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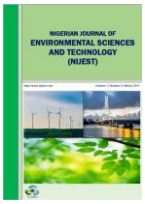

Occurrence and Health Risk of Heavy Metals and Microorganisms in Wastewater Collected from selected Eateries in Lekki, Lagos, Nigeria

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ABSTRACT

The number of eateries is growing around the world because they provide jobs and food to urban people who do not have time to cook. However, there are concerns that eatery wastewater may contain hazardous compounds and microorganisms. In view of the above, this study determined the chemical characteristics, heavy metal concentrations, and microbiological loads of wastewater collected from three eateries in Lekki, Lagos, Nigeria. The human exposure to heavy metals via oral and dermal contact, as well as the hazard quotient of daily exposure to these heavy metals, was also calculated. The chemical characterization revealed that nitrate, ammonia, and phosphate levels in all of the wastewater samples were above the limits of the Federal Environmental Protection Agency, while sulphate levels were normal. Copper, lead, cadmium, nickel, and chromium levels were within the permissible levels, but zinc was above the limits in the three eateries. The average daily oral and dermal exposure to heavy metals was normal, while the hazard quotient of daily dermal exposure to zinc and chromium in the three eateries was abnormal (> 1). In all of the eateries, bacterial and fungal levels were above permitted limits, but no coliforms were found. The results imply that the wastewater from the three eateries are hazardous and could pose environmental and health hazards. It is recommended that eatery owners treat wastewater before releasing it into the environment.

Keywords: Ammonia, Average daily Ingestions, Bacteria, Eateries, Lead, Wastewater

1.0. Introduction

Studies have linked increasing heavy metal exposure and microbial infection to the rising prevalence of diseases worldwide (Wu *et al*., 2019; Yahaya *et al*., 2020a). More than 200 diseases are caused by pathogenic bacteria and chemicals found in food alone, ranging from diarrhea to cancer (WHO, 2020). Biogeochemical cycles, soil fertility, decomposition of dead plants and animals, biodegradation of organic chemicals, and health promotion all require microorganisms (Felicita and Marija, 2017; Macro, 2020). At certain levels, however, some bacteria, fungi, protozoa, and viruses can cause diseases (Steffan *et al*., 2018). Heavy metal has no precise definition; however it is broadly described as any element having a high molecular weight and a density five times that of water (Yahaya *et al*., 2020b). The most common heavy metals are lead (Pb), cadmium (Cd), arsenic (As), mercury (Hg), manganese (Mn), nickel (Ni), zinc (Zn), chromium (Cr), cobalt (Co), copper (Cu), molybdenum (Mo), and antimony (Sb) (Bhargava *et al*., 2017). In small quantities, heavy metals perform biological functions in the body (Yahaya *et al*., 2019). However, at certain concentrations,

they can cause health problems such as respiratory, genetic, and hematological diseases, as well as damage to the skin, eyes, and brain (Yahaya *et al*., 2011; Yahaya *et al*, 2012).

Sources of heavy metals in the environment include soil erosion, weathering, agrochemicals, mining, and wastes (liquid, solid and gas) from homes and industries (Chen *et al.*, 2017; Du *et al.*, 2020). Microorganisms, on the other hand, may be found almost anywhere and are the most common type of life on the earth (Felicita and Marija, 2017). Almost every industry releases harmful chemicals or microorganisms into the environment. Eateries, in particular, release significant amounts of microorganisms and chemical-laden wastewater into the environment as a result of increased urbanization (Khedkar and Singh, 2018). Food scraps, oils, soaps, plastic packaging, and human wastes, among other things, are found in eatery wastes (Turek *et al*., 2019; Tyta, 2019). These wastes end up in water bodies, posing a threat to drinking and domestic water quality (Wang *et al*., 2020; Jingxi *et al*., 2020). It can also compromise the aquatic ecosystem by raising the water's organic loads, resulting in lower dissolved oxygen levels and nutrient overload (Okoh *et al*., 2007). This necessitates safety assessment of wastewaters from various eateries before they are dumped into the environment.

In Lagos, Nigeria, the number of eateries is rapidly expanding because they provide jobs and meals to urban residents who do not have time to cook. However, a review of the literature revealed that the safety of wastes generated by eateries in the city has not been assessed. The safety assessment of the wastes becomes necessary to ensure a sustainable environment in which eateries can expand without jeopardizing people's health or the environment. As a result, this study evaluated the chemical characteristics, heavy metal concentrations, and microbial loads of wastewater from selected eateries in Lekki, Lagos, Nigeria, as well as the health hazards they pose.

2.0. Methodology

2.1. Description of the study area

This study was conducted in Lekki area of Lagos, Nigeria (Figure 1). Lekki is located between the longitudes of 4° 00'E and 4° 15'E, as well as the latitudes of 6° 22'N and 6° 37'N (Opadokun *et al*., 2015). Lagos has a total area of 3577 km^2, including water bodies (Aniyikaye *et al*., 2019). On the north and east, Lagos is bordered by Ogun State, while on the south and west, it is bordered by the Atlantic Ocean and the Republic of Benin, respectively. Lagos is predominantly covered in tropical swamp forest, which includes both freshwater and mangrove swamp forests (Aniyikaye *et al*., 2019). The wet season, which begins in April and ends in October, and the dry season, which begins in November and ends in March, are the two major seasons in the state. The daily temperature averages between 26 °C and 30 °C. Lagos is estimated to have a population of around 17.5 million people (Aniyikaye *et al*., 2019). Lekki is one of Lagos' most densely populated areas, populated largely by the wealthy and home to a number of eateries.

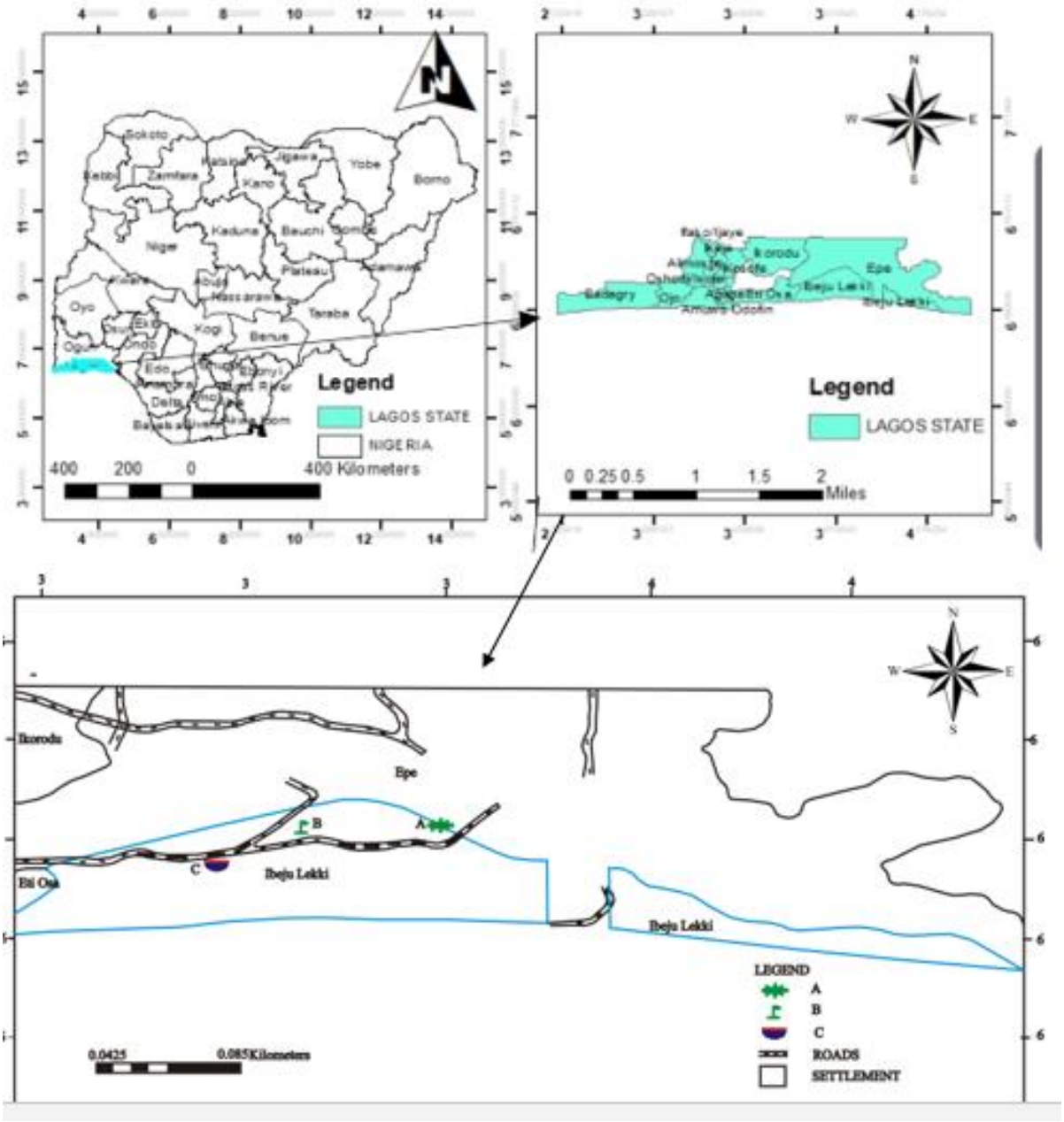

Figure 1: Map of Lagos showing the study areas

2.2. Sample collection

Between February and April 2021, wastewater samples were collected every other week in pre-sterilized, clean, and dry polyethylene bottles from three eateries in Lekki, Lagos. The bottles were sealed tightly and transported to the laboratory, where they were refrigerated at about 4 $^{\circ}$C.

2.3. Quality control

Analytical reagent grade chemicals were employed throughout. All preparations and dilutions were done with distilled water. For digestion, HNO_3 (69%) and HCl (98%) were used. Stock standard solutions of 1000 ppm were prepared for the selected heavy metals: chromium (Cr), cadmium (Cd), zinc (Zn), nickel (Ni), lead (Pb), and copper (Cu).

2.4. Chemical characterization and heavy metal analysis

One hundred millilitres (100 ml) of each sample was transferred into a digesting tube. Twelve millilitres (12 ml) of a combined mixture of HNO_3 and HCl in a ratio of 1:3 were added to the sample and heated on a hot plate inside a fume cupboard. The temperature was gradually raised, beginning at 50 $^{\circ}$C and rising to 300 $^{\circ}$C. The digestion was completed in about 41 minutes, as indicated by the

appearance of white fumes. The mixture was allowed to cool before being filtered into a 50-ml volumetric flask and filled with distilled water to the 50-ml mark. The filtrate was poured into a plastic bottle and labelled appropriately, after which a UNICAM atomic absorption spectrophotometer, model 969, was used to estimate the levels of the selected heavy metals.

The same spectrophotometer was used to determine the levels of phosphate, ammonia, sulphate, and nitrate in the samples, following the guidelines of Okezie *et al*. (2020).

2.5. Microbial analysis

The microbial load of each sample was determined as described by Palamuleni and Akoth (2015). Total bacteria was determined by plating out and filtering 0.1 ml of the original water sample on nutrient agar plates and incubating it aerobically at 37 °C for 24 hours. At the end of incubation, the colonies that developed were counted using a colony counter. The coliform colonies were estimated by pouring the sample on Mac Conkey agar plates and incubating it at 37 °C for 24 hours. Fungi colonies were estimated the same way as the total bacteria, but the nutrient was supplemented with an antibiotic to prevent bacterial growth.

2.6. Health risk evaluation

The health risks of the wastewater were evaluated from the average oral exposure (*AOE*) and average dermal exposure (*ADE*) to the heavy metals in the samples using equations 1 and 2 (USEPA, 2004). The hazard quotient (*HQ*) of the heavy metals via oral and dermal exposure was also estimated using equation 3 (USEPA, 2003).

$$AOE = \frac{COH \times Ir \times Ef \times Ed}{ABW \times At} \quad (1)$$

According to Yahaya *et al*. (2020a), the full meaning and standard values of the variables in equation 1 are as follows: *AOE* represents the average oral exposure per kilogram of body weight; *COH* indicates the concentration of heavy metals in water (mg/L); *Ir* shows the ingestion rate per unit time (L/day) = 2; *Ef* is the exposure frequency (days/year) = 365; *Ed* denotes the exposure duration (years) = 55 (Nigerians' life expectancy); *ABW* is the average body weight (kg) = 65; *At* is the average time (*Ed* x *Ef*) = 20075.

$$ADE = \frac{COH \times \mathrm{SSA} \times DPC \times Et \times Ef \times Ed}{ABW \times At} \quad (2)$$

From Equation 2, *ADE* is the average dermal exposure; *SSA* is the skin surface area (cm^3) = 28,000; *DPC* represents the dermal permeability constant (cm/h) of heavy metals: Pb = 0.004, Ni = 0.0002, Cd = 0.001, Cr = 0.002, Zn = 0.006, and Cu = 0.001. All of the other variables are as shown in Equation 1.

$$HQ = \frac{Exposure\ (AOE\ or\ ADE)}{RFD} \quad (3)$$

In Equation 3, *HQ* represents the hazard quotient via oral or dermal contact (no units) and *RFD* denotes the oral/dermal reference dose (mg/L/day). According to Yahaya *et al*. (2020a), *RFD* (oral and dermal) for Pb = 1.4, 0.42; Ni = 20, 5.40; Cd = 0.5, 0.005; Cr = 3.0, 0.015; Zn = 0.3, 0.3; Cu = 40, 12.

2.7. Data analysis

Data were compiled as mean ± standard deviation (SD) using the Excel software.

3.0. Results and Discussion

3.1. Chemical characteristics of the wastewater

Table 1 shows the levels of the chemical characteristics of the wastewater samples collected from three eateries in Lekki, labeled Eatery A, B, and C. Sulphate was within the permissible limits of the Federal Environmental Protection Agency (FEPA) in all the eateries. However, nitrates, ammonia, and phosphate were above the limits. This result suggests that the wastewater may induce health and environmental hazards. Methemoglobinemia, birth abnormalities, malignancies, and thyroid disorders can all be caused by high levels of nitrate in drinking water or food (Ward *et al*., 2018; Yu *et al*., 2020). High ammonia exposure can cause burns to the eyes, nose, throat, and respiratory tract, as well as blindness and lupus (ATSDR, 2004). Phosphate overload can cause digestive problems (Kumar and Puri, 2012). Generally, phosphate, nitrate, and ammonia anions are acidic and, when absorbed in large amounts, they can cause an acid-base imbalance, resulting in more acidic conditions and acidiosis (Isiuku and Enyoh, 2020). Aquatic plant overgrowth can develop from high nitrate, ammonia, and phosphate ion concentrations in water bodies, resulting in algal blooms (Isiuku and Enyoh, 2020). This causes rapid dissolved oxygen depletion in the water, resulting in suffocation and the death of aquatic plants and animals. Decomposition of dead plants and animals degrades water quality. The results obtained under the current study are consistent with those of Ezigbo and Ezigbo (2020) and Gurd *et al*. (2020), who detected some chemical characteristics of water beyond recommended levels in fast-food wastewater.

Table 1: Chemical characteristics of wastewater obtained from selected eateries in Lekki, Lagos

Characteristics	Eatery A	Eatery B	Eatery C	Limit (FEPA, 1991)
Nitrate	21.287±2.32	22.86±1.45	24.32±2.61	≤20
Ammonia	16.337±1.21	17.98±2.31	17.64±2.02	≤15
Sulphate	5.847±0.006	4.823±0.21	4.980±0.010	≤500
Phosphate	14.870±0.010	20.673±0.015	14.970±0.010	≤5.0

Values were expressed as Mean ± SD and mg/l; FEPA = Federal Environmental Protection Agency

3.2. Levels of heavy metals in the wastewater and health risk

The levels of Cu, Pb, Ni, Cd, Cr, and Zn in the wastewater collected from the three eateries are revealed in Table 2. With the exception of Zn, the heavy metals were within the permissible limits of the FEPA in all the eateries. This result shows that the wastewater can induce Zn toxicity. Long-term, high-dose Zn may disrupt Cu uptake, predisposing to diseases associated with Cu deficiency (Plum *et al*., 2010). The result of the current study is in line with that of Ezigbo and Ezigbo (2020), who found abnormal levels of some heavy metals in wastewater from restaurants. Unfortunately, literature searches did not find more studies with the same objectives as the current study to which the current results can be compared.

Table 2: Levels of heavy metals in wastewater obtained from selected eateries in Lekki, Lagos

Heavy metal	Eatery A	Eatery B	Eatery C	Limits (FEPA, 1991)
Cd	BDL	BDL	BDL	<1
Pb	0.022±0.002	0.020±0.001	0.080±0.002	<1
Ni	BDL	BDL	BDL	<1
Cr	0.017±0.002	0.025±0.003	0.023±0.0005	<1
Zn	2.746±0.002	1.965±0.001	1.444±0.003	<1
Cu	0.326±0.007	0.373±0.002	0.285±0.0005	<1

Values were expressed as Mean ± SD and (mg/l); BDL= Below Detectable Limits; FEPA = Federal Environmental Protection Agency

Further analysis showed that the *AOE* and *ADE* to heavy metals in the wastewater were normal (Table 3). However, Table 4 shows that the *HQ* of Cr and Zn via dermal exposure to wastewater from the three eateries was abnormal (> 1). This again shows that residents are at an increased risk of Zn and Cr toxicities. When skin is exposed to high concentrations of Zn, it develops lesions and slows wound healing, while Cr can induce dermatitis, skin cancer, or allergy (Plum *et al*., 2010; Jumina and Harizal, 2019).

Table 3: Average daily oral and dermal exposure to heavy metals in wastewater obtained from selected eateries in Lekki, Lagos

Heavy metal	Eatery A		Eatery B		Eatery C		Recommended
	Ingestion	Dermal	Ingestion	Dermal	Ingestion	Dermal	(WHO, 2017)
Cd	-	-	-	-	-	-	0.06
Pb	0.001	0.038	0.001	0.009	0.0002	0.014	0.21
Ni	-	-	-	-	-	-	0.50
Cr	0.001	0.015	0.001	0.022	0.001	0.019	0.20
Zn	0.084	7.097	0.060	5.079	0.044	3.732	8.0
Cu	0.010	0.140	0.011	0.161	0.009	0.123	0.90

Values were expressed in mg/day; RDI = recommended daily intake

Table 4: Hazard quotient of heavy metals in the wastewater obtained from selected eateries in Lekki, Lagos

Heavy metal	Eatery A		Eatery B		Eatery C	
	Ingestion	Dermal	Ingestion	Dermal	Ingestion	Dermal
Cd	0.00	0.08	-	-	-	-
Pb	0.00	0.09	0.00	0.00	0.00	0.03
Ni	-	-	-	-	-	-
Cr	0.00	1.00	0.00	1.47	0.00	1.27
Zn	0.28	23.66	0.20	16.93	0.15	12.44
Cu	0.00	0.01	0.00	0.01	0.01	0.01

3.3. Levels of microorganisms in the wastewater

Table 5 reveals the levels of bacteria, coliform, and fungi in the wastewater samples. The total bacteria and fungi were detected above the FEPA permissible limits in all the eateries, while coliform was not detected. These microorganisms may contaminate food and public water supplies, causing waterborne diseases such as diarrhea, typhoid, cholera, giardia, salmonella, and hepatitis A, among others. The high microbial content of the wastewater might have been induced by its high nutrient content, particularly nitrate, ammonia, and phosphate. Wastewaters from eateries contain high organic matter and will require a high microbial load to boost degradation of solid wastes. The result of the current study is consistent with that of Ogidi and Oyetayo (2012), who isolated heavy microorganisms from restaurant wastewaters in Akure, Ondo State, Nigeria. The result is also in line with that of Usman *et al*. (2019), who detected high microbial species in some selected fast-food establishments in Kaduna, Nigeria.

Table 5: Levels of microorganisms in wastewater obtained from selected eateries in Lekki, Lagos

Microorganism	Eatery A	Eatery B	Eatery C	Limit (FEPA, 1991)
Total bacteria	1000±50.0	800±100.0	600±50.0	≤100
Total coliform	ND	ND	ND	<2.2
Total fungi	1000±200	1000≤100.0	1000±100.0	0

Values were expressed as Mean ± SD and CFU/ml; ND= Not Detected; FEPA = Federal Environmental Protection Agency

4.0. Conclusions

The results showed that wastewater obtained from three eateries in Lekki, Lagos, contained non-permissible levels of some water parameters. The affected water parameters include nitrate, phosphate, ammonia, and zinc, as well as bacteria and fungi. The average daily oral and dermal exposure to the heavy metals was normal in all the eateries, but not so for the hazard quotient of daily dermal exposure to zinc and chromium. Overall, the results showed that the wastewater could pose health and environmental hazards if discharged into the environment untreated.

The following are suggested based on the results of the study:

- Owners of eateries should be compelled to treat wastewater before it is discharged into the drains.
- Residents should consider treating groundwater before consuming it if they are located close to an eatery's drains
- The surroundings of eateries should be kept clean and hygienic.

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