THE EFFECTS OF HOTELS EFFLUENT DISCHARGE ON GROUND WATER QUALITY IN LOKOJA, KOGI STATE, NIGERIA

ABSTRACT

*Despite the significant contribution of hospitality industry to the people, economy and beautification of the landscape, hotels generate large volume of effluent from their ancillary activities such as kitchen, room cleaning, toilet, laundry, etc., this effluent has the potential to seep into the underlying aquifer, thereby contaminating the groundwater. This research explores the effects of hotels effluent discharge on groundwater quality in Lokoja, Kogi State, Nigeria. The study has four (4) research objectives to; identify the contaminants present in Hotels' effluent discharge; investigate the levels of physicochemical parameters in the hotels effluent, hotels borehole and borehole within 500m radius of the hotels; determine if the concentrations in groundwater quality parameters are within the safety limits recommended by World Health Organization (WHO), and National Environmental Standards and Regulations Enforcement Agency (NESREA), and, to determine the effective management strategies to minimize the discharge of hotel effluent and protect groundwater resources. Samples of hotels' effluents, water samples from the hotels' borehole, the nearest borehole within 500m radius were taken for laboratory testing. The statistical tool used for the analysis of the laboratory result was the Student T – Test while the 4-point Likert Scale was used for the questionnaires analysis. The result shows the presence of contaminants at varying degrees. Contaminants like DO (8.63mg/l), COD (10.78mg/l), BOD (4.36mg/l), TDS (0.25mg/l), TSS (0.13mg/l), Alkalinity (59.5mg/l), Hardness (30.65mg/l), EC (2.25mg/l), iron (30.1mg/l), sulphide, phosphates, and, nitrate, were present in the hotels effluent. Contaminants are also present in the hotel boreholes and boreholes within 500m radius, they however, fell within acceptable levels. However, the pH of the water samples (*3.40mg/l*), significantly lower than the safe drinking water standard (6.5 – 8.5mg/l) as prescribed by the World Health Organization (WHO) and the National Environmental Standards and Regulations Enforcement Agency (NESREA). The study suggests the investigation and the source of acidity; improve hotel effluent treatment; promote water conservation and reuse; community awareness and education programs; and, strengthen collaboration and monitoring.*

Keyword: Effluent, Groundwater, Water Contamination, Environmental Impact, Hospitality Industry, Hotels, Public Health, Regulations

1.0 INTRODUCTION

The hospitality industry, with its rapid expansion and increasing demand for water-intensive services, has inadvertently become a significant contributor to environmental degradation. One critical aspect of concern is the discharge of effluent from hotels, which often contain a myriad of contaminants that can adversely impact the quality of groundwater. Groundwater, being a vital source of drinking water for many communities, plays a crucial role in sustaining life and ecosystem health. Hotels generate substantial volumes of effluent through various activities such as laundry, kitchen operations, and cleaning processes (Jones, 2018). The effluent, if not properly treated, may contain contaminants such as nutrients, heavy metals, and organic compounds, all of which have the potential to seep into the underlying groundwater aquifers (Smith, C., et al, 2020). Groundwater contamination poses a direct threat to public health as it can result in the consumption of contaminated water, leading to various waterborne diseases and long-term health issues (Environmental Protection Agency (EPA), 2019).

The introduction of contaminants into water bodies (surface and underground) can disturb the natural balance of aquatic flora and fauna, affecting biodiversity and ecosystem services (Hassan, R., et al, 2021). This not only jeopardizes the health of groundwater-dependent ecosystems but also disrupts the delicate equilibrium within the broader environmental landscape. Thus, understanding the intricate interplay between hotels effluent discharge and groundwater quality is essential for devising effective environmental management strategies and ensuring the sustainability of water resources in the face of escalating urbanization and tourism growth.

The effects of hotels' effluent discharge have been documented globally, with studies showing the significant environmental and public health implications associated with untreated or inadequately treated effluent from hospitality establishments (United Nation World Tourism Organization & United Nations Environmental Programme, 2020). At the global level, research indicates that hotels' effluent can contribute to water contamination, affecting both surface water bodies and groundwater resources. A study by Song et al. (2017) investigated the impact of hotels' effluent on water quality in coastal areas of China, revealing elevated levels of contaminants such as nutrients (phosphate, sodium), heavy metals (lead, copper), and organic compounds in receiving waters(Song, S., et al, 2017). Similarly, a global assessment by United Nations Environment Programme (United Nations Environmental Programme, 2018) identified hotels as potential sources of water contamination, emphasizing the need for sustainable effluent management practices to mitigate environmental risks (United Nations Environmental Programme, 2016). The World Travel & Tourism Council (2021) estimates that, hotels globally account for 4% of total water withdrawal (surface and ground), putting stress on already strained resources in water-scarce regions. Over extraction can deplete groundwater reserves and exacerbate challenges for local communities (World Travel & Tourism Council, 2021). According to Intergovernmental Panel on Climate Change (IPCC) (2022), rising temperatures and extreme weather events can alter groundwater recharge patterns and increase contaminant mobilization, potentially magnifying the negative effects of hotel effluent (International Panel on Climate Change (IPCC), 2022).

At the international level, many countries have implemented regulations and initiatives to address the environmental effects of hotels' effluent discharge. In India, for example, the Ministry of Environment, Forest, and Climate Change (MoEFCC) has developed guidelines for effluent management in hotels and resorts, mandating the installation of effluent treatment plants (ETPs) to ensure compliance with water quality standards (Ministry of Enviornment. Forest and Climate Change (MoEFCC) India, 2019). Recent studies from regional-level also bring to the fore the specific environmental and health risks associated with hotels' effluent discharge. A study conducted in Kenya by Wambua et al. (2020) investigated the physicochemical and microbiological characteristics of effluent from hotels, revealing high levels of contaminants such as grease, oil, phosphate, Biochemical Oxygen Demand (BOD), Total Suspended Solids (TSS), and Fecal Coliforms. Similarly, at the national level, the Nigeria's National Environmental Standards and Regulations Enforcement Agency (NESREA) regulates effluent discharge from hotels and other industries, with a focus on protecting water resources and public health (National Environmental Standards & Regulations Enforcement Agency (NESREA). Nigeria, 2018). This study stresses the potential for hotels' effluent to contaminate water bodies and pose health risks to nearby communities reliant on surface water sources for drinking and domestic use.

Groundwater serves as a vital source of drinking water for many communities, towns and cities worldwide, including Lokoja, the Kogi State Capital City, Nigeria. The discharge of hotels effluent into the environment has raised concerns among the public, academics and policymakers regarding the potential effects on groundwater quality (Ojoawo, et al, 2017). Contamination of the groundwater could have severe consequences such as water borne diseases for human health and well-being (Akani, A. O., Asamoah, R. K., & Sule, I. O., 2017). It is therefore on this ground that this study intends to investigate the effects of hotels effluent discharge on Lokoja groundwater.

Lokoja is an expanding city both in human population and accommodations (residential and hotels) and as a model city, the commercial activities too have increased over time, hence the demand for hospitality industry services have continued to increase. There has been phenomenal growth in the number of hotels in Lokoja, ranging from small guest inn to five star hotels. The increasing discharges of effluent from hotels in Lokoja have significant effects on the groundwater quality. This arises from the potential presence of contaminants such as nutrients, heavy metals, and organic compounds in the effluent, which can infiltrate and contaminate the underlying aquifers. Understanding the nature and extent of this contamination is essential for implementing effective environmental management strategies (Eaton, A. D., et al. 2015).

The increased number of hotels has inadvertently contributed to the overall effluent generation. In order to meet the growing demands of temporary accommodations and leisure seekers, both government and individuals built several hotels. These hotels generate substantial amount of effluents from the kitchen, laundry, and, cleaning services which in most cases are not treated before discharge into the septic tank posing a great chance of percolation into the underlying aquiver. Adeyemi, et al. (2017) studied groundwater quality levels and human exposure in Southwest Nigeria. The study identified the main cause-effect relationship between human activities and the state of groundwater quality using a communication tool (the DPSIR Model; Drivers, Pressures, State, Impact and Response) (Adeyemi, et al. 2017).

This study points two key issues, first, there's a gap in research specifically examining the effects of hotels effluent on Lokoja's groundwater quality. While broader studies on similar topics might exist, a detailed study focusing on Lokoja's unique characteristics seems to be missing (Jones, P. 2018). Secondly, the study suggests that current regulations might be insufficient for monitoring and controlling hotel effluent discharge. Weak regulations or poor enforcement could allow for uncontrolled release of contaminants, emphasizing the need for stronger environmental policies and governance (UNEP. 2015).

Lokoja as an ancient city, the first administrative capital of the old Northern and Southern Protectorate and recently, the Kogi State Capital has grown and developed immensely, contributing to the establishment of many hotels in the city. Lokoja houses many tertiary institutions ranging from Federal University Lokoja (FUL), Salem University (SU), The Kogi State Polytechnic (KSP), Federal Medical Center (FMC), Kogi State Specialist Hospitals (KSSH) and many more institutions; these institutions attracts large amount of people into the city. These people usually seek a temporary accommodation in hotels and lodging facilities thereby contributing to the overall water consumption of the city and consequently effluent generation within these hotels. Additionally, Kogi State being the gateway to about ten (10) states in Nigeria records high level of commutation within the state. Lokoja has a large fish market and other agricultural produce are transported to Lokoja for sale, this has increased commercial activities of the city. Politically, Kogi State campaign rallies flag-off and grand finale are mostly held in Lokoja, politicians secure hotels reservations for their guests and this has significantly increased hotel patronage in the city. Interestingly, Lokoja as an urban center boast of numerous hotels and lodging facilities. Despite the various studies done, none worked on the effects of hotels effluent discharge on Lokoja groundwater quality. Thus; the study intends to add to knowledge.

Despite several studies conducted on hotels effluent discharge, they exist absence of studies on Lokoja hotels effluent discharge, and, it is against this backdrop that this research intends to investigate the effects of Hotel’s effluent discharge on Lokoja groundwater quality and (1) Identify the contaminants present in Hotel’s effluent discharge in the study area. (2) Investigate the levels of physicochemical parameters in the hotels effluent, hotel boreholes and boreholes within 500m radius of the hotels. (3) Determine if the concentrations in groundwater quality parameters are within the safety limits recommended by World Health Organization (WHO), and National Environmental Standards and Regulations Enforcement Agency (NESREA) in the study area. (4) Determine the effective management strategies to minimize the discharge of hotel effluent and protect groundwater resources. The identified issues, groundwater contamination, inadequate regulatory measures, emphasize the importance of this research for informed decision-making, sustainable water resource management, and the overall well-being of the local community.

2.0 MATERIALS AND METHODS

2.1 The Study Area

Lokoja is the Kogi State Capital and is situated between latitude 70^{o} 80’ 23’’N and 70^{o} 90’ 75’’N and longitude 60^{o} 57’ 83’’E and 60^{o} 79’ 33’’E at an altitude of 53m (173ft) (Maha, Ehisienmhen, Ezelobe, Olaoluwa, et al, 2023). Lokoja is strategically positioned (central) in Nigeria; it is bordered on the North by the FCT at a distance of 165km, West by Koto – Karfi and Bassa, south by Adavi and East by Kabba/Bunu LGA. The City experiences a tropical wet and dry savanna climate, classified as AW according to the Köppen Climate Classification (Wikipedia, 2014). The wet season spans approximately seven months, from late April to October, and a dry season that covers the remaining five months (Ajayi, T. R., 2013).

Lokoja’s humidity levels can be relatively high throughout the year due to its proximity to water bodies, particularly the Niger and Benue rivers with average daily temperatures ranging from 25°C to 35°C. However, temperatures can occasionally exceed 40°C during the dry season, especially in March and

April (Ojo, O. J., 2017). Despite the seasonal variation in rainfall, Lokoja is susceptible to occasional flooding, particularly during the peak of the rainy season when heavy downpours can overwhelm drainage systems and inundate low-lying areas (Ojo, O. J., 2017). Lokoja is primarily influenced by River Niger and Benue, the drainage pattern of Lokoja is dendritic, with tributaries flowing into the Niger and Benue rivers from surrounding upland areas. These tributaries contribute to the overall drainage of the city and play a crucial role in regulating water flow and managing flood risk. Mostly gneiss, migmatite and amphibolite with older granite intrusives, Lokoja is located on a transition zone between the Precambrian Basement Complex and the sedimentary basins of northern Nigeria. The city's geology is characterized by a mixture of crystalline rocks, such as granite and schist, in the upland areas, and sedimentary deposits, including sandstone and shale, in the low-lying areas (Okeke, F. N. 2012).

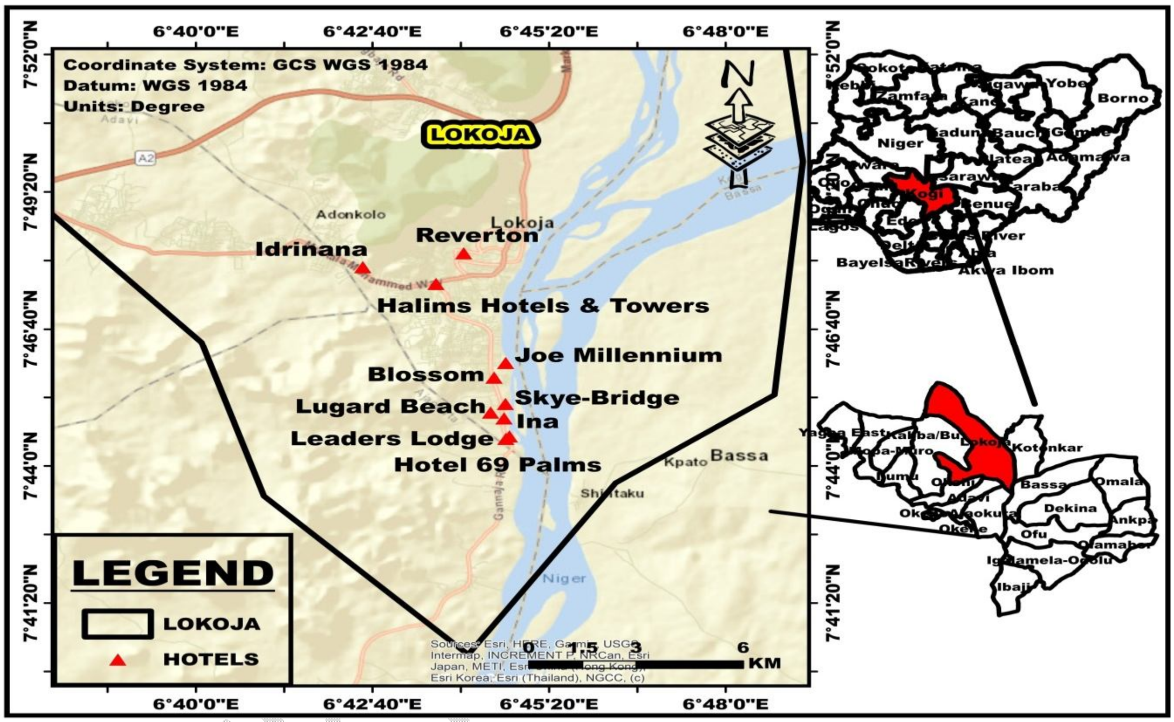

Fig .1: Nigeria showing Kogi State, Kogi State showing Lokoja LGA and Lokoja LGA showing Lokoja the study areas

Source: Department of Geography & Environmental Studies, PAAU

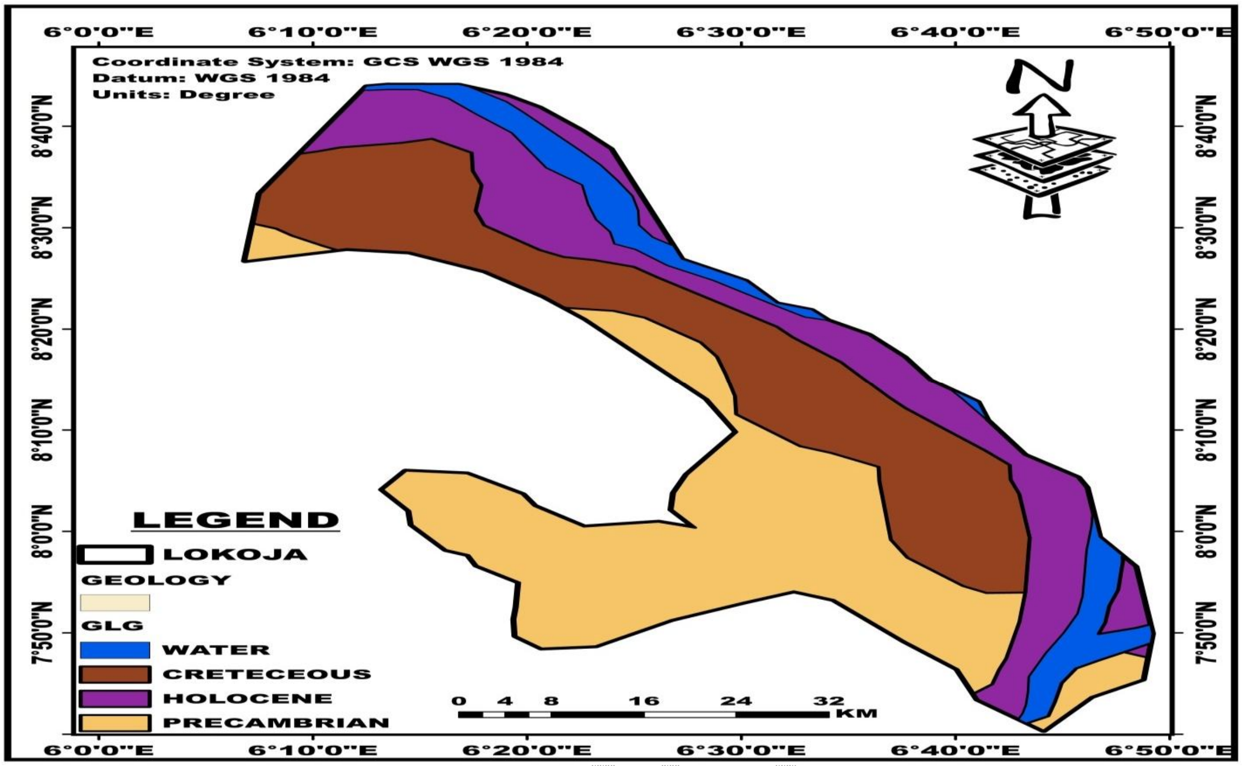

Fig 2: Lokoja's geology
Source: Department of Geography & Environmental Studies, PAAU

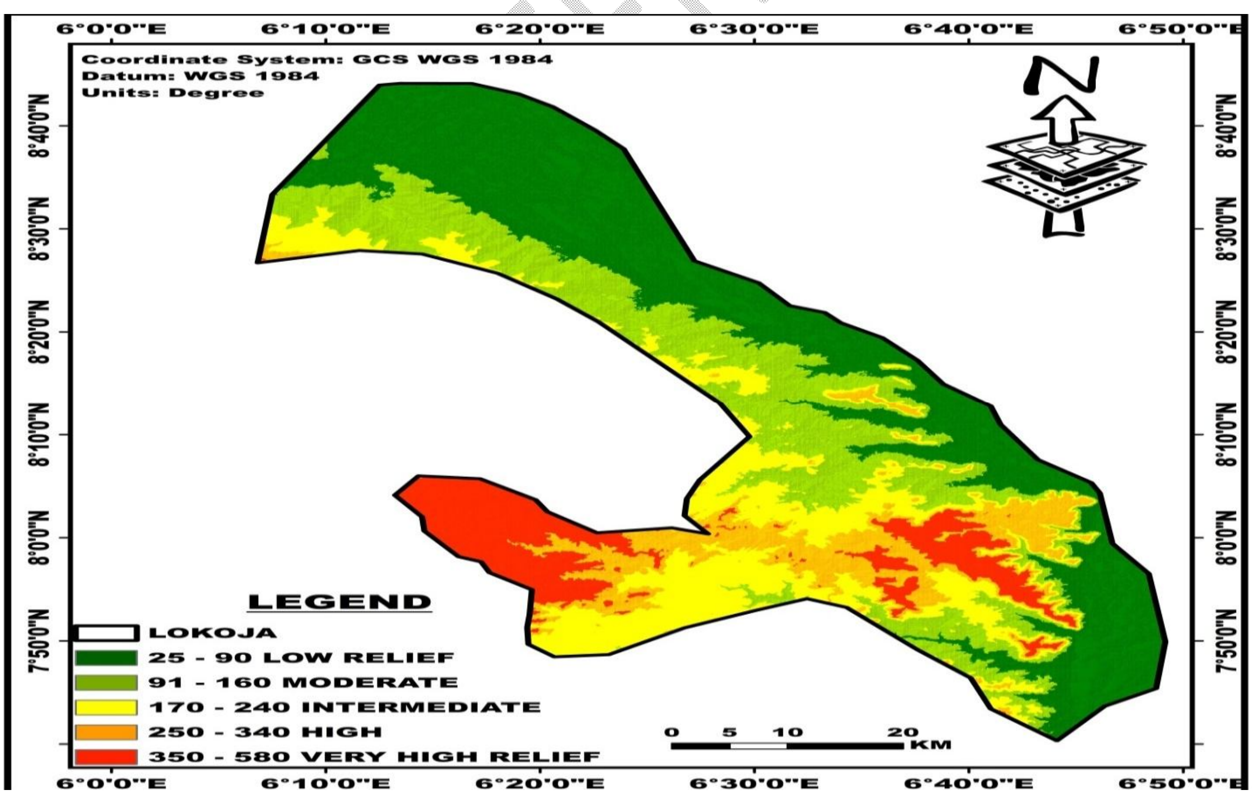

Fig 3: Lokoja's relief
Source: Department of Geography & Environmental Studies, PAAU

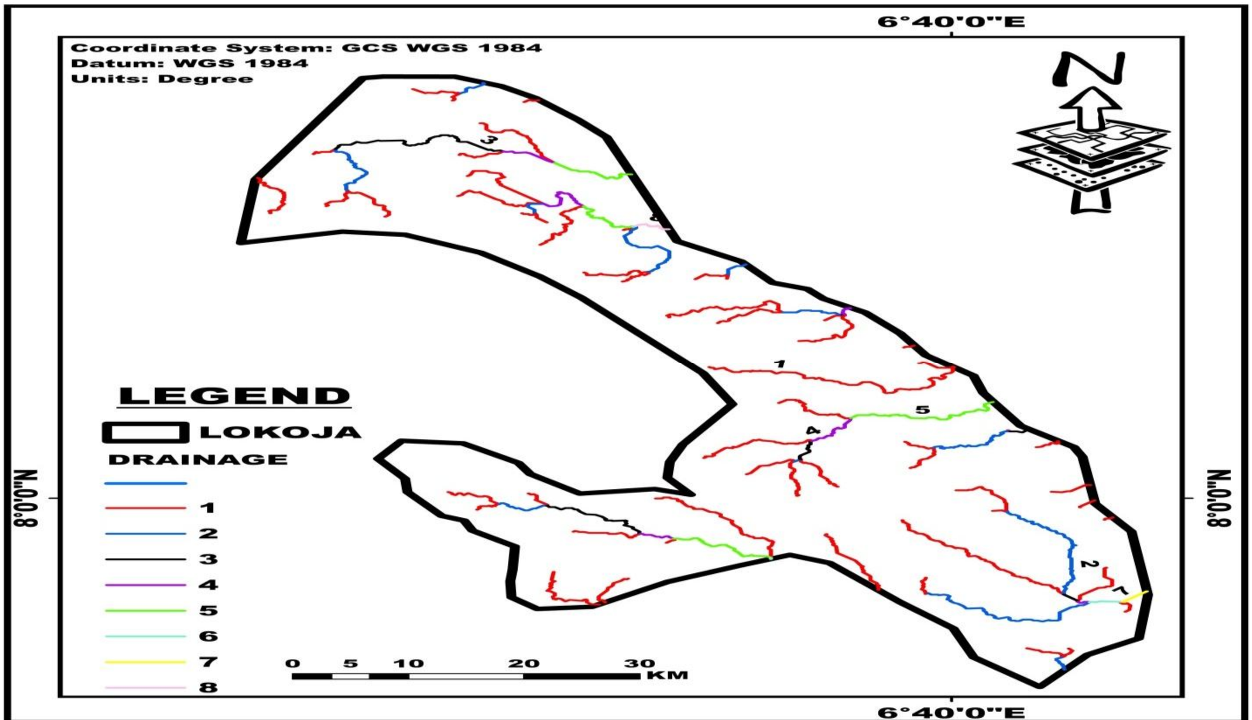

Fig 4: Lokoja showing Lokoja's drainage
Source: Department of Geography & Environmental Studies, PAAU

Lokoja's location has contributed to its rapid growth in socio-economic status, the city has an estimated population of 195,261 persons in 2006 (National Population Commission (NPC), 2022). Using The Mehta (2004) population projection method and projected to 2024 at the national growth rate of 2.63%, Lokoja current population stands at an estimated 319,763 persons. Lokoja has diverse soil types influenced by its geological formations and climatic conditions. The predominant soil types in the region include Ferralic Luvisols, Acrisols, and Fluvisols (Adesiyan, S. O., 2018). Ferralic Luvisols are characterized by their reddish-brown color and high fertility, making them suitable for agricultural activities. Agricultural activities in the area are primarily focused on the cultivation of crops such as rice, yam, cassava, and maize, which are well-suited to the local soil and climatic conditions Adesiyan, S. O. (2018). According to Adesina (2015), Lokoja falls within the Guinea Savanna ecological zone, characterized by a mix of grassland, woodland, and forest vegetation types. The natural vegetation of Lokoja includes species such as tall grasses, shrubs, and scattered trees adapted to the region's tropical climate and seasonal rainfall patterns. Grasslands dominate the landscape, supporting grazing activities and providing habitat for wildlife species such as antelopes, monkeys, and birds. Woodland areas are characterized by a mix of savanna trees, including Acacia (wattles), Terminalia (yellowwood), and Vitellaria (Shea tree) of the mearnsii, paradoxa and almond species, interspersed with grasses and shrubs. Forest patches are found along riverbanks and in protected areas, harboring diverse plant species and serving as important habitats for biodiversity conservation (Adesina, F. A., et al. 2015).

According to Ifatimenhin, Essoka & Ahmed (2012), the land use classes in lokoja consist of the built up areas, light vegetation, vacant land and rock outcrops. These classes increase at the expense of cultivated land and thick vegetation. There was a reduction of about 6.96% in cultivated land from 36.25% in 1987 to 29.29 in 2001. This is because, over the years, there is a steady decline in agricultural practice. This has resulted to the light vegetation in the area (Ifatimenhin O.O., Essoka, P.A. & Ahmed, A. 2012).

Socio-economically, Lokoja serves as an economic nerve center of some sorts, facilitating various social, economic, political, and cultural activities. The town is a commercial hub, attracting commercial immigrants from different parts of Nigeria thereby increasing the need for hospitality services. Agricultural activities in the area involve the cultivation of crops like rice, beans, maize, and yam. Additionally, Lokoja has three major markets: New Market (International Market), Old Market, and, Kpata Market. Kpata and New Market have their market day every five days. The essential products sold in these markets are grains, vegetable, fish, and general household items. The location of the state capital in Lokoja, Kogi State Polytechnic, Federal University, Salem University, Kogi State Specialist Hospital, and, Federal Medical Centre has further stimulated the growth of hotels, restaurants, commercial banks, and residential developments in the city. Lokoja primarily serves administrative, agricultural, educational, commercial, residential, religious, and recreational purposes.

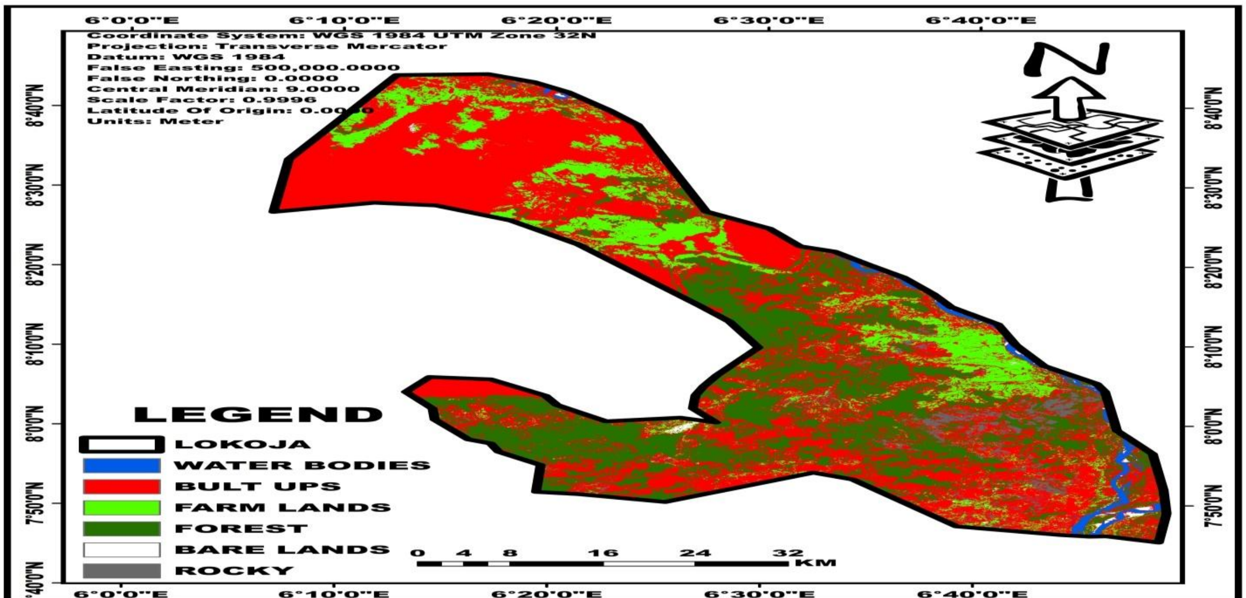

Fig 5: Lokoja Land use, Land cover
Source: Department of Geography & Environmental Studies, PAAU

2.2.1 Materials

The primary data was gotten from the laboratory analysis (using the WHO standard) of the samples collected. The secondary data sources are the textbooks, journals, magazines, newspapers, pamphlet, other academic research works (both published and unpublished), government agencies like the National Environmental Standards and Regulations Enforcement Agency (NESREA), Nigeria Standard for Drinking Water Quality (NSDWQ), and World Health Organization (WHO) etc. The data required for this research are the physicochemical parameters of the effluent and water samples collected and they are; (i) Electrical Conductivity (EC), (ii) Total Dissolved Solids (TDS), (iii) Dissolved Oxygen (DO), (iv) Biological Oxygen Demand (BOD), (v) Chemical Oxygen Demand (COD), (vi) pH, (vii) Hardness, (viii) Nutrients (phosphate, Nitrate), and, (ix) Heavy Metals (iron, lead, copper)

2.2.2 Methods

In this research, the design employed was the experimental (laboratory analysis of the samples collected) and survey. To achieve the study objectives, a reconnaissance survey was carried out to properly the researcher with the study area before the commencement of the main research. The sources of data for this study are primary and secondary data sources. Purposive sampling technique was employed to select a total of four (4) hotels. Air – tight plastic containers were used to collect samples from the sampled hotels, the hotel's boreholes and the nearest borehole within 500m radius. The sampled hotels are three star hotels; either located in the city center, in densely populated areas and records one of the highest patronages in the city. The hotels are Reverton Hotel (Hotel A), Idrinana Hotel (Hotel B), Hotel 69 Palms (Hotel C) and Halims Hotels and Towers (Hotel D). A total of two samples each were collected from each of the hotels, representing one sample of the effluent discharge and another sample of the hotel's borehole water at the outlet (i.e. point of consumption) using an air-tight plastic bottle already deionized with distilled water. Water sample of the nearest borehole to each of the hotels within the 500m radius were collected in order to determine if there exists a transportation or existence of the constituents of the effluent from the source to the surrounding groundwater. All the samples collected were taken to the department of Chemistry, Prince Abubakar Audu University for the laboratory testing and analysis. For objective (iv), using the Krejcie & Morgan (1970) method, a total of three hundred and eighty five (385) questionnaires were administered, but, only a total of two hundred and sixty – three (263) questionnaires were duly filled and returned representing 68.3% of the total questionnaires administered (Krejcie, R.V., & Morgan, D.W. 1970).

The physicochemical parameters that were investigated in this research includes pH, alkalinity, chemical oxygen demand, dissolved oxygen, biological oxygen demand, total suspended solid, total dissolved solid, electrical conductivity, total hardness and nutrients (sulphate, phosphate, nitrate, lead, iron, and copper).
The various samples that were collected for this research were subjected to the laboratory testing for the different parameters intended to discover new or validate an already established facts using the American Public Health Association (APHA) and American Water Workers Association (AWWA) methods.

3.0 RESULTS AND DISCUSSION

3.0.1 Results

Table .1: Laboratory Results (raw data) of Physiochemical Parameters of samples tested

Parameters	A1	A2	A3	A4	B1	B2	B3	B4	C1	C2	C3	C4	Permissible Limits (Mg/L) WHO	Permissible Limits (Mg/L) NESREA
pH	6.40	5.90	5.8	6.2	3.4	3.65	3.5	4.00	5.40	5.60	6.2	4.90	6.5 – 8.5	6.5-8.5
Total dissolved solids (mg/L)	0.35	0.20	0.22	0.24	0.1	0.18	0.12	0.14	0.22	0.14	0.14	0.13	500 – 1000	500
Total suspended solid (mg/L)	0.2	0.15	0.05	0.10	0.08	0.10	0.10	0.1	0.18	0.10	0.12	0.10	30 – 50	30
Chloride	0.80	0.91	2.10	2.10	2.59	2.62	1.86	2.42	2.59	2.48	2.61	2.26	250 – 500	250
Nitrate	2.30	2.22	2.62	2.32	3.00	3.24	3.34	3.43	2.82	2.75	3.10	3.05	10 – 50	10
Hardness	32.6	46.0	25.4	18.6	27.4	27.4	23.6	28.1	26.0	23.5	22.9	29.1	100 – 200	100
Bio O_2 Demand	4.3	5.59	3.08	4.47	3.21	2.98	3.32	3.1	3.62	3.42	3.82	3.6	30 – 250	30
Chemical O_2 Demand	13.97	8.21	10.56	10.36	8.72	7.55	6.78	7.89	6.99	7.2	6.89	8.11	150 – 500	150
Electrical conductivity (µs/cm)	2.28	2.20	2.3	2.19	1.08	1.1	1.2	1.3	1.10	1.50	1.30	1.70	400 – 800	400

Key: A1 = Reverton, A2 = Idrinana Hotel, A3 = 69 Palms Hotel, A4 = Halims Hotels & Towers, B1 = Reverton borehole, B2 = Idrinana Hotel borehole, B3 = 69 Palms Hotel borehole, B4 = Halims Hotels & Towers borehole, C1 = Closest borehole to Reverton, C2 = Closest borehole to Idrinana Hotel, C3 = Closest borehole to 69 Palms Hotel, C4 = Closest borehole to Halims Hotels & Towers

The results above clearly shows that there are contaminants present in the hotels' effluent, hotels' boreholes and the nearest boreholes within the 500m radius of the hotels all at varying degrees.

Table.2: Laboratory Analysis Summary

Item	Variable	Minimum	Maximum	Mean	Std. Deviation	Variance
Hotel Effluent (A1 – A4)	pH	5.80	6.40	6.0750	.27538	.076
	Titratable Alkalinity	53.50	63.50	59.5000	4.54606	20.667
	Aluminum	-	-	-	-	-
	Chemical O_2 Demand	8.21	13.97	10.7750	2.38088	5.669
	Dissolved O_2	8.56	8.67	8.6350	.05196	.003
	Bio O_2 Demand	3.08	5.59	4.3600	1.02746	1.056
	Chloride	.80	2.10	1.4775	.72020	.519
	Total Suspended Solid	.05	.25	.1500	.09129	.008
	Total Dissolved Solid	.20	.35	.2525	.06702	.004
	Sulphate	.360	.820	.58000	.188326	.035
	Phosphate	1.200	1.560	1.42000	.157480	.025
	Nitrate	2.220	2.620	2.41500	.179165	.032
	Lead	.511	.802	.63600	.121384	.015
	Iron	21.600	36.600	27.92500	7.052836	49.742
	Nickel	.00	.00	.0000	.00000	.000
Hotel's Borehole (B1 – B4)	pH	3.40	4.00	3.6375	.26260	.069
	Titratable Alkalinity	28.20	30.30	28.9250	.93941	.883
	Aluminum	-	-	-	-	-
	Chemical O_2 Demand	6.78	8.72	7.7350	.80426	.647
	Dissolved O_2	7.58	8.53	8.1450	.43501	.189
	Bio O_2 Demand	2.98	3.32	3.1525	.14592	.021
	Chloride	.62	2.59	1.8725	.89134	.794
	Total Suspended Solid	.08	.11	.0975	.01258	.000
	Total Dissolved Solid	.10	.18	.1350	.03416	.001
	Sulphate	.06	.14	.1135	.03892	.002
	Phosphate	.98	1.31	1.1300	.15642	.024
	Nitrate	3.00	3.43	3.2525	.18536	.034
	Lead	.53	.60	.5623	.02901	.001
	Iron	11.40	12.60	12.0750	.49917	.249
	Nickel	.00	.00	.0000	.00000	.000
Closest Borehole to the Hotels within 500m Radius (C1 – C4)	pH	4.90	6.20	5.5250	.53774	.289
	Titratable Alkalinity	44.20	56.40	49.9750	5.61805	31.562
	Aluminum	-	-	-	-	-
	Chemical O_2 Demand	6.89	8.11	7.2975	.55686	.310
	Dissolved O_2	7.92	8.43	8.1450	.22219	.049
	Bio O_2 Demand	3.42	3.82	3.6150	.16361	.027
	Chloride	2.26	2.61	2.4850	.16052	.026
	Total Suspended Solid	.10	.18	.1250	.03786	.001
	Total Dissolved Solid	.14	13.00	3.3750	6.41678	41.175
	Sulphate	.11	.21	.1405	.04660	.002
	Phosphate	1.22	1.72	1.4150	.21764	.047
	Nitrate	2.75	3.10	2.9300	.17108	.029
	Lead	.56	.80	.6590	.10154	.010
	Iron	18.60	21.20	20.2750	1.15912	1.344
	Nickel	.00	.00	.0000	.00000	.000

Table.2 shows summary of the descriptive statistics of the water quality parameters. The pH of the samples was within 5.87mg/l to 6.4 mg/l, this indicates the effluent discharge from the hotels were slightly acidic. For the hotel boreholes, the acidity of the sample was (3.4 - 4.0mg/l), while the closest boreholes (within 500m radius) to that of the hotels had a pH range of 4.9-6.2. The titrable alkalinity was from 53.50mg/l-63.50mg/l, 28.20-30.30mg/l and 44.20-56.40mg/l for hotel effluent, hotel boreholes and closest borehole to each of the hotels respectively. The contaminants present were; sulphate, phosphate, nitrate, lead, and iron. Aluminum and nickel were absent from the study area. The table also revealed that the biological oxygen demand was; hotel effluents (3.08-5.59), hotel boreholes (2.98-3.32mg/l) and closest borehole (3.42-3.82mg/l) to each hotels respectively.

Table 3: Summary of pH of study area

T – Test Statistics

	N	Mean	Std. Deviation	Std. Error Mean
Hotel Effluent	4	6.0750	.27538	.13769
Hotel Boreholes	4	3.6375	.26260	.13130
Closest Boreholes to Hotel	4	5.5250	.53774	.26887

	Test Value = 6.5					
	t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
Hotel Effluent	-3.087	3	.054	-.42500	-.8632	.0132
Hotel Borehole	-21.801	3	.000	-2.86250	-3.2804	-2.4446
Closest Boreholes	-3.626	3	.036	-.97500	-1.8307	-.1193

The table.3 showed the pH of water sample of the samples. The results indicate that the average pH in the hotels' effluents was 6.0mg/l, the boreholes on site of the hotel were highly acidic with a pH of 3.6mg/l and the closest boreholes to the hotel (within 500m radius) had low acidity of 5.5mg/l. The approved standard is 6.5mg/l. This indicates that the boreholes in the hotels were a little short of the recommended pH. The sample T test performed to evaluate if there was a variance in the pH of the study area and the universally approved standard. The mean pH of the hotel effluent discharges, hotel site boreholes and closest boreholes to the hotels; M = 6.07mg/l, SD=0.28; M = 3.63mg/l, SD=0.26; M = 5.53mg/l, SD=0.54, respectively were not significantly different from the approved pH (t (3) = -3.087, p< .05) for hotels effluents. However, it was statistically different from the approved level compared with hotels borehole and the closest boreholes to the hotels; (t (3) = -21.80, p< .05) and (t (3) = -3.63, p< .036). This indicates that the onsite boreholes in the hotels and the closest boreholes to them were highly acidic which is bad for groundwater. Nevertheless, effluent discharges from Riverton (pH = 6.4mg/l) and Halims Hotels and Towers (6.2mg/l) had the closest pH to the approved standard of 6.5mg/l.

Table 4: Showing Biological Oxygen demand

T – Test Statistics

	N	Mean	Std. Deviation	Std. Error Mean
Hotel Effluent	4	4.3600	1.02746	.51373
Hotel Borehole	4	3.1525	.14592	.07296
Closest Boreholes	4	3.6150	.16361	.08180

	Test Value = 30					
	T	Df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
Hotel Effluent	-49.910	3	.000	-25.64000	-27.2749	-24.0051
Hotel Borehole	-367.984	3	.000	-26.84750	-27.0797	-26.6153

Closest Boreholes	-322.545	3	.000	-26.38500	-26.6453	-26.1247

The table.4 shows Biological Oxygen Demand (BOD) of the samples. The results indicate that the average BOD was 4.36mg/l (hotel effluent), 3.15mg/l (hotel onsite boreholes), and 3.61mg/l (closest borehole to hotels). The sample t test performed to evaluate if there was a variance in the BOD of the study area and the universally approved standard, indicated a statistically different result from the approved level compared with all study samples. The hotel boreholes, effluent discharges and the closest boreholes to the hotels; (t (3) = -49.910, p = .000), (t (3) = -367.98, p = .000), and (t (3) = -322.55, p = .000) were well below the permissible limits.

Table.5: Summary of Total Suspended Solid

T – Test Statistics

	N	Mean	Std. Deviation	Std. Error Mean
Hotel Effluent	4	.1500	.09129	.04564
Hotel Borehole	4	.0975	.01258	.00629
Closest Boreholes	4	.1250	.03786	.01893

	Test Value = 30					
	t	Df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
Hotel Effluent	-653.981	3	.000	-29.85000	-29.9953	-29.7047
Hotel Borehole	-4752.819	3	.000	-29.90250	-29.9225	-29.8825
Closest Boreholes	-1578.208	3	.000	-29.87500	-29.9352	-29.8148

The table 5 shows the total suspended solid in water bodies of the samples. The results indicated an average mean of 0.15mg/l (hotel effluent), 0.09mg/l (hotel boreholes), and 0.12mg/l (closest borehole). The sample t test performed to evaluate if there was a variance in the total suspended solid and the universally approved standard, indicated a statistically different but significant result from the approved level compared with all study samples. The hotel effluents, site borehole and the closest boreholes to the hotels; (t (3) = -653.98, p = .000), (t (3) = -4752.82, p= .000), and (t (3) = -1578.21, p = .000). This indicated that hotel's effluent discharge on Lokoja groundwater quality was very minute compared to the accepted level of suspended solid approved of 30-50mg/l.

Table.6: Summary of Chemical Oxygen Demand

T – Test Statistics

	N	Mean	Std. Deviation	Std. Error Mean
Hotel Effluent	4	10.7750	2.38088	1.19044
Hotel Borehole	4	7.7350	.80426	.40213
Closest Boreholes	4	7.2975	.55686	.27843

	Test Value = 150					
	t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
Hotel Effluent	-116.953	3	.000	-139.22500	-143.0135	-135.4365
Hotel Borehole	-353.779	3	.000	-142.26500	-143.5448	-140.9852
Closest Boreholes	-512.527	3	.000	-142.70250	-143.5886	-141.8164

The table.6 shows summary of Chemical Oxygen Demand(COD) of the samples. The results indicated an average mean of 10.78mg/l (hotel effluent), 7.74mg/l (borehole onsite), and 7.29mg/l (closest borehole). The sample t test performed to evaluate if there was a variance in the total suspended solid and the universally approved standard, indicated a statistically significant result from the approved level compared with all study samples. The COD from the study was lower than the allowed effluent discharge, universally. The hotel effluents (t (3) = -116.95, p= .000), site borehole water sample (t (3) = -353.78, p =

.000) and the closest boreholes to the hotels (t (3) = -512.53, p = .000). This indicated that hotel's effluent discharge on Lokoja groundwater quality was negligible was contained a lesser amount of oxidizable organic material in the sample, which will improved dissolved oxygen levels.

Table 7: Summary of Lead in Groundwater

T – Test Statistics

	N	Mean	Std. Deviation	Std. Error Mean
Hotel Effluent	4	.635	.121384	.060692
Hotel Borehole	4	.6547	.02901	.01451
Closest Boreholes	4	.659	.10154	.05077

	Test Value = 0.05					
	t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
Hotel Effluent	-71.904	3	.000	-4.364000	-4.55715	-4.17085
Hotel Borehole	-305.946	3	.000	-4.43775	-4.4839	-4.3916
Closest Boreholes	-85.502	3	.000	-4.34100	-4.5026	-4.1794

The table 7 shows the amount of Lead in the water sample on the selected hotels and the nearest boreholes in the study area. The results indicate that the average amount of Lead in the hotels effluent (.64mg/l), the site boreholes of the hotels (.65mg/l) and the closest boreholes (.66mg/l). The approved standard of effluent discharge was 0.01-0.05mg/l. This indicates that the boreholes in the hotels came short of the recommended levels. The sample t-test performed to evaluate this variance indicated a statistically significant difference from the approved levels; (t (3) = -71.904, p = .000) for hotels effluent discharge, hotel site boreholes (t (3) = -305.946, p = .000) and (t (3) = -85.50, p = .000) for the closest boreholes to the selected hotels. This indicates that the samples gotten from the hotel's boreholes, hotel effluents and the closest boreholes to the hotels had a higher Lead contamination which is bad for ground water.

Table 8: Showing level of Phosphate in Hotel's groundwater

T – Test Statistics

	N	Mean	Std. Deviation	Std. Error Mean
Hotel Effluent	4	1.42000	.157480	.078740
Hotel Borehole	4	1.1300	.15642	.07821
Closest Boreholes	4	.1405	.04660	.02330

	Test Value = 1					
	t	Df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
Hotel Effluent	5.334	3	.013	.420000	.16941	.67059
Hotel Borehole	1.662	3	.195	.13000	-.1189	.3789
Closest Boreholes	-36.888	3	.000	-.85950	-.9337	-.7853

The table.8 shows the amount of phosphate in the water sample on the selected hotels in the study area. The results indicate that the average amount of phosphate in the hotel's effluents (1.42mg/l), hotel boreholes (1.13mg/l) and the closest boreholes (0.14mg/l). The approved standard of effluent discharge was 1.0. This indicates that the boreholes in the hotels were above the permissible levels. The sample t-test performed indicated a statistically significant amount to the approved levels at the hotels effluents (t (3) = 5.334, p = .013), and (t (3) = -36.888, p = .000) for the closest boreholes to the selected hotels. The hotel borehole was not statistically significant (t (3) = 1.662, p = .195). However, the closest boreholes to the hotels were within permissible limits. This result indicated that the samples gotten from the study area were not detrimental to ground water.

Table 9: Showing amount of Nickel in Hotel's groundwater

T – Test Statistics

	N	Mean	Std. Deviation	Std. Error Mean
Hotel Borehole	4	.0000	.00000[a]	.00000
Hotel Site	4	.0000	.00000[a]	.00000
Closest Boreholes	4	.0000	.00000[a]	.00000

a. t cannot be computed because the standard deviation is 0.

The table.9 above indicates that nickel was not discovered in the samples tested from the hotels, their sites or boreholes closest to them. Therefore, they meet the internationally accepted standard for permissible discharge into groundwater.

Table 10: Summary on effective management strategy

S/N	EFFECTIVE MANAGEMENT STRATEGY	Mean	SD
1	Implementing effluent treatment measures at hotel sites can effectively reduce the discharge of contaminants into groundwater	4.00	0.82
2	Identifying and controlling specific sources of acidity in groundwater is crucial for mitigating their effect on water quality	3.5	0.5
3	Raising awareness among local communities about groundwater quality issues is essential for promoting sustainable water management practices	2.0	1.0
4	Strengthening regulatory frameworks and monitoring systems is crucial for ensuring compliance with effluent discharge standards and protecting environmental health	3.5	0.5
5	Supporting the implementation of effluent treatment technologies can improve groundwater quality in your area	4.0	0.82
6	Collaborative efforts between government agencies, industries, and community organizations are necessary for effective groundwater management	2.0	1.0
7	Establishing long-term monitoring programs to track changes in groundwater quality parameters is essential	3.0	0.71
8	Public participation in water quality monitoring efforts is crucial for promoting transparency and accountability in environmental management	4.0	0.82
9	Participating in community initiatives aimed at protecting groundwater resources and promoting sustainable water use practices	2.0	1.0
10	Investing in research and innovation for effluent minimization and wastewater treatment can contribute to long-term environmental sustainability	3.50	0.50

The summary of the results indicates that respondents generally expressed positive attitudes towards the effective management strategies for effluent discharge and groundwater quality. Items 1, 5, and 8, which relate to the importance of implementing effluent treatment measures, raising awareness, and investing in research and innovation, received higher mean scores of 4.00, indicating a strong agreement among respondents. Conversely, items, 3, 6, and 9, which pertain to the identification and control of acidity sources and community participation, received lower mean scores of 2.00, indicating disagreement or uncertainty among respondents.

3.1.2 Discussion

Findings from the study and test of samples taken from the study areas indicated the presence of contaminants in the groundwater in hotels and the sites around them. The sample analysis results on table.1 indicate the presence of nitrate (2.22 – 2.62mg/l), sulphate (2.01 – 2.71mg/l), phosphate and lead. Although these were found at moderate quantities and fall well within the permissible levels of effluents discharge (10 – 50mg/l, 10 – 50mg/l). Significantly, iron was found more in Reverton Hotel (36.6mg/l) and Idrinana hotels' effluent (35.3mg/l) discharges and the boreholes closest to the hotels, but it was lower in the hotel onsite boreholes (least in Reverton borehole with 21.6mg/l). More lead concentrations were found at, 69 Palms and Idrinana effluent discharges, and the closest borehole Reverton, and Halims Hotels and Towers. Nitrate was higher in the hotels boreholes, than in their effluents or those boreholes closest to them. Phosphate was higher in samples of effluents gotten Reverton and Halims hotels than other samples taken. However, there were neither traces of nickel nor aluminum found in any samples analyzed. The presence of iron (Fe^{3+}) and nitrate agrees with literature on the soil profile samples earlier documented that the soil of Lokoja is predominantly classified as Ferralic Luvisols, Acrisols, and Fluvisols, characterized by its brown coloration due to the presence of iron oxide, relatively low organic matter content but is rich in iron and aluminum oxides (Ezekwe, I. C., et al. 2016, Ogunwale, A. B., & Ajanaku, K. O. 2016). This so due to the tropical region with high rainfall and is typically found in areas with the formations the study area falls into. The pH reported from this finding was highly acidic in contrast to previous study by Sale et al. 2019, Hiscock & Grismer 2014, & Sale, JF; Yahaya, A; Ejim, CC; Okpe, IW. 2019,).

In determining the levels of physicochemical parameters in the different samples of the hotels' boreholes and the boreholes within 500m radius to the hotel, the samples were analyzed and reported on table .1. Based on the approved standard range of 6.5mg/l to 8.5mg/l for water, the average pH value of the water samples from the study was 5.8mg/l, 3.40mg/l and 4.9mg/l for hotels' effluents, hotel boreholes and closest boreholes to the hotel. Comparatively, it can thus be explained that the pH of the water samples from the 12 samples were abnormally slightly acidic. The Total Dissolved Solids (0.1 – 0.35mg/l) and Total Suspended Solids (0.05 – 0.18mg/l) were well below the permissible levels (30 – 50mg/l and 150 – 500mg/l) of effluent discharges. The Biological Oxygen Demand (BOD), which was the amount of oxygen present in the soil for aerobic bacteria growing was sufficient and promoted a flow of the ecosystem chain (2.98 – 5.59mg./l). In the same light, Chemical Oxygen Demand (COD) was also at average levels (13.97 – 6.78mg/l) which showed a support for oxidization occurred effortlessly without the need for microbes. High levels of COD reduced the level of dissolved oxygen in the soil after effluents are discharged which in turn affects quality of water (UNEP. 2017). Although the high volume of hotels activities and effluent discharged into ground water and soil around their sites from such activities, the samples in these selected hotels are well below the permissible limits. This finding negates that of Jacob, Ndukwe, Gimba, et al (2022) who reported high levels of Nitrate, Sulphide and Lead in Lokoja (Jacob, A. A., Ndukwe, G. I., Gimba, C. E., et al, 2016). However, the low pH value of the water from the samples might be as a result of water contamination brought about by influx of debris, poor sanitation practices, the soil profile and contaminants into the stream from agricultural lands and other human activities.This assertion agrees with Follett & Delgado, (2002), that prominent source of increased groundwater acidity is the use of nitrogen-based fertilizers in agriculture. The nitrification process, where ammonia from fertilizers is converted into nitrate by soil bacteria, produces hydrogen ions, leading to a decrease in pH and increased acidity.Similarly, Drever (1997), opined that aquifers composed of silicate minerals, such as granite or sandstone, generally exhibit lower buffering capacities. These rocks lack the carbonate minerals necessary for neutralizing acids, leading to the potential for more acidic groundwater. The weathering of silicate minerals can produce acidic conditions through the release of hydrogen ions (H^{+}) into the water. The study area has been noted as a region of intensive human activities, mining activities and low agricultural production by the inhabitants (Sale, JF; Yahaya, A; Ejim, CC; Okpe, IW. 2019). In consequence, residues and waste materials, both liquid and solids have been generated from the city highlands and subsequently washed down by rain via surface run-offs. There was no nickel or aluminum in the samples tested from hotels, hotels' borehole and the boreholes within 500m radius.

Findings from this study agree with Chiazor, Kemah, Obihan & Abraham (2016) on the presence of contaminants in samples but disagree with the result on the high levels reported. According to them, there are primarily high levels of acidity or alkalinity and hardness of borehole samples, contamination of toxic metals, and, high particulate load (Chiazor Stephen Ngozi-Chika, Kemah Patrick Ugbaje, et al., 2016). These contaminants cause detrimental effects on aquatic biota that cause serious health hazards. Nevertheless, the contaminants found from sample analysis, pose little to no risk on the groundwater and safe drinking water in Lokoja. Furthermore, it is well documented in literature that hotels generate substantial volumes of effluents through various activities such as laundry, kitchen operations, and cleaning processes Hassan, R., et al. (2021, Environmental Protection Agency (EPA), 2019 & Jones, A. B. 2018). The introduction of contaminants can disturb the natural balance of aquatic flora and fauna, affecting biodiversity and ecosystem services. These effluents, if not properly treated, may contain contaminants such as nutrients, heavy metals, and organic compounds, all of which have the potential to seep into the underlying groundwater aquifers (Smith, C., et al, 2020, Chiazor S. N., Kemah P. U., Obihan I. & Abraham O. 2016, & Lukubye, B. & Andama, M, 2017).

In answering the third research question on the concentrations in groundwater quality parameters within the safety limits recommended by WHO and NESREA, findings from analysis indicated that most of the water parameters met the recommended standards. However, the pH was highly acidic (3.4 – 4.0mg/l) below the recommended level for safe drinking water, especially for Reverton, Idrinana, Halims and Hotel 69 Palms Hotel's borehole, however, only the sample of the nearest borehole to Halims Hotels and Towers (C3) records pH figure (6.20mg/l) closer to the recommended permissible limits of both WHO & NESREA (6.5 – 8.5mg/l). The location and region the hotels and boreholes sampled fall into plays a significant role (Sale, JF; Yahaya, A; Ejim, CC; Okpe, IW. 2019). The finding does not align with previous studies of Rufai, Olufemi, & Solomon (2013) who reported higher conductivity, nitrate, chloride and sulphate that were way lesser in this study. They also reported a lower total alkalinity (Nwuchola Comfort Ojoma, Omejeh Timothy Enejoh, & Rufai Jibrin, 2024). This study reported a similar level of hardness of water. Higher concentrations of contaminants disrupt the natural balance of aquatic life thereby, affecting biodiversity and ecosystem services Smith, C., et al. 2020, Chiazor Stephen Ngozi-Chika, Kemah P. U., Obihan I. & Abraham O. 2016, & Lukubye, B. and Andama, M, 2017). Groundwater contamination poses a direct threat to public health as it can result in the consumption of contaminated water, leading to various waterborne diseases and long-term health issues (Environmental Protection Agency (EPA), 2019). Although there were contaminants in samples from the study area, however, they were within the permissible limits by WHO and NESREA. These findings was also supported by Nwuchola, Omejeh & Rufai (2024), who reported presence of physicochemical contaminants in Lokoja groundwater but found that they were within the safety limits prescribed by WHO (Nwuchola Comfort Ojoma, Omejeh Timothy Enejoh, & Rufai Jibrin, 2024).

The findings from the study indicated a nuanced attitude among respondents towards effective management strategies for effluent discharge and groundwater quality. While certain strategies, such as effluent treatment and awareness-raising, received higher levels of agreement (with a mean score of 4.0 respectively), others, like the identification of acidity sources and community involvement, elicited more diverse opinions. This aligns with previous research, such as National Environmental Standards and Regulations Enforcement Agency (NESREA), Nigeria, 2018, & Sale, JF; Yahaya, A; Ejim, CC; Okpe, IW., 2019), which reported mixed attitudes among stakeholders towards environmental management initiatives. The variability in responses underscores the complexity of environmental management initiatives. The variability in responses underscores the complexity of environmental challenges and highlights the importance of context-specific and inclusive approaches to decision-making processes. These findings contribute towards environmental management strategies, emphasizing the need for collaborative efforts to address complex environmental issues (Brown, L. R., 2018).

Effluent minimization strategies are crucial for mitigating the environmental effects of effluent discharge, especially in regions like Nigeria where water resources are scarce. Key strategies tailored to the Nigerian context include improving effluent treatment infrastructure, promoting water reuse, raising public awareness, and enforcing regulations to ensure compliance with effluent discharge standards (National Environmental Standards and Regulations Enforcement Agency (NESREA), Nigeria. 2018), Sale, JF; Yahaya, A; Ejim, CC; Okpe, IW. 2019, & Ocholi, I.U., Ejoba, R Abuh, H.O. 2016). Additionally, encouraging the adoption of green technologies, supporting research and innovation, integrating sustainable practices into industries. (United Nations Economic Commission for Europe (UNECE) (2022), & Food and Agriculture Organization of the United Nations (FAO), 2022). Fostering partnerships, providing incentives, and implementing robust monitoring and reporting systems are essential steps towards effective effluent minimization.

By implementing these strategies comprehensively, hotels and industries can significantly reduce the discharge of effluents into the environment and safeguard its water resources for future generations. Effluent minimization efforts not only protect the environment but also promote sustainable development, enhance public health, and contribute to the overall well-being of communities across the country Adeyemi, et al. (2017 & World Health Organization and United Nations Childrens Fund, 2014). Collaboration between government agencies, private sector stakeholders, academia, and civil society organizations is crucial for addressing effluent minimization challenges collectively and achieving long-term sustainability in water management.

4.0 CONCLUSION

The study on the Effects of Hotels Effluent Discharge on Groundwater Quality in Lokoja, Kogi State, Nigeria carries significant implications for environmental management, public health, and sustainable development in the region. By shedding light on the potential impact of effluent discharge, particularly in terms of acidity levels, the study discovers contaminants in varying proportions in both the effluents and the water samples collected at the different sites, the study points the urgency of implementing effective contamination control measures to safeguard the environment.

In investigating the Effects of Hotels Effluent Discharge on Groundwater Quality in Lokoja, Kogi State, Nigeria, water samples were collected from four hotels, their respective boreholes and the nearest boreholes within 500m radius, with the aim of assessing physicochemical parameters and heavy metals levels. The study was guided by waste management theory, which emphasizes the importance of minimizing waste generation and controlling contaminant discharge to protect environmental health.

The study findings amplify the importance of addressing the acidic pH levels observed in groundwater samples, despite overall compliance with WHO and NESREA permissible emission standards. It is concluded that no water sample can be totally pure but possess impurities and contaminants. The study recommends (i) investigate and address the source of acidity, (ii)improve hotel effluent treatment (iii)promote water conservation and reuse, (iv)community awareness and education programs, (v)strengthen collaboration and monitoring.

Disclaimer (Artificial intelligence)

Option 1:

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

Details of the AI usage are given below:

1.

2.

3.

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