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# Physico-chemical, heavy metal, and microbiological analysis of effluent from a confectionery company in Lagos State, Nigeria

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## Abstract

Wastewater from the confectionery industry exhibits marked daily and seasonal variations, complicating its management and disposal. This study investigated the physico-chemical characteristics, heavy metal content, and microbial load of effluents from a confectionery processing plant using American Public Health Association (APHA) standard procedures. At the discharge point, the effluent showed temperature (25.02±0.15 °C), turbidity (1.00 NTU), pH (6.20±0.29), electrical conductivity (2295.00±3.62 $\mu$s/cm), total dissolved solids (1708.00±19.70 mg/L), total suspended solids (6252.00±0.30 mg/L), total hardness ($CaCO_3$) (1141.30±0.03 mg/mL), oil and grease (5.60±0.00 mg/L), dissolved oxygen (4.76±0.02 mg/L), COD (8900±0.00 mg/L), BOD (181.80±0.37 mg/L), free chlorine (0.25 mg/L), phosphate (9.418 mg/L), nitrate (387.60 mg/L). Heavy metals (mg/mL) included Mg (25.71), Zn (¡0.0010), Pb (¡0.0100), Cu (0.0100), Mg (0.0564), Ni (0.0064), and Cd (¡0.0020). The total plate count was (238 cfu /100 mL), while the total coliforms count exceeded 1600 MPN/100 mL. Comparison with FEPA and NESREA discharge standards indicated that most parameters met regulatory limits, except TDS, TSS, alkalinity, nitrate, chloride, phosphorus, oil and grease, total coliforms, Fe, BOD, and COD, which exceeded permissible thresholds. The release of such inadequately treated effluents poses environmental and public health risks. Strengthened regulatory enforcement is recommended in industrial zones such as Lagos State, Nigeria.

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## 1. Introduction

The extensive water demand ranks food production industry as a significant consumer of water. Food processing industries constitute a diverse range of sectors. These include confectionery, distillers, beverages, snacks, and dairy. These sectors are involved in various stages of food production, processing, and manufacturing to give a wide array of food and beverage products [1]. The amount of water consumed in the production of food and beverages can vary based on factors such as the specific type of food, process parameters, size of the industrial unit, and the cleaning operations and equipment employed during the process [2]. Water used in the food industry is closely linked to maintaining high product quality [3, 4]. In addition to being a major consumer of water, the food industry also generates substantial amounts of wastewater or effluents as a byproduct of its operations [5]. Production, cleaning, sanitising, chilling, and material transport activities are just a few of the plant operations that result in wastewater in these

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industries. However, because of the abundance of organic materials in these wastewaters, their contents are mainly biodegradable. Additionally, these constituents are sometimes non-toxic. Consequently, the wastewater from food processing industries tends to have high biochemical oxygen demand (BOD), chemical oxygen demand (COD), and suspended solids (SS) concentrations [1].

The confectionery industry is a prominent sector within the food industry and holds considerable global significance. It produces a variety of sweets, including gum products and chocolate. These confectionery items typically contain substantial amounts of sugar, sugar substitutes, cocoa, fats, emulsifiers, and flavours, which are utilised during manufacturing processes [6]. The confectionery manufacturing process involves multiple stages that require water, including fermentation, grinding, pulverising, mixing, pressing, drying and cleaning. Throughout these steps, the raw materials utilized are liquid, thus generating wastewater. Most of the organic content from confectionery wastewater in manufacturing is sourced from the sugars and vegetable fats employed in the process. Pollution may result from the discharge of untreated discharge of effluent containing these substances into aquatic bodies. According to general knowledge, industrial wastewater is complex and contains different inorganic and organic components [7].

Effluent is a term that is often used to describe liquid waste, discharged from either a commercial establishment, farm, household or factory into a water body such as a river, lake or lagoon. Wastewater or effluent is defined as the water generated during the operational processes of any industry [8].

Wastewater contains obnoxious and potentially harmful compounds that pollute and contaminate receiving water bodies. The microbiological contamination of water, particularly with pathogenic bacteria, is one of the most significant aspects of water pollution. Enteric bacteria are responsible for the majority of aquatic illnesses. Water contamination is a severe environmental issue because both man and the biodiversity of the water bodies are negatively impacted. Indicator microorganisms like faecal coliforms (FC) are frequently used to determine freshwater quality. Coliforms and *Escherichia coli* are currently two of the most significant bacteria used to define water quality and assess health risks [9, 10].

Wastewater properties vary based on the particular operations and technological procedures used by each sector, resulting in a distinct profile of wastewater or effluent. There are various types of wastewater, including saline water, runoff, wash water, and water resulting from alkaline and acid waste neutralization. The composition of an effluent can include a wide range of chemicals, with their nature, quantity, and combination being determined by factors such as the industry's activities, technological processes, concentrations from utility use, contaminants introduced during the operation, and the nature of raw materials. Human activities that lead to the release of effluents negatively affect the lakes, rivers, oceans, and groundwater. These effluents contain myriads of pollutants, including various chemicals, pathogens, and alterations in physicochemical or sensory properties. The changes in the physical properties of water include acidity levels, conductivity, temperature, and eutrophication. These changes disrupt aquatic ecosystems and general water quality [11].

The ultimate objective of wastewater treatment is to alter its composition such that the resulting effluent either eliminates or, at the very least, substantially reduces its harmful effects on the environment or renders it suitable for reuse. A conventional treatment process comprises primary, secondary, and tertiary stages, each serving a critical function in purifying wastewater to levels appropriate for discharge into natural water bodies or for recovery and reuse across industrial, commercial, and domestic applications. This systematic management of industrial effluents, municipal sewage, and greywater collectively constitutes the practice of sanitation [3].

In Nigeria, as in many other developing countries, industries commonly discharge effluents without adequate treatment. This practice threatens water quality, aquatic habitats, and surrounding ecosystems. Industrial wastes often contain toxic and hazardous substances, many of which pose serious health risks. The release of untreated effluents into water bodies, therefore, contributes substantially to environmental degradation, endangering the well-being of local communities [12]. The wastewater from food-processing industries in particular presents public health and environmental concerns. Several studies in Nigeria have assessed industrial effluents to evaluate their impacts and associated risks [13]. The available studies predominantly concentrate on aspects such as the physicochemical characteristics of the effluents, generic and reproductive biomarkers, waste generation, management practices, and wastewater treatment technologies within the food industry. However, there is still a dearth of thorough studies devoted to the initial assessment of wastewater output from the nation's food industry. The preliminary evaluation of wastewater effluent is crucial for identifying the composition, pollutant levels, and potential environmental impacts of the effluent discharged by food companies. This evaluation can provide valuable insights into the efficiency of existing wastewater treatment methods employed by these companies and help assess their compliance with regulatory standards and guidelines [5, 6, 13]. Such assessments are valuable for identifying potential health risks associated with untreated or inadequately treated effluents from food-processing facilities. Accordingly, this study was undertaken to quantify the major pollutants in the effluent and wastewater from a confectionery company by analyzing key physical, chemical, and microbial parameters, and to evaluate their potential environmental impacts on nearby water bodies.

## 2. Materials and methods

### 2.1. Materials

### 2.1.1. Sampling location

This research was conducted on wastewater effluent from OK SWEETS Limited, a sugar and confectionery product manufacturing company located at Oshodi Industrial Estate, Lagos State, Nigeria. Coordinates of the location is (6°32′51″ N. 3°20′19″).

### 2.1.2. Sample collection

Samples were taken at several locations at the wastewater treatment facility, such as before treatment (Sample A), after treatment (Sample B) and the point of discharge (Sample C). Plastic bottles were used for the sample collection. The sample bottles were first rinsed three times with the effluent before collecting the sample, and then stoppered with a cap or cover. 50 cL of each sample was collected in three separate containers and placed in an ice chect for onward transportation to the laboratory for analysis.

### 2.1.3. Glassware

All the glass wares used for the analysis were thoroughly washed with detergent solution, rinsed with distilled and de-ionized water, and oven-dried for 1h at 120 $^\circ C$ before use.

### 2.2. Methods

### 2.2.1. Physico-chemical analysis

The physico-chemical characteristics (color, temperature, pH, oil and grease, total suspended solids, total solids, alkalinity, acidity, total hardness, chloride, sulphate, nitrate, and phosphate content) of the effluent samples were analyzed by using the methods described in WHO, 2022 [14] with some modifications by Aderibigbe *et al.* [1].

### 2.2.2. Color

This was determined using the visual inspection method. A color chart was used under natural lightening to determine the color of the wastewater sample.

### 2.2.3. Odour

This was done using olfactory evaluation method. The wastewater sample was half filled in a tidy wide mouth glass stopper bottle. After inserting the stopper, the glass bottle was shaken vigorously for 3 seconds. The bottle's stopper was taken off, and the smell was sampled by bringing it up to the nostril.

### 2.2.4. Temperature

A portable mercury-in-glass thermometer was used for temperature measurement.

### 2.2.5. pH check

The pH meter was first calibrated with pH 4 and pH 7 standard buffer solutions. It was then used to take the pH of the wastewater sample when the reading was stable.

### 2.2.6. Oil and grease determination

A 5 mL solution of concentrated $H_2SO_4$ was mixed with 50 mL of the wastewater in a separatory funnel. 30 mL of n-hexane was also added to the acidified sample and shaken vigorously for 2 min, and then the mixture was left to separate into aqueous and organic layers. The two layers are drained separately into two different beakers. The aqueous layer was re-extracted with 30 mL n-hexane twice without the acid. The extracts (organic) from the subsequent extractions are added to the first extract and filtered into a dry, cleaned and weighed conical flask. The flask is placed in a water bath (set at 70 $^\circ C$) and evaporated to dryness. It was then transferred to an oven to remove any trace of the organic solvent. The flasks and the contents were cooled in a dessicator and weighed. A repeated cycle of drying (for 30 min), cooling and weighing was continued until the difference in weight was stable. The value of the oil and grease was obtained using equation (1):

$$\text{Oil \& grease (mg/L)} = \frac{\text{Weight of extract} \times 100000}{\text{Volume of Sample used}}. \tag{1}$$

### 2.2.7. *Determination of total suspended solids (TSS)*

The sample was homogenized thoroughly. 100 mL of the sample was measured and filtered through a vacuum filtration setup on a pre-weighed ($W_1$) glass fiber. The glass fiber was removed and placed in a petri dish and placed in the oven for 1 h 30 min at 105 $^\circ C$ until it dried to a constant weight. The glass fibre was then cooled in a desiccator and weighed ($W_2$). The TSS was determined by using equation (2):

$$\text{TSS in mg/L} = \frac{(W_2 - W_1) \times 1000}{\text{Volume of Sample (mL)}}, \tag{2}$$

where $W_1$ = Initial weight of the filter, $W_2$ = final weight of the filter.

### 2.2.8. *Determination of total solids*

Labelled petri-dishes were washed and dried in an oven for 30 min, then transferred to a desiccator to cool. After cooling, the dishes were weighed. The wastewater sample was stirred and a 25 mL pipette was used to transfer the sample into the petri dishes. The dishes were then placed in a water bath and the contents were allowed to evaporate until they became completely dried and later transferred to the oven for complete dryness at 104±1 $^\circ C$ for 1 h. The dish was cooled in a desiccator to ambient temperature and the final weight checked. The final weight readings were recorded and the average value was taken. Equation (3) was used to calculate the total solids:

$$\text{Total Solid (mg/L)} = \frac{\text{Weight of solids (g)} \times 1000 \times 1000}{\text{Sample Volume(mL)}}, \tag{3}$$

where Weight of solids (g) = (weight of dish + solids)(g) − weight of empty dish (g).

### 2.2.9. *Determination of specific gravity*

A pycnometer (specific gravity bottle with stopper) was dried and weighed, and the result was recorded as $W_1$. It was cleaned and dried with soft tissue paper, filled with distilled water, and weighed as $W_3$. The pycnometer was emptied and filled with the wastewater sample to be determined. The wastewater sample was added in such a way that the pycnometer as well as the capillary hole in the stopper is filled with water and weighed as the total weight as $W_2$. The Specific gravity was calculated by using equation (4):

$$\text{Specific gravity (g/cm}^3\text{)} = \frac{W_2 - W_1}{W_3 - W_1}, \tag{4}$$

where $W_1$ = weight of empty dried pycnometer, $W_3$ = weight of empty dried pycnometer + distilled water, and $W_2$ = weight of empty dried pycnometer + sample.

### 2.2.10. *Determination of alkalinity*

A pipette was used to transfer 25 mL of the effluent sample into conical flask. And two drops of methyl orange indicator was added. The mixture was then titrated with the acid 0.02N $H_2SO_4$ till a pinkish-red color end point was observed. Alkalinity was calculated with equation (5):

$$\text{Alkalinity (mg/L)} = \frac{\text{Average Titre Value} \times \text{Factor of Titrant} \times 1000}{\text{Volume of Sample (mL)}}. \tag{5}$$

### 2.2.11. *Determination of acidity*

A 25 mL portion of the wastewater sample was measured using a pipette and transferred into a conical flask, after which two drops of phenolphthalein indicator were added. It was then titrated with a 1 M solution of NaOH till a pink-color end point was observed. The acidity was calculated by using equation (6):

$$\text{Acidity (mg/L)} = \frac{\text{Average Titre Value} \times \text{Factor of Titrant} \times 1000}{\text{Volume of Sample (mL)}}. \tag{6}$$

### 2.2.12. *Determination of total hardness*

With the aid of a pipette, 25 mL of the wastewater sample was quantitatively transferred into a 250 mL conical flask containing 1 mL of $NH_4Cl$ buffer. 0.5 g of potassium cyanide and two drops of erichrome black T indicator was added to obtain a wine reddish color. The mixture was then titrated with standard 0.01 M EDTA solution until blue coloration was obtained. Equation (7) was used to estimate the total hardness of the effluent.

$$\text{Hardness CaCO}_3\text{(mg/L)} = \frac{\text{ATV} \times B \times F \times 1000}{\text{Volume of sample (mL)}}, \tag{7}$$

where ATV= Average tire value, $B$ = 1 mg $CaCO_3$ equivalent to 1.00 mL EDTA titrant, $F$ = (0.01M EDTA Factor), Calcium Hardness (mg/L) = Total Hardness × 0.4008, Magnesium Hardness (mg/L) = (Total hardness − Calcium hardness) × 0.2431.

### 2.2.13. Chloride determination

A 25 mL portion of effluent sample was measured into a 250 mL conical flask and 1.0 mL of 5% $K_2CrO_4$ was added. The mixture was swirled to homogenize and then titrated with standard 0.0141 M $AgNO_3$ to orange/reddish yellow end point. Reagent blank was also prepared and titrated. The chloride present in the effluent was estimated with equation (8):

$$\mathrm{Cl^-(mg/L)} = \frac{(A - B) \times M \times F \times 35450}{\text{Volume of sample (mL)}}, \tag{8}$$

NaCl (mg/L) = $\mathrm{Cl^-} \times 1.65$, where $A$ = Average titre value of the sample, $B$ = Average titre value of the blank, $M$ = Molarity of $AgNO_3$, $F$ = Titrant factor.

### 2.2.14. Determination of sulphate

Sulphate buffer (20 mL) was added to 100 mL of filtered sample (to maintain sample pH). 0.511 g of $BaCl_2$ was added (while stirring on a magnetic stirrer) to precipitate sulphate in the sample.

### 2.2.15. Determination of nitrates

A 10 mL portion of the wastewater was measured into a porcelain crucible and dried completely using a water bath. The resulting solid was dissolved by adding 2 mL of phenol disulphonic acid, with continuous stiring using a glass rod. To adjust the pH to alkaline, a concentrated NaOH solution and distilled water were added while stirring. The mixture was filtered into a Nessler tube and diluted with distilled water to a final volume of 50 mL and allowed to stand for color development. Using a Spectrophotometer at 410 nm, the absorbance of the mixture was read. Nitrate concentration was calculated by referencing a calibration curve generated from standard solutions.

### 2.2.16. Determination of phosphates

A 35 mL portion of the test solution was added to 10 mL of vanadate-molybdate solution. This mixture was then quantitatively transferred into a 50 mL standard flask and distilled water was added to make it up to the calibration mark. 10 mL, 20 mL, 30 mL, 40 mL, and 50 mL of the stock sulphate, phosphate, and nitrate solution were diluted with distilled water to create a series of standard solutions (10 to 50 ppm). A UV spectrophotometer was used to measure the absorbance at 490 nm.

### 2.2.17. Turbidity

The turbidity was determined using the nephelometric method with a turbidity meter. The meter is used to measure the intensity of light scattered at a 90-degree angle from an incident light beam passing through the water sample. The meter's detector, positioned at a right angle to the light source, captures the scattered light. The amount of scattered light correlates directly with the turbidity level. The result was expressed in Nephelometric Turbidity Units (NTU) [15].

### 2.2.18. Dissolved oxygen determination

The DO sensor was connected to the meter and switched on. The BOD bottle was filled with the raw homogenized sample to the brim which was regulated at a temperature of $20 \pm 3\ ^\circ C$. The cleaned probe of the calibrated DO meter was dipped into the sample. The blinking $O_2$ signal displayed was allowed to be stable. The DO value displayed in mg/L was recorded [1, 14].

### 2.2.19. Determination of chemical oxygen demand (COD)

The wastewater sample was homogenized by shaking vigorously and aliquot (2.5 mL) was mixed 3.5 mL of concentrated sulfuric acid and 2.5 mL of 0.04M $K_2Cr_2O_7$ in a COD reagent vial and sealed tightly. The mixture was then heated in a digestion block (COD reactor) at 150 °C for 2 h. After cooling to ambient temperature, the absorbance was measured at 600 nm using a UV-Vis spectrophotometer. COD concentrations were determined from a calibration curve constructed using potassium hydrogen phthalate standards [16].

### 2.2.20. Biochemical oxygen demand (BOD) determination

The wastewater sample was collected in a 300 mL BOD sample bottle without trapping air bubbles and the initial dissolved oxygen (DO) level was measured using the DO meter and recorded as $DO_1$. The BOD bottle was then sealed and incubated in the dark for 5 days at $20\ ^\circ C$. The final DO level was measured as $DO_5$ [17]. Equations (9) and (10) were used to estimate $BOD_5$.

$$\mathrm{BOD_5(mg/L)} = (\mathrm{DO_1} - \mathrm{DO_5}) \times \mathrm{DF}, \tag{9}$$

$$\text{DF (dilution factor)} = \frac{\text{Volume of BOD bottle (mL)}}{\text{Sample volume used for DO (mL)}}, \tag{10}$$

where $BOD_5$ = Biochemical oxygen demand after 5 days, $DO_1$ = Initial Dissolved oxygen at day 1, and $DO_5$ = Final dissolved oxygen after incubation for day 5.

### 2.2.21. *Total aerobic microbial count*

One milliliter of the sample was transferred into a sterile Petri dish. For bacterial enumeration, 15–20 mL of sterile, liquefied soybean casein digest agar (SCDA), cooled to 45 $^\circ C$, was aseptically poured into the plate. For fungal enumeration, starch casein agar (SCA) and Sabouraud dextrose agar (SDA) were used. The plates were gently rotated clockwise and counterclockwise on the laminar airflow (LAF) platform to ensure uniform mixing. The media was then allowed to solidify under LAF conditions.

After solidification, plates containing SCDA were incubated at 30–35 $^\circ C$ for 3–5 days for bacterial growth, while plates containing SDA and SCA were incubated at 20–25 $^\circ C$ for 5 days for fungal growth. Upon completion of incubation, the number of colony-forming units (CFU) was counted using a colony counter [18].

### 2.2.22. *Tests for E. coli species*

Following the incubation time, the broth was shaken and 1 mL was transferred (from Tube A) to 100 mL of sterilised MCB (macConkey broth), where it was incubated for 24 to 48 hours at 42-440$^\circ C$. It was subcultured on a macConkey agar plate, and the plates were incubated for 18 to 72 hours at 30-350$^\circ C$. Pink, non-mucoid colony growth suggested the potential presence of *E. coli* whereas ”no growth” indicated the absence of *E. coli*, and the effluent sample was deemed to have passed the *E. coli* test [19].

### 2.2.23. *Determination of heavy metals*

Effluent and water samples were first filtered through filter paper into 100 mL prewashed plastic bottles, and the pH was adjusted to 3.5 using analytical-grade HCl. The samples were stored at room temperature prior analysis. For heavy metal determination, 50 mL aliquots were digested with 10 mL of concentrated $HNO_3$ in an Erlenmeyer flask under a fume hood. The mixture was heated on a hot plate to a residual volume of approximately 10 mL, cooled, diluted to 50 mL with distilled water, and filtered through Whatman filter paper into a 100 mL volumetric flask. The final volume was adjusted to the mark with distilled water.

The concentrations of Pb, Cd, Cr, Cu, and Mn were quantified using a flame atomic absorption spectrophotometer (FAAS; Buck Scientific VGP 210, USA, 2005) with an air–acetylene flame and digital readout system. Element-specific hollow cathode lamps were employed at the following wavelengths: Cd (228.8 nm), Cr (357.9 nm), Cu (324.8 nm), Mn (279.5 nm), and Pb (283.3 nm). Samples were aspirated via a nebulizer, and absorbance values were recorded for quantification.

### 2.3. *Statistical analysis*

The values obtained were analyzed as mean of triplicate determinations.

## 3. Results and discussion

In many confectionery companies, there are significant issues with the quality of industrial effluent. The production of wastewater with a high level of organic compounds (sugars, fats, and proteins) is significantly influenced by the confectionery sector, which raises the BOD and COD indices. The physic-chemical characteristics of the samples of the confectionery effluent are displayed in Table 1. The results show that the appearance of effluent from Ok Sweets factory is cloudy with particles at the point of discharge (Sample C) after it has been treated. The odour is objectionable in contrast to the FEPA unobjectionable standard limit leading to offensive odour in the environment and water bodies. Proteins and other organic molecules may have putrefied, releasing dissolved organic and inorganic substances including phosphorus, nitrogen, and sulphur [19]. Additionally, some of the gases in effluent from confectioneries may emit unpleasant odours.

Naturally occurring freshwater often has a pH between 6 and 9. Majority of freshwater are largely neutral and have good buffering. To safeguard and benefit organisms, wastewater pH must be between 6 and 9 according to USEPA [15], and it must also be between 6.5 and 8.5 for drinking water according to WHO [14]. Since their metabolic processes depend on the pH of their surroundings, aquatic species are susceptible to pH fluctuations. It can be observed from this study that the pH falls within the range specified by NESREA and FEPA limits, posing no threat to aquatic life [20].

The DO of the effluent also reached a concentration (4.76±0.02 mg/mL) below the WHO limit of 5.0 mg/L for dissolved oxygen in aquatic life. Low DO levels lead to septic conditions of the water bodies that are not favorable to living aquatic animals. This work reveals that the effluent contains organic material that is degraded by microbial action and it thus consumes the available oxygen, leading to a decline in DO level which is fatal to aquatic life.

It was observed also that BOD of the discharged effluent (181.80±0.37 mg/mL) exceeded NESREA standard limit of 50 mg/L [21], indicating a high concentration of biodegradable organic matter. Elevated BOD levels suggest that the wastewater has a high biochemical oxygen demand, which can increase the pollution load of receiving water bodies and formation of ”dead zones” where aquatic life cannot exist. High COD levels in the effluent represent high levels of organic content, which can bring DO levels down, and affect the ecology of the area. The study also points out that the effluent gives rivers that come into contact with it hypoxic conditions, which affects the lives of organisms present in the water in the most terrible ways.

The turbidity value of the factory’s effluent was 1 NTU at the point of discharge while the NESREA standard is 5 NTU Maximum. The outcomes showed that the company’s treated effluents were not turbid. High levels of suspended and colloidal particles in waste

Table 1: Physico-chemical characteristics of confectionery effluent samples.

| Parameters | Units | A | B | C | NESREA (Limit) |
|---|---|---|---|---|---|
| Appearance | - | Cloudy liquid with particles | Colourless liquid with particles | Cloudy liquid with particles | Colourless |
| Odour | - | Objectionable | Unobjectionable | Objectionable | Unobjectionable |
| Colour | Cu | 20.00 | 10.00 | 5.00 | - |
| *Temperature | °C | 25.40±0.06 | 25.00±0.00 | 25.20±0.15 | 40 |
| Specific gravity | g/cm$^3$ | 1.0059 | 1.0063 | 1.0071 | - |
| *Conductivity | µs/cm | 585.00±5.77 | 2315.00±1.08 | 2295.00±3.62 | - |
| Turbidity | NTU | 10.00 | 5.00 | 1.00 | 5 (Max) |
| *pH | - | 4.40±0.13 | 8.00±0.90 | 6.20±0.29 | 6 - 9 |
| *Total solids | mg/L | 5650.00±0.00 | 6170.00±0.00 | 7960.00±0.00 | 500 (Max) |
| *Total dissolved solids | mg/L | 420.50±2.65 | 1723.00±1.08 | 1708.00±1.70 | 25 (Max) |
| *Total suspended solids | mg/L | 5229.50±0.27 | 4447.00±0.39 | 6252.00±0.30 | - |
| *Total settleable solids | mg/L | 2.00±0.10 | 0.05±0.16 | 0.06±11 | - |
| *Total hardness ($CaCO_3$) | mg/L | 101.00±0.00 | 1181.70±0.03 | 1141.30±0.03 | 150 (Max) |
| *Alkalinity | mg/L | 0.00 | 454.00±0.03 | 434.30±0.03 | - |
| *Acidity | mg/L | 94.08±0.50 | 5.76±0.10 | 13.44±0.25 | - |
| *Calcium | mg/L | 40.48±0.00 | 473.63±0.03 | 457.43±0.03 | - |
| *Magnesium | mg/L | 6.37±0.14 | 21.60±0.11 | 25.71±0.10 | 50 (Max) |
| *BOD | mg/L | 182.40±0.48 | 180.00±0.59 | 181.80±0.37 | 90 (Max) |
| *COD | mg/L | 10100.00±0.00 | 8566.60±0.38 | 8900.00±0.00 | - |
| *Dissolved oxygen | mg/L | 1.27±0.03 | 7.47±0.09 | 4.76±0.02 | 10 (Max) |
| *Oil and grease | mg/L | 386.20±0.00 | 1.80±0.00 | 5.60±0.00 | 0.5 (Max) |
| Free chlorine | mg/L | < 0.0040 | 0.3600 | 0.2500 | 2.0 (Max) |
| Phosphorus | mg/L | 3.5270 | 0.8500 | 3.1390 | 250 (Max) |
| *Chloride | mg/L | 59.98±0.11 | 243.61±0.25 | 269.92±0.05 | 250 (Max) |
| Sulphate | mg/L | 16.73 | 201.30 | 136.39 | - |
| Phosphate | mg/L | 10.58 | 2.560 | 9.418 | - |
| Nitrate | mg/L | 374.93 | 357.61 | 387.60 | 10 (Max) |
| Nickel | mg/L | < 0.0100 | 0.0073 | 0.0064 | 0.05 (Max) |
| Sodium | mg/L | 38.6000 | 64.1550 | 66.4700 | 200 (Max) |

Note: A: Before treatment; B: After treatment; C: Point of discharge. * Values presented as mean ± standard deviation of sample.

effluent discharges cause high turbidity. This limits the amount of light that some aquatic life needs to perform photosynthesis [22]. Inadequate nourishment from poor photosynthesis would result in stunting and lack of plant life in receiving waters. This discovery was connected to earlier studies, which all revealed high turbidity values in several rivers receiving brewery effluent, which must have been influenced by brewery wastewater [23–25]. The effluent showed high total suspended solids (TSS) at the point of release, with an average level of 6252 mg/L and total dissolved solids of 1708.00±1.70 mg/L. The range of TSS shows that the level of suspended solids and dissolved solids are much higher than 25 mg/L and 30 mg/L limit by NESREA and FEPA for TSS and 500 for TDS respectively. Confectionery industry effluents are distinguished by suspended elements such as coagulated milk and concentrates. The amount of TS, total dissolved solids (TDS), and TSS downstream increased as a result of the effluent's influx. The high dissolved solids level downstream is the cause of the cloudiness or lack of transparency of the river. High levels of solids generally combined with a lack of transparency in the river water can impede the photosynthetic process, which is crucial for aquatic plants. High suspended solids levels can have negative aesthetic and ecological implications on a water body [22]. They can also affect how much it would cost to purify the water if it were to be used for public water supply pipes. It is noted that while creating a suitable treatment process for effluents and river water, the kind of suspended solids in the river and the composition of the effluent play vital roles.

The ability of a strong acid to be neutralized by water is measured by its alkalinity. The alkalinity of water and pH are closely linked. Alkalinity for the effluent at the point of discharge was 434.30±0.30 mg/L against the 150 mg/L NESREA standard. When these values are compared, it becomes clear that the effluent is far more concentrated than what is typically advised. Small changes in alkalinity induce pH shifts, which have a variety of effects on aquatic flora and wildlife [26]. Therefore, excessive alkalinity discharges from the factory could cause vegetation and fauna in the receiving water to die off.

The nitrate concentration in the discharged effluent (387.60 mg/L) greatly exceeds the permissible limits set by NESREA (10 mg/L) and FEPA (20 mg/L). Although nitrate is essential for plant growth and development, concentrations ≥10 mg/L can adversely affect water quality. Elevated nitrate levels promote excessive growth of aquatic plants and, when combined with phosphorus, intensify eutrophication, leading to ecosystem imbalance. This process disrupts key parameters such as dissolved oxygen, temperature, and overall water chemistry. In addition to ecological impacts, nitrate concentrations of 10 mg/L or higher pose risks to warm-blooded animals by inducing hypoxia (low oxygen conditions). Naturally, surface waters contain minimal nitrate (typically < 1 mg/L), but levels may reach up to 30 mg/L in effluents from wastewater treatment facilities. High nitrate exposure has also been linked to methemoglobinemia in bottle-fed infants consuming contaminated drinking water [27].

The average chloride concentration in the effluent at the discharge point was 269.92 mg/L, exceeding the NESREA guideline

Table 2: Concentration of the heavy metals in the confectionery effluent samples.

| Elements (mg/L) | A | B | C | NESREA (Limit) | FEPA (Limit) |
|---|---|---|---|---|---|
| Zinc | 0.0861 | < 0.0010 | < 0.0010 | 2 (max) | < 1 |
| Lead | < 0.0100 | < 0.0100 | < 0.0100 | - | < 1 |
| Copper | 0.0210 | 0.0145 | 0.0100 | 0.5 (max) | < 1 |
| Manganese | 0.0814 | 0.0558 | 0.0564 | 0.2 (max) | 5 |
| Cadmium | < 0.0020 | < 0.0020 | < 0.0020 | 1.0 (max) | < 1 |
| Iron | 2.1398 | 0.6158 | 1.5803 | 0.5 (max) | 20 |
| Chromium (hexavalent) | 0.0109 | 0.0179 | 0.0182 | 0.5 (max) | < 1 |

Note: A: Before treatment; B: After treatment; C: Point of discharge.

Table 3: Results for the microbial analysis of the confectionery effluent samples.

| Microbial Test | Units | A | B | C | NESREA (Limit) | FEPA (Limit) |
|---|---|---|---|---|---|---|
| Total plate count | Cfu/100 mL | 250 | 0 | 238 | - | - |
| Total coliform count | MPN/100 mL | >1600 | <1.8 | >1600 | 400 (max) | 400 (max) |
| E. coli | Cfu/100 mL | Absent | Absent | Absent | - | - |

Note: A: Before treatment; B: After treatment; C: Point of discharge.

value of 250 mg/L but remaining below the FEPA limit of 600 mg/L. Elevated chloride levels in surface waters pose several risks, the most significant being chronic toxicity, which disrupts the osmotic balance of aquatic organisms. Chloride also increases water conductivity, enhancing its corrosive potential. In metal distribution systems, chloride reacts with metal ions to form soluble salts, thereby elevating metal concentrations in drinking water. Although protective oxide films can form on lead pipes, chloride accelerates galvanic and pitting corrosion, undermining long-term infrastructure integrity.

The phosphorus level in the effluent was 3.139 mg/L, which was higher than the recommended maximum of 2 mg/L by NESREA standards. Phosphorus is the main nutrient that limits the growth of algae in most freshwater environments such as lakes, rivers, and reservoirs, as well as in some coastal waters affected by river runoff [28]. Phosphorus inhibits growth mostly through toxicity or indirect effects under certain conditions, but when available in optimal forms and amounts, it fuels algal blooms by lifting nutrient limitations and supporting metabolic functions [29, 30]. Human activities that introduce additional phosphorus into water bodies can therefore boost the likelihood of algal blooms, which is a prelude to eutrophication. Eutrophication occurs when increased phosphorus from human activities boosts algae growth, disrupting aquatic ecosystems. Ecosystems completely shift at a certain phosphorus discharge threshold, and the water quality deteriorates over time.

Oil and grease in the effluent at the point of discharge was 5.60 mg/L which is within the limit of 10 mg/L given by NESREA. The formation of surface films and coastal deposits can result from the release of oil and grease into the surface or groundwater, which can degrade the ecosystem and poses health risks. These pollutants disrupt aquatic environments, harm wild life, and can interfere with water treatment and human health [31].

The confectionery effluent showed low-to-moderate heavy metal contamination as shown in Table 2. Fe, Cu, Mn, and Cr(VI) were detected in measurable concentrations, while Pb and Cd were below detection limits. Iron presented the most critical compliance issue, exceeding the NESREA discharge limit of 0.5 mg/L both before treatment (2.14 mg/L) and at the final discharge point (1.58 mg/L). Although treatment reduced iron concentrations by approximately 71%, the subsequent rebound between treatment and discharge suggests either post-treatment contamination, corrosion of pipes, or cross-mixing with untreated wastewater streams.

Zinc and copper were effectively removed, with zinc showing 98.80% reduction and copper approximately 31% reduction. Manganese decreased by 31%, while Cr(VI) concentrations increased slightly after treatment ( from 0.0109 to 0.0182 mg/L) though still well below the 0.5 mg/L NESREA threshold. Similar rebound behaviour for iron and low-level chromium presence have been observed in Nigerian confectionery and food processing effluents, where infrastructural limitations and poor conveyance contribute to secondary contamination [32, 33].

The negligible levels of Pb and Cd are encouraging, reflecting the relatively low heavy-metal inputs from confectionery processes compared to metal-based industries [34]. However, the persistence of iron contamination indicates the need for upgrading treatment facilities, introducing polishing steps such as adsorption or sand filtration, and routine effluent monitoring. These steps are consistent with recommendations for ensuring industrial compliance and safeguarding Lagos water bodies [35, 36].

The persistence of Cr(VI) (0.0182 mg/L at discharge) is noteworthy. Although well below the 0.5 mg/L threshold, Cr(VI) is highly toxic and carcinogenic, and its presence in food industry effluents suggests contamination through raw water supplies or processing aids. Previous studies have emphasized that trace Cr(VI) in industrial effluents warrants confirmatory speciation using validated methods such as ETA-AAS or ICP-MS [37].

From an ecological standpoint, elevated Fe concentrations can impair benthic ecosystems through iron floc deposition, while even trace Cr(VI) poses mutagenic risks to aquatic organisms. Similar findings in Lagos industrial effluents highlight the importance of treatment optimization and post-treatment quality assurance [38]. Low Pb and Cd levels are reassuring, but continued monitoring is essential, as episodic spikes have been reported in urban industrial discharges [39].

Table 3 shows the results of the microbial analysis of the confectionery effluent samples. The total coliform count in the effluent discharge exceeded 1,600 MPN/100 mL which is far above the FEPA and NESREA permissible limit of 400 MPN/100 mL. Such elevated coliform levels significantly increase the bacterial load of receiving water bodies [40]. Bacteriological analysis confirmed sewage contamination, rendering the water unsafe for both drinking and recreational purposes.

### 3.1. *Heavy metal concentration*

The concentration of heavy metals in the confectionery effluent samples is shown in table 2.

### 3.2. *Microbial analysis*

The results for the microbial analysis of the confectionery effluent samples are presented in table 3.

## 4. Conclusion

This study evaluated the characteristics of wastewater effluents from a confectionery company and highlights various approaches to wastewater management, including mechanical, physicochemical, and biological treatment methods. Physicochemical analysis revealed that the surface water around the facility in Lagos State is contaminated. If used for domestic purposes, such water poses potential risks to human health, as parameters including TDS, TSS, alkalinity, nitrate, chloride, iron, $BOD_5$, COD, phosphorus, and total coliform counts all exceeded the permissible limits established by FEPA and NESREA. The indiscriminate discharge of confectionery effluents into streams and other surface waters represents a major source of environmental pollution. Consequently, stricter enforcement of environmental regulations is necessary, particularly for food and confectionery industries operating in industrial zones such as Lagos State, Nigeria, to reduce organic load, suspended solids, and nutrient concentrations in treated wastewater.

## Data availability

No additional data was used beyond those presented in the manuscript.

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