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# Assessment of Wastewater Quality Discharged from Some Selected Bakeries in Benin City, Nigeria

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## ABSTRACT

Nigeria's limited freshwater resources are at risk due to the discharge of wastewater from water-intensive industries, such as food processing, that does not comply with the regulations of the National Environmental Standards and Regulation Enforcement Agency (NESREA). This could significantly harm both the ecosystem and human health. This study aims to assess the physicochemical and biological properties of wastewater discharged from selected bakeries in Benin City, Nigeria, to determine compliance with NESREA standards and highlight potential environmental risks. Wastewater samples were randomly collected from five bakeries in Benin City and examined for their physicochemical and biological features. The findings indicated that, except for potential of Hydrogen (pH), total dissolved solids (TDS), chemical oxygen demand (COD), chloride ($Cl^-$), Ammonium Nitrogen ($NH_4N$), and lead (Pb), all other parameters were within NESREA's permitted limits for food industry effluent discharge. The average pH value (5.9) was below the permitted range, but the average TDS (4754.2 mg/l), COD (1058.34 mg/l), $NH_4N$ (3.068 mg/l), Cl (2984.86 mg/l), along with Pb (0.0724 mg/l) values are substantially over NESREA standards. These results show non-compliance with NESREA rules, stressing the necessity for regulatory entities to monitor the quality of bakery wastewater in the research region to guarantee high-quality effluent discharge.

**Keywords:** Bakeries, Guidelines, Health consequences, Industries, Wastewater.

## 1. INTRODUCTION

Globally, freshwater is now under serious danger from pollution since freshwater reserves (both quality and quantity) are falling, mostly owing to human activities **(El Kharraz et al., 2012; Zeng et al., 2013; Qasim and Mane, 2013; Akharame et al., 2017)**. Anthropogenic influences, such as rising industrialization, play a crucial role in this worldwide trend **(Chong et al., 2010; UN-Water, 2011)**. In Nigeria, the rapid rise of metropolitan areas (such as Benin City) has led to an increase in industrial activity, including bakery businesses.

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However, the release of bakery effluent into the environment without sufficient treatment is a substantial environmental concern since it includes high amounts of contaminants, including fat, oils, grease, particulates, BOD, COD, and other pollutants **(Enduramaxx, 2023)**.

Bakery effluent may be particularly hazardous to the environment without adequate treatment. When released by industry, it commonly contaminates surface waterways and subsurface aquifers. When injected into surface waters, it depletes dissolved oxygen levels, generating harsh circumstances for aquatic life **(Enduramaxx, 2023)**. Bakery effluent may contain chemicals such as oils and cleaning agents, along with flour residues. If not properly managed, these substances can seep into groundwater, affecting its quality. When nutrients (e.g., nitrogen and phosphorus) from ingredients and food remnants enter groundwater, they may induce eutrophication, leading to excessive algal growth and oxygen depletion. A high salt level in bakery wastewater may raise soil salinity and influence the aquifer's composition. Saline groundwater is unfit for drinking or irrigation. Some bakery components (e.g., chocolate, food colourings) may contain heavy metals (like cadmium, lead, arsenic, etc.). These metals may leak into groundwater, causing long-term concerns **(El-Heloui et al., 2016; El-Rawy et al., 2022)**. Hence, monitoring the quality of bakery wastewater released into the environment to ensure that correct treatment is carried out is vital to limit these detrimental impacts and maintain water quality.

This problem is addressed by national, regional, and international environmental organisations that establish guidelines for regulating the release of industrial wastewater to the natural environment **(Akharame et al., 2017; Akharame and Ogbebor, 2023; USEPA, 2024)**. They also oversee adherence to these regulations. In Nigeria, addressing the pollution of industrial wastewater is a major responsibility of the NESREA (National Environmental Standards and Regulations Enforcement Agency). NESREA creates guidelines as well as standards for regulating the release of industrial wastewater into the environment and monitors adherence to these regulations on a national, regional, and global scale. However, they are not effectively executed due to a lack of coordination, as many companies continue to neglect proper maintenance of their effluent treatment facilities, which leads to poor treatment as required by NESREA **(Akharame et al., 2017)**. As a result, pollutants are often released into our waterways, severely harming their ecosystems and diminishing their recreational and aesthetic value **(Odutayo et al., 2016; Okereke et al., 2016)**.

Industries have been employing traditional pollution metrics like TSS (total suspended solids), BOD (biochemical oxygen demand), TP (total phosphorus), COD (chemical oxygen demand), and TN (total nitrogen), among others, to show the limits of effluent treatment method performance **(Aniyikaiye et al., 2019; Daouda et al., 2021)**. While some of these parameters have been found to be non-compliant, studies like **(Osibanjo et al., 2011; Ayobahan et al., 2014; Chris-Otubor et al., 2015; Akpen et al., 2016; Amoo et al., 2017; Akharame et al., 2017),** and others consistently stress the importance of appropriate continuous monitoring of effluents released from industries in order to make sure the regulating agencies are meeting standards. Few research projects have been undertaken in Benin City to investigate the effluent that bakeries release. In order to identify any potential risks related to these effluents.

This study intends to examine the physicochemical quality of wastewater released from a few chosen bakeries in Benin City, Edo State, Nigeria. The investigation will highlight areas of non-compliance with legal requirements, provide important insights into the effectiveness of current wastewater management procedures in the bread industry sector, and stress the importance of ongoing monitoring to protect the environment and public health. These results might inform more effective regulations and encourage the region's adoption of better wastewater treatment technologies.

## 2. MATERIALS AND METHODS

### 2.1 Study Area

Benin City, located in the rainforest region of Nigeria, receives between 1500 and 2500 mm of rain annually. Between 25°C and 28°C is the average monthly temperature **(Rawlings and Ikediashi, 2020)**. According to **(Ikhile, 2016)**, the city is situated on sedimentary layers from the South Sedimentary Basin, namely the Benin Formation. Over 90% of this geological layer consists of vast, porous, coarse sand that is combined with thick layers of clay and shale. These layers have a significant potential to retain groundwater **(Adegbite et al., 2018)**. Ferruginized or lateritized clay sand makes up Benin City's reddish topsoil **(Ikhile, 2016)**. Two distinct seasons characterize the climate: the dry season, which spans from November to February, as well as the rainy season, which spans from March to October with a brief respite in August **(Rawlings and Ikediashi, 2020)**. But because of climate change and global warming, rainfall is unpredictable all year long, with double peaks in July and September. Benin City is shown on a map in **Fig. 1**.

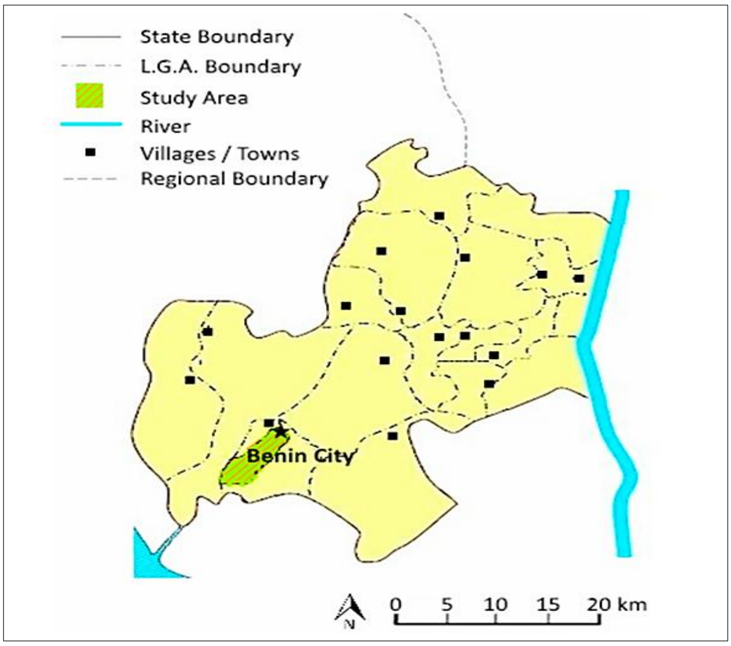


**Figure 1.** The Edo State map featuring Benin City (**Cirella et al., 2019**)

### 2.2 Wastewater Sampling and Analysis

Wastewater samples from five separate bakeries in Benin City, Edo State, Nigeria, were randomly collected at the discharge site during August and September of 2024. **Table 1** and **Fig. 2** show the locations of the bakeries. The samples were placed in appropriately labeled, pre-treated two-liter plastic bottles after being washed three times with wastewater before commencing collection. After that, they were kept in an ice chest at the Martlet Environmental Research Laboratory in Benin City. Prior to testing, every sample was kept at

4°C in a refrigerator. Together with a biological parameter (Coliforms-Col.), the analysis looked at 19 physiochemical parameters like pH, Electrical Conductivity (EC), Total Dissolved Solids (TDS), Total Hardness (TH), Bicarbonate ($HCO_3^-$), Nitrate ($NO_3$-), Nitrite ($NO_2^-$), Sulphate ($SO_4^{2-}$), Iron (Fe), Lead (Pb), Zinc (Zn), Arsenic (As), Copper (Cu), Cadmium (Cd), Chromium (Cr), and Ammonium Nitrogen ($NH_4N$). The laboratory studies were conducted using the American Public Health Association's recommendations **(APHA, 1998; APHA, 2005)**. Additionally, **Table 2** provides information on the methods used to analyze aspects of wastewater quality. Microsoft Excel (2016 edition) was used to statistically analyze wastewater quality data.

**Table 1.** The GPS location coordinates for the wastewater sample sites

| Samples ID | GPS Coordinates | |
|---|---|---|
| | Latitude (N) | Longitude (E) |
| B1 | 6°24'33'' | 5°37'15'' |
| B2 | 6°24'13'' | 5°36'12'' |
| B3 | 6°25'14'' | 5°37'28'' |
| B4 | 6°25'12'' | 5°36'41'' |
| B5 | 6°24'28'' | 5°36'19'' |

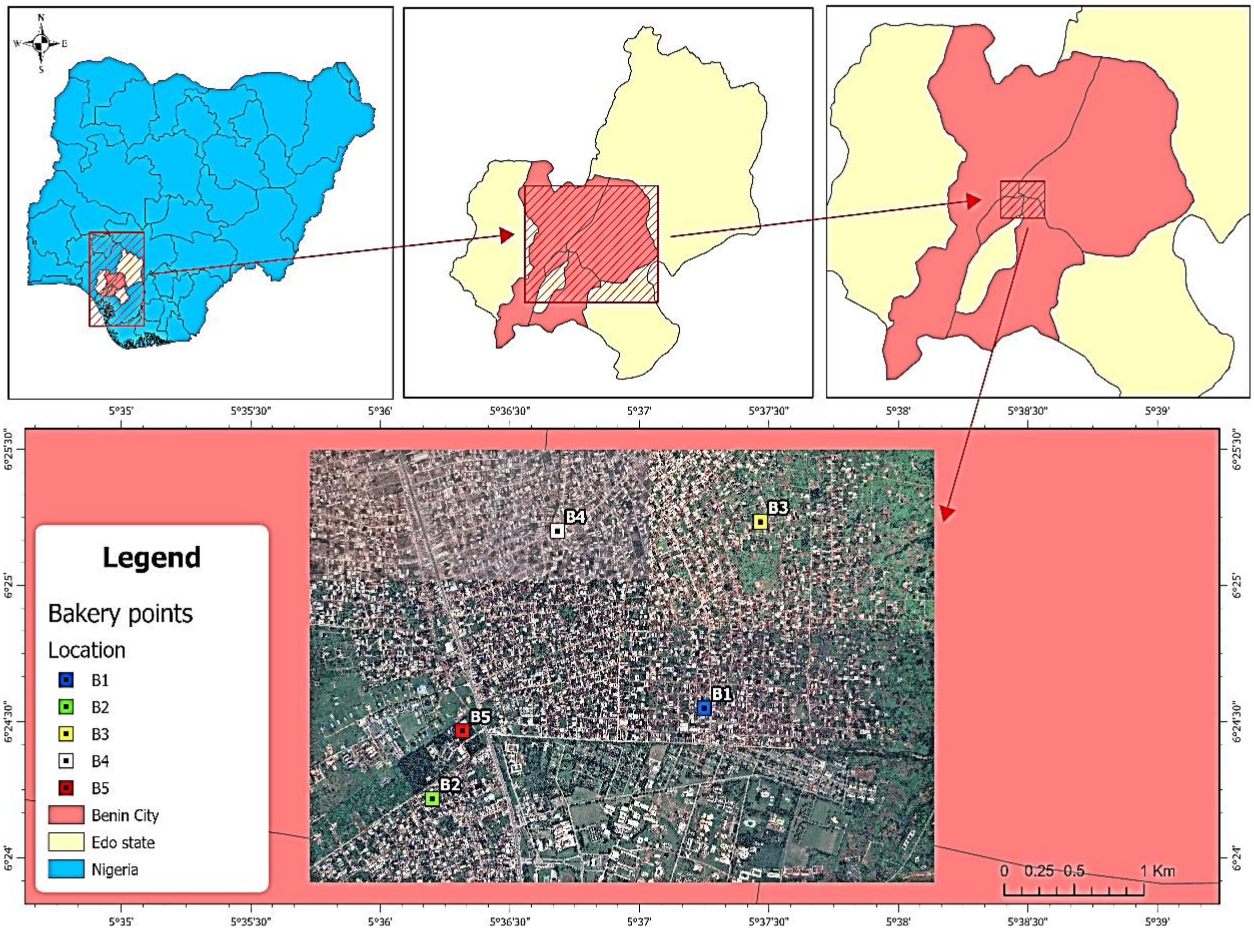


**Figure 2.** The study area map depicting all the sampling areas.

**Table 2.** Utilized techniques in assessing the wastewater quality parameter

| **Parameter** | **Analytical Methods** |
|---|---|
| pH | Electronic pH meter (Cyber Scan) |
| Electrical Conductivity | Flame Photometry |
| Total Dissolved Solids | Flame Photometry |
| Total Hardness | Titrimetry |
| Chemical Oxygen Demand | Dichromate |
| Bicarbonate | Titrimetry |
| Nitrate | Spectrophotometry (Atomic Absorption Spectrophotometer-AAS) |
| Nitrite | Spectrophotometry (Atomic Absorption Spectrophotometer-AAS) |
| Sulphate | Spectrophotometry (AAS) |
| Phosphorous | Colorimetry |
| Chloride | Titrimetry |
| Iron | Spectrophotometry (AAS) |
| Lead | Spectrophotometry (AAS) |
| Zinc | Spectrophotometry (AAS) |
| Arsenic | Spectrophotometry (AAS) |
| Copper | Spectrophotometry (AAS) |
| Cadmium | Spectrophotometry (AAS) |
| Chromium | Spectrophotometry (AAS) |
| Ammonium Nitrogen | Titrimetry |
| Coliforms | Membrane Filtration Method |

## 3. RESULTS AND DISCUSSION

**Tables 3 and 4** provide the findings of the investigation. **Table 3** provides a full description of the physicochemical characteristics of the bakery effluent, whereas **Table 4** presents descriptive data for these characteristics. Among the exceptions of pH, TDS, COD, $NH_4N$, Cl, as well as Pb, the parameters examined are all below and within the **(NESREA, 2009)** allowable limits for food industry effluent discharge, according to the results in **Tables 3 and 4**. The measured pH values in **Table 4** are below the **(NESREA, 2009)** permitted range of 6.5 to 8.8, with an average of 5.9 and a range of 5.4 to 6.1. The high acidity of wastewater is likely caused by the high organic content of components such as dairy products, sugar, lipids, oil, and wheat **(Struk-Sokolowska and Tkaczuk, 2018; Foodsafe Drains, 2024)**. Previous research has also reported on the acidity of bakery effluent **(Chen et al., 2006; Krzanowski et al., 2008)**. By lowering the level of oxygen content in the water bodies, such acidic effluent may have an impact on aquatic life. Additionally, if it penetrates the soil, it may change the pH of the soil, which would affect plant development and soil microbes **(Blue Swell Initiative, 2024; PRI Environmental, 2024).**

Having an average of 4754.2 mg/l, the recorded levels of TDS ranged from 802 mg/l to 20,000 mg/l, far beyond the statutory **(NESREA, 2009)** limit of 500 mg/l. Similarly, EC values varied from 1612 mg/l to 40,000 mg/l**,** with an average of 9540.6 mg/l**.** Although (**NESREA, 2009)** does not provide a specific limit for EC, its strong correlation with TDS suggests that the high levels observed in this study may pose potential risks to environmental and water safety. Ingredients and additives (like salts, sugars, and preservatives), cleaning agents (such as chemicals and detergents), and flour and dough residues that dissolve in water are some of the reasons for these high TDS levels. Water quality is worsened and unsuitable for drinking, irrigation, industrial use, and aquatic life

when bakery wastewater with high TDS levels enters natural water bodies. For sensitive species, it may induce stress or even death by disturbing the osmotic balance of aquatic animals **(Peng et al., 2020)**. Furthermore, by altering soil water retention and nutrient availability, increased TDS levels could hamper plant growth **(Foodsafe Drains, 2024).**
While $NH_4N$ levels varied between 0.53 mg/l and 12.33 mg/l, averaging 3.068 mg/l, COD levels ranged from 30.2 mg/l to 5125 mg/l, averaging 1058.34 mg/l. Statutory **(NESREA, 2009)** requirements that are 60 mg/l just for COD, as well as 1.0 mg/l just for $NH_4N$, are considerably surpassed by these findings. Numerous organic and inorganic components, including wheat, sugar, starch, proteins (milk, eggs), fats, oils, greases, yeast, dough, detergents, and sanitizers, are probably to blame for the large amounts. In their examination of bakery effluent, **(Alam et al., 2023)** reported comparable high quantities of COD and $NH_4N$. Elevated levels of COD and $NH_4N$ indicate that wastewater includes a considerable amount of organic matter, which may lead to nutrient pollution and excessive growth of aquatic plants and algae (eutrophication) when discharged. Aquatic life may die from hypoxic situations brought on by this large drop in dissolved oxygen **(Annunziato, 2021)**.

**Table 3.** Physicochemical attributes of bakery effluent

| Parameters | Bakery | | | | |
|---|---|---|---|---|---|
| | **BWW1** | **BWW2** | **BWW3** | **BWW4** | **BWW5** |
| pH | 5.4 | 6.0 | 6.0 | 6.0 | 6.1 |
| EC (µS/cm) | 40000 | 2588 | 1612 | 1686 | 1817 |
| TDS | 20000 | 1227 | 802 | 838 | 904 |
| TH (mg/l) | 377.0 | 126.9 | 106.0 | 122.3 | 153.5 |
| COD (mg/l) | 5125 | 44.3 | 30.2 | 32.1 | 60.1 |
| $HCO_3^-$ (mg/l) | 7123 | 202.3 | 171.3 | 188.2 | 280.4 |
| $NO_3^-$ (mg/l) | 18.10 | 1.84 | 1.11 | 1.43 | 2.10 |
| $NO_2^-$ (mg/l) | 1.89 | 0.051 | 0.038 | 0.047 | 0.065 |
| $SO_4^{2-}$ (mg/l) | 10.41 | 0.73 | 0.40 | 0.51 | 0.88 |
| P (mg/l) | 7.14 | 0.612 | 0.451 | 0.551 | 0.885 |
| Cl (mg/l) | 12101 | 774.2 | 565.5 | 601.4 | 882.2 |
| Fe (mg/l) | 0.550 | 0.601 | 0.643 | 0.611 | 0.589 |
| Pb (mg/l) | 0.066 | 0.074 | 0.078 | 0.081 | 0.063 |
| Zn (mg/l) | 0.363 | 0.399 | 0.432 | 0.404 | 0.380 |
| As (mg/l) | ND | ND | ND | ND | ND |
| Cu (mg/l) | 0.276 | 0.304 | 0.315 | 0.313 | 0.288 |
| Cd (mg/l) | 0.040 | 0.044 | 0.045 | 0.056 | 0.047 |
| Cr (mg/l) | 0.156 | 0.171 | 0.177 | 0.174 | 0.161 |
| $NH_4N$ (mg/l) | 12.33 | 0.80 | 0.53 | 0.66 | 1.02 |
| Total Coliform Counts (CFU/ML) | $1\times10^3$ | $1\times10^3$ | $1\times10^3$ | $1\times10^3$ | $1\times10^3$ |

The average of the recorded chloride (Cl) values was 2984.86 mg/l, extending between 565.5 mg/l and 12101 mg/l. While the average lead (Pb) level was 0.0724 mg/l, extending between 0.063 mg/l and 0.081 mg/l. Statutory **(NESREA, 2009)** standards that are 250 mg/l just for Cl, as well as 0.05 mg/l just for Pb, are exceeded by these values. While lead contamination may come from obsolete plumbing systems and equipment that include lead-based items, the high chloride levels are probably caused by the extensive use of sodium chloride in baking. Water quality and plant growth may be significantly influenced by excessive quantities of these substances **(Tadesse et al., 2017; Asche and Lead, 2013)**. When lead, a potent neurotoxin, contaminates drinking water, it may cause kidney damage, high blood pressure in adults, and developmental issues in children, among other severe health hazards. Even though there were low quantities of total coliforms in the effluent—possibly as a consequence of the high baking temperature—untreated or poorly treated bakery effluent may have a major detrimental effect on the environment and public health.

**Table 4.** Statistical Description of Bakery Effluent Properties

| Parameters | Max. | Min. | Mean | Std. Deviation | Variance | NESREA Limit (2009) |
|---|---|---|---|---|---|---|
| pH | 6.1 | 5.4 | 5.9 | 0.282843 | 0.08 | 6.5-8.8 |
| EC (µS/cm) | 40000 | 1612 | 9540.6 | 17031.77 | $2.9\times10^{8}$ | - |
| TDS | 20000 | 802 | 4754.2 | 8524.32 | 72664026 | 500 |
| TH (mg/l) | 377 | 106 | 177.14 | 113.0213 | 12773.813 | - |
| COD (mg/l) | 5125 | 30.2 | 1058.34 | 2273.363 | 5168181 | 60 |
| $HCO_3^-$ (mg/l) | 7123 | 171.3 | 1593.04 | 3091.624 | 9558139.8 | - |
| $NO_3^-$ (mg/l) | 18.1 | 1.11 | 4.916 | 7.379826 | 54.46183 | 10 |
| $NO_2^-$ (mg/l) | 1.89 | 0.038 | 0.4182 | 0.822819 | 0.6770307 | - |
| $SO_4^{2-}$ (mg/l) | 10.41 | 0.4 | 2.586 | 4.377743 | 19.16463 | 250 |
| P (mg/l) | 7.14 | 0.451 | 1.9278 | 2.918146 | 8.5155767 | 2.0 |
| Cl (mg/l) | 12101 | 565.5 | 2984.86 | 5097.705 | 25986597 | 250 |
| Fe (mg/l) | 0.643 | 0.55 | 0.5988 | 0.033856 | 0.0011462 | - |
| Pb (mg/l) | 0.081 | 0.063 | 0.0724 | 0.007701 | 0.0000593 | 0.05 |
| Zn (mg/l) | 0.432 | 0.363 | 0.3956 | 0.026044 | 0.0006783 | 2 |
| As (mg/l) | 0 | 0 | 0 | 0 | 0 | - |
| Cu (mg/l) | 0.315 | 0.276 | 0.2992 | 0.016784 | 0.0002817 | 0.5 |
| Cd (mg/l) | 0.056 | 0.04 | 0.0464 | 0.005941 | 0.0000353 | 1.0 |
| Cr (mg/l) | 0.177 | 0.156 | 0.1678 | 0.008927 | $7.97\times10^{-5}$ | 1.0 |
| $NH_4N$ (mg/l) | 12.33 | 0.53 | 3.068 | 5.180798 | 26.84067 | 1.0 |
| Total Coliform Counts (CFU/ML) | 0 | 0 | 0 | 0 | 0 | 400 |

NESREA: National Environmental Standards and Regulations Enforcement Agency (2009)

## 4. CONCLUSIONS

In Benin City, Nigeria, the effluent quality stemming from a range of bakeries was investigated using physicochemical and microbiological methods. The results showed that, except for pH, TDS, COD, Cl, $NH_4N$, and Pb, all other parameters adhered to the NESREA allowable standards required for effluent discharge from the food industry. The average values recorded were 5.9, 4754.2 mg/l, 1058.34 mg/l, 3.068 mg/l, 2984.86 mg/l, and 0.0724 mg/l for pH, TDS, COD, $NH_4N$, $Cl^-$, and Pb, respectively. These findings indicate that the bakery wastewater does not meet NESREA regulations and that its ongoing release may harm ecosystems and public well-being. Nigerian regulatory agencies (NESREA) must adequately monitor the quality of Benin City's bakery wastewater in order to guarantee high-quality effluent discharge.

## Credit Authorship Contribution Statement

Animetu Rawlings: Conceptualization, Methodology, Writing – original draft, Writing – review & editing, Investigation (analyzing the results). Grandeur Omogbeimhe Ogbeji-Pat: Investigation (sampling and conducting experiments).

## Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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# تقييم جودة مياه الصرف الصحي المُصرّفة من بعض المخابز المختارة في مدينة بنين، نيجيريا

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قسم الهندسة المدنية، كلية الهندسة، جامعة بنين، مدينة بنين، ولاية إيدو، نيجيريا

الخلاصة

تتعرض موارد المياه العذبة المحدودة في نيجيريا للخطر بسبب تصريف مياه الصرف الصحي من الصناعات كثيفة الاستهلاك للمياه، مثل تصنيع الأغذية، والتي لا تتوافق مع لوائح الوكالة الوطنية للمعايير البيئية وإنفاذ اللوائح (NESREA). وقد يُلحق هذا ضررًا بالغًا بالنظام البيئي وصحة الإنسان. تهدف هذه الدراسة إلى تقييم الخصائص الفيزيائية والكيميائية والبيولوجية لمياه الصرف الصحي المُصرّفة من مخابز مختارة في مدينة بنين، نيجيريا، لتحديد مدى امتثالها لمعايير NESREA وتسليط الضوء على المخاطر البيئية المحتملة. جُمعت عينات مياه الصرف الصحي عشوائيًا من خمسة مخابز في مدينة بنين وفُحصت خصائصها الفيزيائية والكيميائية والبيولوجية. وأشارت النتائج إلى أنه باستثناء احتمالية تركيز الهيدروجين (pH)، والمواد الصلبة الذائبة الكلية (TDS)، والطلب الكيميائي للأكسجين (COD)، والكلوريد ($Cl^-$)، ونيتروجين الأمونيوم ($NH_4N$)، والرصاص (Pb)، فإن جميع المعايير الأخرى كانت ضمن الحدود المسموح بها من NESREA لتصريف مياه الصرف الصناعي من الصناعات الغذائية. كان متوسط قيمة الرقم الهيدروجيني (5.9) أقل من النطاق المسموح به، إلا أن متوسط قيم المواد الصلبة الذائبة (4754.2 ملغم/لتر)، وCOD (1058.34 ملغم/لتر)، وNH₄N (3.068 ملغم/لتر)، والكلوريد (2984.86 ملغم/لتر)، بالإضافة إلى الرصاص (0.0724 ملغم/لتر) تتجاوز بكثير معايير NESREA. تُظهر هذه النتائج عدم امتثال المخابز في منطقة البحث لقواعد NESREA، مما يؤكد على ضرورة قيام الجهات التنظيمية بمراقبة جودة مياه الصرف الصحي للمخابز لضمان تصريف عالي الجودة.

**الكلمات المفتاحية:** المخابز، الإرشادات، الآثار الصحية، الصناعات، مياه الصرف الصحي.