzer (HANNA combo

tester H198130, Denver, USA). The concentration of metals were determined using the fast-sequential atomic absorption spectrophotometer (Model AA240S, Varian technologies, USA).

Fig 2: Waste stabilization pond of Kaduna Refining and Petrochemical Company
Source: Ezeonuegbu *et al.,* (2021)

RESULTS AND DISCUSSION

Physicochemical characteristics of wastewater taken from the waste stabilization pond of KRPC is presented in Table 1. Chemical oxygen demand (65.85mg/L), biological oxygen demand (32.32 mg/L), oil and grease (231.97mg/L), nitrate (16.95mg/L), turbidity (5.37NTU), phosphate (10.06mg/L) and sulphate (140.36mg/L) where found to exceed the permissible limit set by FMENV. The mean concentrations of arsenic (4.59mg/L), nickel (0.15mg/L), iron (0.62mg/L), lead (0.67mg/L), cadmium (0.04mg/L) and chromium (0.29mg/L) were higher than the acceptable limits of FEMNV while other metals were found to be within the permissible levels (Table 2). Petrochemical refineries have been found to generate significant amounts of wastewater whose physicochemical properties can greatly affect public health and the receiving environment if not adequately treated to safe levels dimmed acceptable by environmental regulatory agencies. The turbidity value which was higher than the acceptable limit could be due to presence of suspended or residual solids accumulated during refining processes and from runoffs (Al-Zahrani *et al.,* 2015; Odesiri *et al.,* 2017), as well as chemical reactions such as oxidation or precipitation and even microbial activities. Turbidity can have significant impacts on aquatic lives as it can reduce the amount of light penetration required by submerged aquatic vegetation (Ogbu *et al.,* 2016) and can also affect the growth and reproduction of plants and animals and interfere with the balance of aquatic ecosystem by altering the food web relationships between species (Ezeonuegbu *et al.,* 2021).

This result was similar to that of Sabah *et al.* (2016) who reported value of 5.26 while working with KRPC effluent. The high BOD and COD may be due to relative waste loading, and higher degree indicates the presence of large amount of organic and inorganic pollutant and higher levels of microbial activities with consequent depletion of oxygen content. BOD and COD are important indicators of pollution levels in water and the potential impact on aquatic ecosystem. These results were similar to the findings of Omitoyin *et al.* (2017) who reported BOD value of 32.80 mg/L and Egekwu (2017) who recorded DO (0.82mg/L) but was in disagreement with the findings of Azeez (2017) and Ezeonuegbu (2021) who reported BOD values of 130mg/L and 145.3mg/L and COD of 171.2mg/L and 166.67mg/L respectively. The differences in results could be due to differences in sampling season.

Table 1: Physicochemical characteristics of the wastewater

Parameters	Mean ± SE	Recommended limit (FMENV)
PH	8.18±0.042	6.0-9.0
Temperature (°C)	26.29±0.342	40
Turbidity (NTU)	5.37±0.033	5.0
Dissolved Oxygen (mg/L)	0.86±0.003	10.0
Total Dissolved Solids (mg/L)	195.33±0.233	500
Biological Oxygen Demand (mg/L)	32.32±0.141	10.0
Electrical Conductivity (µs/cm)	159.71±0.113	400
Oil and Grease (mg/L)	231.97±0.962	10.0
Chemical Oxygen Demand (mg/L)	65.85±0.018	50.0
Nitrate (mg/L)	16.95±0.052	10
Sulphate (mg/L)	140.36±0.329	50
Phosphate (mg/L)	10.06±0.006	5
Chloride (mg/L)	40.08±0.047	250

Key: °C=degree centigrade; NTU= Nephleometric Turbidity Units; mg/l=milligram per litre; µs/cm=micro siemens per centimeter; SE=Standard Error; FMENV=Federal Ministry of Environment Nigeria

Table 2: Metal contents in the wastewater

Metal	Symbol	Mean±SE (mg/L)	Permissible Limit (FMENV)
Arsenic	As	4.59±0.324	0.050
Nickel	Ni	0.15±0.008	0.070
Iron	Fe	0.62±0.015	0.300
Lead	Pb	0.67±0.026	0.050
Cadmium	Cd	0.04±0.003	0.005
Chromium	Cr	0.29±0.028	0.05
Cobalt	Co	0.16±0.006	0.5
Zinc	Zn	0.30±0.03	5.000
Manganese	Mn	0.56±0.020	5.000
Copper	Cu	0.13±0.008	1.000
Magnesium	Mg	1.65±0.077	150

Keys: mg/l=milligram per litre; SE=Standard Error; FMENV=Federal Ministry of Environment Nigeria

The value observed for oil and grease could be due to high contents of hydrocarbon compounds in the effluent. High levels of oil and grease inhibit the growth of microorganisms in water thereby disturbing the ecological balances which would consequently affect human health and can also affect the fertility of the land (Norisetty *et al.,* 2011). This value was higher than the findings of Norisetty *et al.* (2017) and Ameh (2017) who recorded an average oil and grease content of 192 and 37mg/L respectively from KRPC wastewater. The values of nitrate, phosphate and sulphate observed could be due to chemical reactions from raw materials used in refining process (Al-Moubaraki and Obot, 2021) and also from agricultural runoffs. High nitrate, phosphate and sulphate if allowed into rivers could lead to eutrophication and death of aquatic lives due to oxygen depletion (Ali *et al.,* 2017).

Metals are ubiquitous, naturally occurring elements, some of which are essential for life, but when released into the environment in high concentrations, they can have adverse effects on human health and the environment (Ali *et al.,* 2019). High levels of metals observed in this study may have originated from corrosion products of equipment and pipes, chemical additives, feedstock, catalysts used and by-products of refining processes. Long-term exposure to these metals can have various toxic effects and can lead to serious health problems including respiratory irritation, liver and kidney damage, increased risk of different forms of cancer amongst others.

*Conclusion***:** This study has established the need for continuous assessment of wastewaters generated from various industries including petrochemical and related industries. Adequate treatment of wastewaters should be ensured by these industries using efficient treatment technologies in other to guarantee public health and environmental safety.

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