DETERMINATION OF THE PHYSICOCHEMICAL PROPERTIES OF WASTEWATER OBTAINED FROM A SOAP-MAKING INDUSTRY

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Abstract
Water contamination, particularly of surface water, is predominantly attributed to anthropogenic activities, notably the indiscriminate discharge of effluents (comprising both industrial and domestic wastes) into local drainage systems, which ultimately convey these pollutants into natural water bodies. This study aims to assess the physicochemical characteristics of wastewater sourced from a soap-manufacturing industry. Parameters such as pH, temperature, electrical conductivity, total solids (TS), and dissolved oxygen (DO) were analyzed using a Hanna multi-parameter probe (HI 9813-6 pH/EC/TDS/°C Meter). Additionally, Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD), oil/grease content, and heavy metal concentrations were determined in accordance with standard analytical procedures. Three effluent samples, collected from designated point-source discharges within the industrial facility, were examined. The zinc concentrations (15.13 mg/L (A), 12.21 mg/L (B), 5.88 mg/L (C) for the effluent samples were found to exceed the permissible limits established by the Federal Environmental Protection Agency (FEPA). Furthermore, Samples A and B exhibited critically elevated COD levels (97, 92) respectively, which are deemed highly non-compliant with FEPA guidelines. The findings of this study underscore the urgent necessity for the treatment of industrial effluents prior to their release into the environment.

Keywords: *Physicochemical properties, industrial pollution, wastewater, heavy metals*

Introduction

Industrial wastewater treatment plants are critical nodes in environmental management, yet their efficacy is often compromised when effluents are discharged without adequate treatment. Globally, surface water bodies such as rivers, lakes, and coastal zones bear the brunt of these discharges (Ajibade *et al.*, 2021a). Untreated or poorly treated industrial effluents introduce a toxic cocktail of pathogens (e.g., E. coli, Salmonella), heavy metals (e.g., lead, mercury, cadmium), and synthetic chemicals (e.g., surfactants, phenols) into aquatic ecosystems (Alaneme *et al.*, 2024). These contaminants trigger cascading ecological disruptions: heavy metals bioaccumulate in fish tissues, impairing their reproductive and neurological functions (Ajala *et al.*, 2022), while excessive nutrients like phosphorus and nitrogen fuel eutrophication, depleting oxygen levels and causing mass die-offs of aquatic life (Ajibade *et al.*, 2021b). Such degradation not only reduces biodiversity but also diminishes the recreational and economic value of water resources, as seen in the decline of fisheries and tourism in polluted regions like Nigeria's Niger Delta (Zabbey *et al.*, 2021). In developing countries, where most industrial wastewater is discharged untreated, these challenges are magnified by population growth, climate variability, and weak infrastructure, creating a vicious cycle of water scarcity and pollution (Rotimi *et al.,* 2021).

Most industries dispose of their effluents without treatment, especially in most developing countries like Nigeria (Ilori *et al.*, 2019; Adewumi and Ajibade, 2019). The discharge of industrial effluent into water bodies is one of the main causes of environmental pollution and degradation in many cities, especially in developing countries. Many of these industries lack liquid and solid waste regulations and proper disposal facilities, including for harmful waste. Such waste may be infectious, toxic or radioactive (Anjali *et al.*, 2014). Determination of the nature and source of chemical species in the industrial environment is of primary importance in the study of trace element pollution (Ogunfowokan *et al.*, 2005).

This study zeroes in on Lagos' soap-making sector, a burgeoning industry driven by high demand for household and commercial cleaning products. The toxic chemicals may destroy the aquatic organisms, which in turn may result in the disruption of the food chain and aquatic ecosystem (Ajibade *et al.*, 2021c, d). Good quality surface water relies on various factors including its physicochemical characteristics as well as the magnitude of the pollution load. The physicochemical characteristics of the water can reveal particular conditions for the ecology of aquatic organisms and soil conditions (Raji *et al.*, 2015; Rajaram and Ashutost, 2008). In this paper, the physicochemical properties of effluents obtained from three major soap-making industries in Lagos, and their compliance with FEPA (Federal Environmental Protection Agency) guidelines for interim uniform effluent limits in Nigeria were studied.

Materials and Method

Effluent samples were collected from three (3) different industries in Ikeja and Ikorodu local

Table 1: Location of sampling site

S/N	Effluent Sample	Location
1.	Effluent A	Agbara
2.	Effluent B	Ogba
3.	Effluent C	Amuwo-Odofin

Figure 1: Map of the sampling site 1 (Agbara) in Ogun, Nigeria

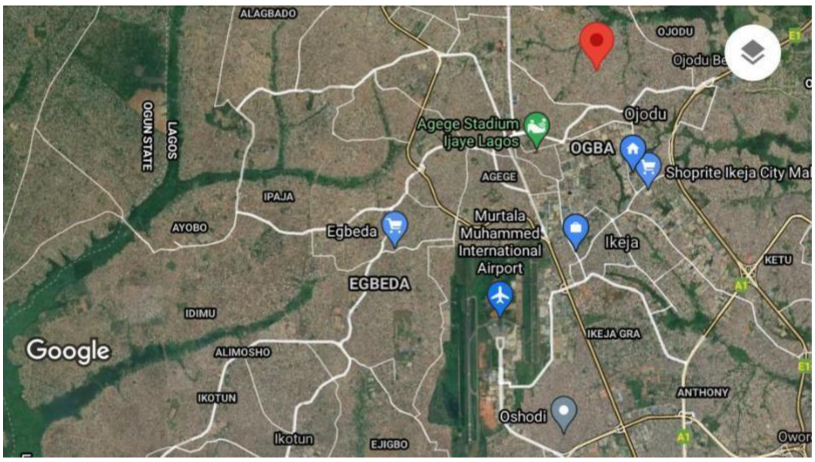

Figure 2: Map of the sampling site 2 (Ogba) in Lagos, Nigeria

Figure 3: Map of the sampling site 3 (Amuwo-Odofin) in Lagos, Nigeria

government areas of the state in the year 2010. Table 1 shows the sampling sites for this research:

Effluent sampling was carried out using clean, high-density 2-liter polyethylene bottles, chosen in accordance with standard requirements for the various physicochemical analyses to be conducted. Samples were collected at designated discharge points where the industrial effluents entered drainage channels. To ensure the integrity of the samples, proper precautionary measures were taken during collection.

Prior to sample collection, all sampling containers were thoroughly washed with dilute hydrochloric acid to eliminate any residual contaminants. They were subsequently rinsed multiple times with distilled water and allowed to air dry. At the point of sampling, the containers were again rinsed twice with the effluent to be collected in order to condition the bottles and prevent dilution or contamination effects. Immediately after collection, the water samples were stored in an ice chest at low temperatures to minimize biological activity and preserve the integrity of the analytes. The samples were then transported to the laboratory under preserved conditions for further physicochemical analysis.

All measuring instruments and analytical meters were properly calibrated and validated according to the manufacturer's specifications to ensure the accuracy and reliability of the measurements. The in-situ parameters, including temperature (°C), pH, electrical conductivity (EC), total dissolved solids (TDS), and dissolved oxygen (DO), were measured at the sampling site using a Hanna multi-parameter probe (HI 9813-6). Prior to measurement, the pH electrode was calibrated using standard buffer solutions of pH 4.0, 7.0, and 10.0. The electrode was then immersed directly into each sample, and the readings were taken and recorded accordingly.

Oil and grease content were analyzed using the HACH DR 2000 direct reading spectrophotometer, following Method 8041, which ensures high sensitivity and specificity for hydrocarbon detection. Turbidity was similarly assessed using the same spectrophotometer based on Method 8237. Chemical Oxygen Demand (COD) was determined using the standard dichromate reflux method as described in recognized water analysis protocols. The Biochemical Oxygen Demand (BOD) was estimated using the HACH Winkler titrimetric method. This involved measuring the dissolved oxygen (DO) levels in the effluent samples on the initial day of sampling (Day 0) and after a five-day incubation period at 20 °C in complete darkness. The DO depletion was used to estimate the BOD, using a control blank for accuracy. Alkalinity of the wastewater was evaluated through an acid-base titration technique. An aliquot of the water sample was titrated against a standardized 0.05 N sulphuric acid solution, with methyl orange serving as the endpoint indicator. For the analysis of heavy metals, including cadmium (Cd), iron (Fe), zinc (Zn), and lead (Pb), spectrophotometric measurements were conducted using an Atomic Absorption Spectrophotometer (AAS), specifically the Perkin Elmer Analyst 200 model equipped with an air-acetylene flame. This method provides high precision and sensitivity for trace metal detection.

Results and Discussion

The result of the various physicochemical laboratory tests, and their limits, in comparison to Federal Environmental Protection Agency (FEPA) guidelines for interim uniform effluent limits, are given in Table 2.

Table 2: Comparison of results with FEPA guidelines for interim uniform effluent limits in Nigeria

S/N	PARAMETERS	Effluent A	Effluent B	Effluent C	FEPA STANDARD
1.	Appearance	Clear	Not Clear	Clear	Clear
2.	Colour	Colourless	Green	Colourless	Colourless
3.	Temperature (ºC)	27.0	27.0	29.0	> 40
4.	pH	11.8	11.7	8.0	6.0 – 9.0
5.	Total Suspended Solids (mg/L)	12.0	32.0	0.10	30
6.	Total Dissolved Solids (mg/L)	12,162	6,630.0	211.01	NS
7.	Sulphide (mg/L)	0.02	0.01	0.01	0.2
8.	Cadmium (mg/L)	0.913	0.724	-	> 1
9.	Copper (mg/L)	0.134	0.125	0.010	> 1
10.	Nickel (mg/L)	0.169	0.153	0.002	> 1
11.	Zinc (mg/L)	15.132	12.210	5.880	> 1
12.	Dissolved Oxygen DO (mg/L)	3	2.5	4.05	NS
13.	Chemical Oxygen Demand COD (mg/L)	97	92	84	NS
14.	Sodium (mg/L)	39.32	143.11	4.72	NS
15.	Alkalinity-M (mg/L $CaCO_3$)	64	64	20	NS
16.	Acidity- P (mg/L $CaCO_3$)	ND	ND	4.0	NS
17.	Turbidity (FTU)	35	2,250	10	NS
	MICROBIOLOGICAL CHARACTERISTICS				
18.	Total Bacteria Counts (cfu/mL)	1.0×10^4	1.0×10^3	1.0×10^3	1.0×10^2
19.	Total Faecal Coliform (cfu/mL)	1.0×10^3	1.0×10^2	1.0×10^2	400 MPN/100 ml

Note: NS - Not stated, ND - Not detected

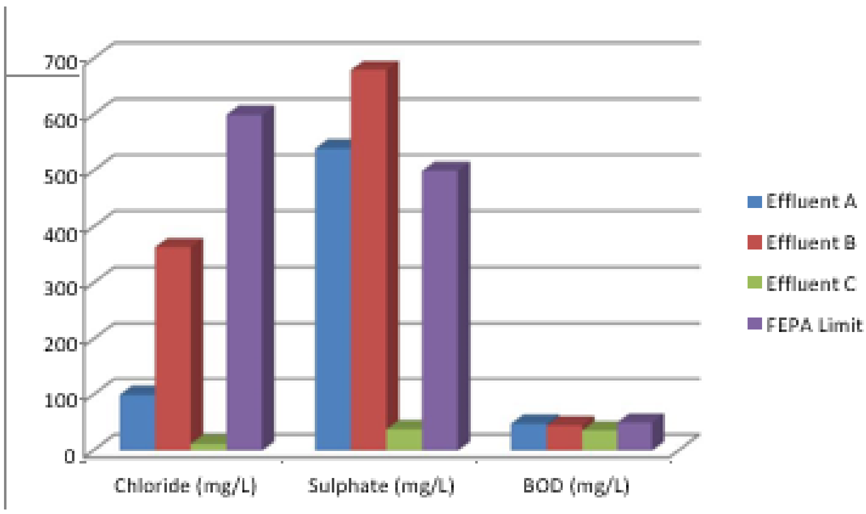

Figure 4: Effluent Composition - Chloride, Sulfate, and BOD Levels Compared to FEPA Standard

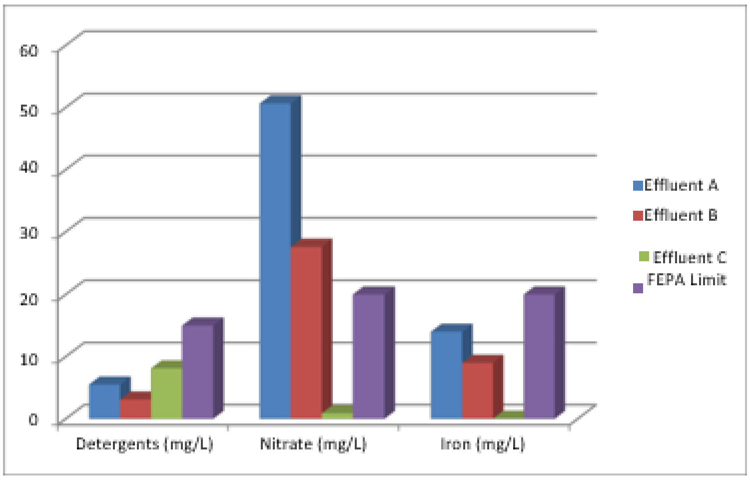

Figure 5: Effluent Composition - Detergents, Nitrate, and Iron Levels Compared to FEPA Standard

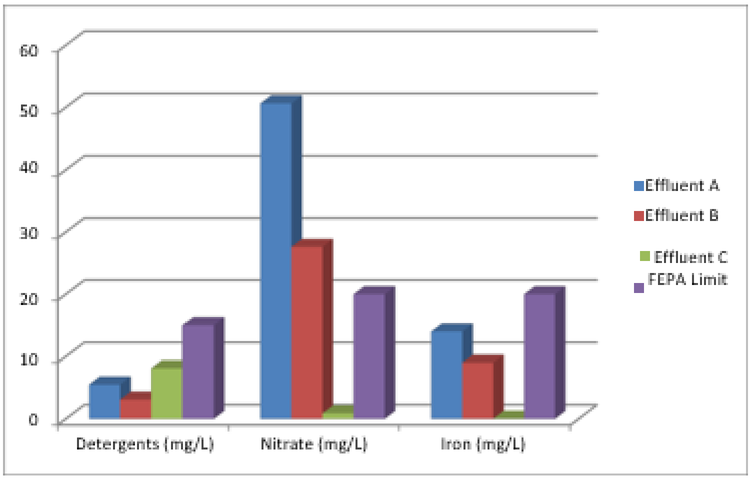

Figure 6: Effluent Composition - Oil and grease, Manganese, and Nitrogen Levels Compared to FEPA Standa

pH

The pH level is a critical determinant of water quality, as it significantly influences the survival and physiological processes of aquatic organisms. Deviations from the optimal pH range can lead to ecological imbalance and toxicity. The appropriate adjustment of pH through chemical agents, such as Sodium Hydroxide (NaOH), Lime (CaO), or Magnesium Hydroxide for acidic conditions, and Hydrochloric Acid (HCl) or Carbon dioxide (CO_2) for alkaline conditions, is essential to maintain environmental compliance and ecological safety.

The pH values recorded for effluent samples A, B, and C were 11.8, 11.7, and 8.0, respectively. While sample C falls within the Federal Environmental Protection Agency (FEPA)'s permissible range of 6.0–9.0, samples A and B greatly exceed this threshold, indicating highly alkaline conditions. Such elevated alkalinity can adversely affect aquatic ecosystems by increasing the solubility and mobility of toxic metals and compounds, which may bioaccumulate and disrupt aquatic biodiversity, especially among pH-sensitive organisms.

Temperature and Colour

Effluent temperature is another influential parameter, as it affects the solubility of gases, especially oxygen, and modulates the metabolic rates of aquatic organisms. The effluent temperatures ranged from 27°C to 29°C, which are within acceptable limits; however, prolonged discharge at these levels warrants monitoring due to potential thermal pollution. In terms of colour, samples A and C were colourless, conforming to FEPA's requirement, while sample B exhibited a green hue, indicative of possible algal content or contamination from industrial dyes. Colouration in effluents can reduce light penetration in aquatic systems, impairing photosynthesis and potentially leading to eutrophication.

Turbidity
Turbidity reflects the concentration of suspended solids, affecting both light penetration and the aesthetic quality of water. Effluent samples A, B, and C had turbidity values of 35 FTU, 2,250 FTU, and 10 FTU, respectively. Although FEPA does not prescribe a specific limit for turbidity, the exceptionally high turbidity in sample B (2,250 FTU) is a cause for concern. Such elevated turbidity can significantly inhibit photosynthesis by blocking sunlight, affect aquatic respiration, and contribute to the sedimentation of vital habitats.

Biochemical Oxygen Demand
Biochemical Oxygen Demand is an essential parameter for evaluating the level of biodegradable organic matter in water. The BOD values recorded were 48 mg/L (A), 45 mg/L (B), and 36 mg/L (C), all within the FEPA threshold of 50 mg/L. However, the relatively high values in samples A and B suggest notable organic pollution, potentially from residual fatty acids, glycerol, or other organic byproducts of soap manufacturing. These elevated BOD levels, though compliant, indicate a substantial oxygen demand, which could reduce available oxygen for aquatic life if not properly managed.

Dissolved Oxygen
Dissolved Oxygen is fundamental to the survival of aerobic aquatic organisms. FEPA recommends a minimum DO level of 2 mg/L to support aquatic life. The DO values measured were 3 mg/L (A), 2.5 mg/L (B), and 4.05 mg/L (C). All samples meet this baseline, with sample C offering the most oxygen-rich environment. Nevertheless, the relatively lower values in samples A and B suggest oxygen depletion risks, potentially resulting from the decomposition of organic matter and high BOD levels.

Chemical Oxygen Demand
COD serves as an indicator of the total quantity of oxygen required to oxidize both biodegradable and non-biodegradable organic compounds. The COD values for effluents A, B, and C were 97 mg/L, 92 mg/L, and 84 mg/L, respectively. Although FEPA does not specify a strict limit for COD, these values signify a substantial organic pollutant load, with sample A presenting the highest. Elevated COD levels are associated with reduced DO, which can lead to anaerobic conditions harmful to aquatic fauna.

Total Dissolved Solids
TDS quantifies the combined content of all inorganic and organic substances dissolved in water. The TDS levels recorded were 12,162 mg/L (A), 6,630 mg/L (B), and 211.01 mg/L (C). Although FEPA does not establish a definitive limit for TDS in effluents, excessive concentrations, as observed in samples A and B, can lead to salinity issues, making the water unsuitable for irrigation, drinking, and aquatic life. High TDS can also increase electrical conductivity and interfere with nutrient absorption in plants.

Iron
Iron is an essential micronutrient for both flora and fauna; however, excessive iron concentrations can be toxic. The iron concentrations in samples A, B, and C were 12.0 mg/L, 9.0 mg/L, and 0.031 mg/L, respectively, all below FEPA's maximum allowable limit of 20 mg/L. Nonetheless, elevated iron levels can promote the proliferation of iron bacteria and cause physiological stress in fish, especially by clogging gills and supporting algal growth.

Chloride
Chloride is a major inorganic anion that, in elevated concentrations, can harm plants and aquatic ecosystems. Effluent samples A, B, and C contained chloride levels of 100.0 mg/L, 364.0 mg/L, and 12.0 mg/L respectively, all within the FEPA permissible limit of 600 mg/L. However, the relatively high level in sample B could be indicative of saline intrusion or industrial chemical input.

Zinc
Zinc concentrations in all samples significantly exceeded the FEPA guideline of 1 mg/L, with values of 15.132 mg/L (A), 12.210 mg/L (B), and 5.880 mg/L (C). Though zinc is an essential trace element, at high levels, it becomes toxic, impairing gill function in fish, inhibiting aquatic reproduction, and bioaccumulating through the food chain. The persistent presence of elevated zinc across all samples highlights a serious industrial pollution concern, likely from galvanizing, plating, or dyeing activities, necessitating immediate mitigation strategies.

Detergent
Detergents in wastewater pose risks due to their surfactant properties, which can reduce water surface tension and disrupt respiratory processes in aquatic organisms. While the detergent concentrations in most samples were within acceptable limits, sample C recorded a slightly elevated concentration of 8.10 mg/L, suggesting possible contamination from domestic or industrial cleaning agents.

Oil and Grease
Oil and grease are known to form surface films, reducing oxygen transfer and harming aquatic ecosystems. Effluent samples A, B, and C recorded oil and grease values of 7.30 mg/L, 2.50 mg/L, and 1.02 mg/L, respectively, which are all within the

FEPA limit of 10 mg/L. Despite compliance, the presence of these substances, especially in sample A, underscores the need for enhanced grease-trap or separator mechanisms.

Nitrates
Excess nitrate levels in water bodies can cause eutrophication and disrupt aquatic life. Effluent samples A and B contained nitrate concentrations of 50.63 mg/L and 27.63 mg/L, both exceeding the FEPA limit of 20 mg/L, while sample C had a compliant value of 0.88 mg/L. The elevated nitrate levels likely stem from the use of nitrogen-containing compounds in production or cleaning processes and pose a threat to aquatic ecosystems.

Heavy Metals
Heavy metals are persistent and bioaccumulative pollutants with long-term ecological and human health implications. Unlike organic contaminants, they do not degrade and instead accumulate in the food web. While metals such as Ca, Co, Cu, Fe, K, Mg, Mn, Na, Ni, and Zn serve as vital micronutrients in trace amounts, excessive levels become toxic. In this study, apart from zinc, the heavy metal content in all effluent samples fell within FEPA's acceptable limits. However, their presence still necessitates regular monitoring and pre-treatment before discharge.

Conclusion
This study has provided a comprehensive evaluation of the physicochemical properties of wastewater effluents from three selected soap-manufacturing industries, comparing the results with FEPA's Interim Uniform Effluent Standards. Parameters such as temperature, oil and grease, iron, chloride, and BOD were within permissible limits, indicating partial compliance with regulatory standards. Conversely, parameters including TDS, COD, nitrates, and especially zinc were observed at concentrations far exceeding acceptable thresholds, posing substantial threats to aquatic ecosystems and public health. The persistent presence of zinc and other pollutants underscores the necessity for urgent remediation measures, including the implementation of advanced treatment technologies and stringent effluent monitoring protocols. Ultimately, untreated or poorly managed industrial wastewater discharges pose severe risks to environmental sustainability and human wellbeing. Therefore, regulatory compliance must be enforced through consistent oversight and the adoption of best practices in wastewater management.

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