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Impact of Wupa Wastewater Treatment Plant Effluent on Wupa River as a Source for Consumption in Zhidu Settlement

[1]ABUBAKAR Shaibu Eneye, [2]ABDULLAHI Ibrahim, [3]SAMINU Ahmed [4]SANI John Engbonye, [5] YAQUB Abbas Enesi, [6]ALHASSAN Kabir. Gotip Hope Bege
[1,2,3,4&5] Department of Civil Engineering, Nigeria Defence Academy, Kaduna
[6]Water and Sewage Department, FCDA
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Abstract
The qualities of the treated effluent of the Wupa Wastewater Treatment Plant located in a rural community of the Federal Capital Territory (Abuja-Nigeria) were assessed over two seasons (wet and dry). This study evaluated the Wupa Wastewater Treatment Plant (WWTP) with acceptable local (National Environmental Standards and Regulations Enforcement Agency –NESREA) and international (World Health Organization-WHO) standards and the effect on the receiving surface water (Wupa River) sources around Zhidu Settlement in Abuja. Surface water exhibited high seasonal variations and high levels of the assayed parameters were observed during the wet season and low at dry season. The results of the effluent during wet season had pH-7.43, electrical conductivity-445.4µS/cm, total dissolved solid (TDS)-172mg/L, total suspended solids (TSS)-7mg/L, turbidity-4.67NTU, sulphate-5.34mg/l, nitrate-0.8mg/l, fluoride-
0.55mg/l, biological oxygen demand (BOD)-2.9mg/l, chemical oxygen demand (COD)0.4mg/l, dissolved oxygen (DO)-8.39mg/l, copper (Cu)-0,011mg/l, and zinc (Zn)1.6mg/l while total phosphorous (TP), Iron (Fe)and Lead (Pb) had no presence in the effluent with TC and FC being too numerous to count (TNTC). similar analyses were conducted for dry season of the assayed parameters, showcasing slight differences with pH-7.2, electrical conductivity-333µS/cm, total dissolved solid (TDS)-166mg/l, total suspended solids (TSS)-5mg/L, turbidity-4.97NTU, sulphate-5.4mg/l, nitrate-0.8mg/l, fluoride-
0.51mg/l, biological oxygen demand (BOD)-2.55mg/l, chemical oxygen demand (COD)0.2mg/l, dissolved oxygen (DO)8.35mg/l, copper (Cu) 0,014mg/l, and zinc (Zn)-1.8mg/l. Again, total phosphorous (TP), Iron (Fe)and Lead (Pb) had no presence in the effluent with TC and FC being too numerous to count (TNTC). The study revealed that there was no adverse impact of the effluent water on the receiving water body (River Wupa) in terms of physiochemical parameters and heavy metals, the treated effluent from the facility conformed to the specified discharge limits for WHO and NESREA. The paired t-test revealed that seasonal change has significant influenced on analyzed parameters except for pH, that was found to be higher during the dry season but in terms of the bacteriological parameters; values of the total coliform (TC) and faecal coliform (FC) were observed to be higher (TNTC) same as that of the river at both upstream and downstream sections of the sampling stations, which necessitates the development of a maintenance plan for the treatment plant with emphasis on proper maintenance of the unit processes and the need to fully utilize the plant capacity to maximize its operations.

Keywords: *Wastewater, BOD, COD, Heavy metal, WWTP, Water, Effluent, Zhidu, Wupa.*

INTRODUCTION

The world's environment, a delicate tapestry of interconnected physical, chemical, and biological elements, has endured the consequences of human pursuits in the name of survival. In this intricate web of existence, the environment stands as a lifesustaining system that nurtures all living beings and nurtures the growth of societies (Anzaku, Ubangari, & Polycarp, 2022). As the bedrock of global economies, the environment's protection and sustainable management are paramount. These efforts are dedicated to ensuring the perpetual coexistence of the diverse forms of life on Earth, with humanity at its forefront (Anzaku et al., 2022).

Within this context, liquid waste, encompassing substances like fats, oils, grease, and chemicals, emerges as a challenge to both human health and the environment. The intricate relationship between humanity and its surroundings gives rise to wastewater, discharged from domestic, commercial, industrial, and agricultural sources. The complexity of this issue is exemplified in the contents of liquid waste, containing potentially harmful elements such as human waste, food scraps, oils, soaps, and chemicals (Lilley et al., 2014). Recent decades have witnessed a surge in ecological threats and pollution, posing a significant risk to lakes worldwide, which collectively account for over 90% of available surface freshwater (Gong et al., 2016). Amid this escalating challenge, the task of predicting how water quality responds to diverse pollutants becomes an intricate puzzle due to the myriad sources of contamination. In the context of developing countries like Nigeria, the indiscriminate discharge of liquid waste into water bodies, drains, and even onto dry land is a prevalent and hazardous practice. This practice, while convenient, has inflicted pollution upon the environment, creating unsightly and malodorous surroundings. Moreover, this careless disposal method has the potential to contaminate water sources, leading to the outbreak of diseases like cholera (Anzaku et al., 2022).

The ramifications extend beyond aesthetics and hygiene. The unchecked release of liquid waste can significantly impact on surface water quality, emphasizing the critical importance of waste management at every stage of its lifecycle (Anzaku et al., 2022). However, burgeoning populations, urbanization, and improved living standards have fueled the generation of liquid waste at an unprecedented rate in developing countries (Minghua et al., 2009).

In the context of Abuja Municipal Area Council, the surge in population has given birth to densely built environments, where houses stand closely side by side. Unfortunately, this urbanization has brought with it the haphazard discharge of household waste, creating an urgent need to comprehend the generation, disposal, and management of liquid waste (Salami et al., 2011). Amid these challenges, wastewater treatment plants emerge as essential municipal infrastructure, designed to curtail the environmental harm caused by the direct release of wastewater. These plants play a pivotal role in treating diverse effluent sources ranging from domestic to industrial prior to their introduction into aquatic ecosystems. While these plants are crucial in removing or reducing pollutants to safe levels, their effectiveness can vary. Therefore, an in-depth investigation into the impact of these treatment plants on surface water quality is imperative.

The Wupa Sewage Treatment Plant (WWTP) in Abuja, situated near the Wupa River, encapsulates the essence of this study. The plant, designed to accommodate an Average Dry Weather Inflow of 131,000 m3 per day, seeks to manage the liquid waste challenges in the region (GEHS, 2014). However, questions remain about its effectiveness in maintaining water quality in the Zhidu settlement of Idu, Abuja.

Against the backdrop of rapid population growth and urbanization, this study examines the performance of the Wupa Sewage Treatment Plant. The investigation is vital for assessing whether this advanced facility effectively safeguards the quality of surface water sources in its area. Moreover, given the close connection between water quality, public health, and environmental sustainability, the study's insights could inspire improved wastewater management practices, not only in the Zhidu settlement but also in comparable regions globally.

2.0 LITERATURE REVIEW

Surface Water

Surface water is one of the most influenced ecosystems on earth, and its alterations have led to extensive ecological degradation such as a decline in water quality and availability, intense flooding, loss of species, and changes in the distribution and structure of the aquatic biota (Oberdorff et al., 2002), thus, making surface water courses not sustainable in providing goods and services (Poff et al., 1997). For instance, the health of a river system is influenced by various factors, which include the geomorphology and geological formations, physicochemical and microbial quality of the water, the hydrological regimes, and the nature of instream and riparian habitats (Poff et al., 1997).

Water quality is described by chemical, physical, and biological characteristics of water that determine its fitness for a variety of uses and for the protection of the health and integrity of aquatic ecosystems. Each aquatic ecosystem has the natural tendency to adapt and compensate for changes in water quality parameters through dilution and biodegradation of some organic compounds (Dallas, 1998). But when this natural buffering capacity of the aquatic ecosystem is exceeded due to the introduction of various classes of contaminants from point and nonpoint sources on a continuous basis, water pollution sets in.

In Nigeria like most other developing countries in the world, surface water is usually used for domestic, recreational, and agricultural purposes mostly in the rural areas. Water quality is affected by both natural processes and anthropogenic activities. Generally, natural water quality varies from place to place, depending on seasonal changes, climatic changes, and with the types of soils, rocks, and surfaces through which it moves (Edokpayi, 2017). A variety of human activities such as agricultural activities, urban and industrial development, mining, and recreation significantly alter the quality of natural waters and change the water use potential (Edokpayi, 2017).

Surface Water Quality

Surface water refers to anybody of liquid water found on the Earth's surface. This includes ocean water and water deposited in inland repositories, e.g., rivers, streams, lakes, wetlands, reservoirs, and creeks (Dooge, 2009). Freshwater is fundamental for all living organisms, human health, food production, and most industrial processes (Ahmed, 2016; Nguyen and Huynh, 2022). With rapid urbanization, industrialization, and agricultural production, fresh surface water is becoming even more pivotal than ever before for the sustainability of human civilization (Ahmed, 2016).

The pollution of water bodies is threatening the ecological environment and human health (Le Moal et al., 2019). Therefore, many indices for assessing surface water quality (e.g., water quality indices (WQIs), trophic status indices (TSIs), and heavy metal indices (HMIs) based on water quality parameters (WQPs) have been designed to assess water quality. The initial WQI was constructed by aggregating the physical and chemical factors of water bodies (Horton, 1965; Hurley et al., 2012). The WQI provides a more accurate overview of water quality variability in specific areas and can be used to effectively depict water quality (Rangeti et al., 2015; Tyagi et al., 2013). However, no universal WQI exists for evaluating surface water quality, though many modifications have been considered for generating different WQIs based on specific regional conditions (Sutadian et al., 2016; Tyagi et al., 2013). Surface water quality models have progressed significantly—from single- factor models to multi-factor models, from steady-state models to dynamic models, from point-source models to coupling models of point and nonpoint sources, and from zero-dimensional models to one-dimensional, two-dimensional, and three-dimensional models (Wang et al., 2011).

Water Pollution

Water pollution is a critical worldwide problem that impacts the wellbeing of humans, wildlife, and the ecosystem. Contaminated water sources can result in many health problems such as gastrointestinal difficulties, respiratory ailments, and cancer. Pollutants in the water can harm aquatic life, resulting in reduced biodiversity and disturbance of delicate ecosystems (Bashir et al., 2020). To solve this issue, it is essential to comprehend the underlying reasons for water pollution and strive to establish sustainable remedies. Industrial waste is a major contributor to water pollution. Factories and manufacturing industries often discharge harmful chemicals and pollutants into adjacent water bodies, leading to contamination that renders the water dangerous for both humans and wildlife (Siddiqua et al., 2022).

Agriculture significantly contributes to water pollution through the runoff of pesticides, fertilizers, and animal waste, which can contaminate rivers and lakes, causing algae blooms and oxygen deprivation (Burkholder et al., 2007, Ingroa et al., 2023). To address water pollution, regulatory mechanisms should be implemented to oversee and manage the release of contaminants into water sources. Authorities and environmental organizations should set clear regulations and consequences for industries and farming methods that cause water contamination. Moreover, investing in green technologies and sustainable farming methods can decrease the volume of contaminants that flow into our water systems. Another crucial approach for water pollution is enhancing public awareness and education. Most individuals are oblivious to how their regular routines affect water quality, such pouring home chemicals into the drain or leaving garbage on beaches and rivers.

Source of Water Pollution

Water pollution are mainly concentrated in industrialization, agricultural activities, natural factors, and insufficient water supply and sewage treatment facilities. First, industry is the main cause of water pollution, these industries include distillery industry, tannery industry, pulp and paper industry, textile industry, food industry, iron and steel industry, nuclear industry and so on. Various toxic chemicals, organic and inorganic substances, toxic solvents and volatile organic chemicals may be released in industrial production. If these wastes are released into aquatic ecosystems without adequate treatment, they will cause water pollution (Chowdhary et al., 2020). Arsenic, cadmium, and chromium are vital pollutants discharged in wastewater, and the industrial sector is a significant contributor to harmful pollutants (Chen et al., 2019). With the acceleration of urbanization, wastewater from industrial production has gradually increased. (Wu et al., 2020).

In addition, water pollution caused by industrialization is also greatly affected by foreign direct investment. Industrial water pollution in less developed countries is positively correlated with foreign direct investment (Jorgenson, 2009). Second, water pollution is closely related to agriculture. Pesticides, nitrogen fertilizers and organic farm wastes from agriculture are significant causes of water pollution (RCEP, 1979). Agricultural activities will contaminate the water with nitrates, phosphorus, pesticides, soil sediments, salts and pathogens (Parris, 2011). Furthermore, agriculture has severely damaged all freshwater systems in their pristine state (Moss, 2008). Untreated or partially treated wastewater is widely used for irrigation in water-scarce regions of developing countries, including China and India, and the presence of pollutants in sewage poses risks to the environment and health. Taking China as an example, the imbalance in the quantity and quality of surface water resources has led to the long-term use of wastewater irrigation in some areas in developing countries to meet the water demand of agricultural production, resulting in serious agricultural land and food pollution, pesticide residues and heavy metal pollution threatening food safety and Human Health (Lu et al., 2015).

To sum up, water pollution results from both human and natural factors.
Various human activities will directly affect water quality, including urbanization, population growth, industrial production, climate change, and other factors (Halder and Islam, 2015) and religious activities (Dwivedi et al., 2018). Improper disposal of solid waste, sand, and gravel is also one reason for decreasing water quality (Ustaoğlua et al., 2020).

Impact of Water Pollution on Ecosystems and Human Health

Water pollution disrupts the delicate equilibrium of aquatic life, which is among its most significant effects on ecosystems. For the survival of fish, plants, and other organisms that depend on pure water, pollutants can cause damage or death. Ultimately, this may have an impact on the entire ecosystem by causing a disruption in the food chain and a decline in biodiversity. Additionally, pollution can promote the development of toxic algal blooms, which are detrimental to other aquatic organisms and can discharge toxins into the environment (Kazmi et al., 2022).

Additionally, human health is endangered by water pollution. Water that has been contaminated may harbor
detrimental bacteria, viruses, and parasites that are capable of inducing a range of ailments such as respiratory problems, gastrointestinal infections, and skin complaints. Moreover, prolonged exposure to specific waterborne contaminants, such as chemicals or heavy metals, may result in detrimental neurological consequences, cancer development, and reproductive complications (Shetty et al., 2023, Gonsioroski et al., 2020). Because they depend on contaminated water sources, these health hazards pose a heightened threat to communities.

Environmental interdependence exacerbates the detrimental effects of water pollution on both human health and ecosystems. The transboundary spread of pollutants from their source to bodies of water can have detrimental effects on ecosystems situated far from the source (Lu et al., 2021).

Wastewater

Wastewater is defined as any storm water runoff, industrial, domestic, or commercial sewage, or any combination thereof carried by water. The type and volume of wastewater generated are determined by population numbers and the combination of surrounding domestic, recreational, and industrial activities, all of which affect discharge patterns and the chemical status of the treated effluent (CIDWT, 2009).

Efficient waste management systems require proper identification and characterization of the influent entering a wastewater treatment plant (Mara, 2004). This is based on the physical, chemical, and biological characteristics of the influent, the immediate and downstream effects on the environment where the wastewater will be discharged, and current environmental and discharge standards. Four main types of wastewater have been identified: domestic, industrial, agricultural, and urban. Urban wastewater is a combination of domestic and industrial wastewater, along with surrounding sewage infiltration and rainwater. Agricultural wastewater is generated through processes from farms, agricultural activities, and sometimes contaminated groundwater (Hamdy et al., 2005).

The focus is mainly on domestic and industrial sewage as sources of plant influent and contamination; however, agricultural runoff is increasingly important due to the high quantities of pesticides and fertilizers used, ultimately contributing to surface water eutrophication (DWA, 2011). Domestic wastewater consists of black water composed of fecal matter (human and animal wastes) together with grey water from household activities (washing and bathing), forming approximately 32.5% and 67.5% of domestic sewage, respectively (EPA, 2019). Initially, this water is used for drinking, food preparation, hot water systems, bathing, personal hygiene, washing, and gardening, eventually forming part of the domestic wastewater discharged into the environment (DWA, 2011).

Within a household, individual domestic wastewater streams contribute different amounts to the overall nutrient and element load of the discharged effluent. Industrial wastewater, however, consists of industrial wastes such as pulp, paper, petrochemical runoff, chemicals, salts, and acids. These sources vary widely in composition and often require special tertiary treatments to comply with discharge regulations. The composition of industrial wastewater depends on the surrounding industry and the respective contaminant and pollutant composition, with general classification into inorganic and organic industrial wastewater (Rosenwinkel et al., 2005).

Wastewater Treatments

Wastewater comprises of all used water in homes and industries including storm water and runoffs from lands, which must be treated before it is released into the environment in order to prevent any harm or risk it may have on the environment and human health (Edokpayi et al., 2017).

The major aim of wastewater treatment is to protect human health and prevent environmental degradation by the safe disposal of domestic and industrial wastewater generated during the use of water. One of the objectives of wastewater treatment is to recycle wastewater for reuse in irrigation, thereby preserving water resources, which is times, there was no specific treatment given to wastewater. Instead, wastewater was channelled from buildings into waterways through gutters and canals, which eventually ended up in rivers, streams, lakes, and oceans, which were used by people. This natural treatment process based on dilution was adequate presumably due to a smaller population and low population density as well as human activities, resulting in lower pollution load as compared to the present times (Edokpayi et al., 2017).

Increase in population and industrial growth led to the generation of a high quantity of untreated wastewater channelled to water bodies as raw water. Eutrophication, fish kill, and cholera outbreaks have commonly been reported in communities that use contaminated water for domestic and other purposes. This necessitates the consideration of a more advanced technology in treating wastewater. Wastewater treatment facilities were initially designed to remove/decrease conventional pollution parameters (BODs, COD, total suspended solids, and nutrients) from the wastewater stream so that the final effluents do not constitute new sources of pollution (Ratola et al., 2012). However, it has been discovered that the wastewater organic load contains high levels of a variety of hazardous organic pollutants, and thus, additional treatment steps and control measures become very necessary (Ratola et al., 2012).

The quality of wastewater varies according to the types of influents the WWTPs receive such as domestic wastewater, dry and wet atmospheric deposition, urban runoff containing traffic-related pollution, or agricultural runoff (Ratola et al., 2012). The range of contaminants becomes broader when industrial wastewater is included into the raw water stream that enters a WWTP. Recently, it has been shown that Waste water effluents contain emerging organic contaminants such as persistent organic pollutants (POPs), brominated flame retardants, per-fluorinated compounds, and pharmaceuticals, which are not removed during the treatment process. Wastewater treatment technology is fast changing so as to meet the current day challenge. (Ratola et al., 2012)

Waste Water Treatment Plants (WWTPs)

Wastewater treatment is a process which removes and eliminates contaminants from wastewater and converts this into tin effluent that can be returned to the water cycle. Once returned to the water cycle, the effluent creates an acceptable impact on the environment or is reused for various purposes (called water reclamation). The treatment process takes place in a wastewater treatment plant. (Nathanson & Ambulkar, 2020). Over the last two decades, wastewater treatment plants have been found to be an important source of groundwater contamination due to treated wastewater discharge into the environment, and through wastewater reuse in irrigation and managed aquifer recharge (McCance et al. 2018). As a result, there has been an increasing global interest in assessing the impacts of treated wastewater especially issued from secondary treatment on groundwater systems. For instance, several research papers have highlighted that qualitative impacts of treated wastewater on groundwater quality include rapid salinization, high concentrations of nutrients and organic matter, fecal contamination and high numbers of pathogenic microorganisms (Narr et al. 2019; Zaouri et al. 2020). More recently, several reviews have reported that treated wastewater is the main source of emerging organic contaminants in groundwater systems (Fries et al. 2016; McCance et al. 2018).

In fact, a large number of pharmaceuticals, life-style compounds and personal care products are typically detected in groundwater near treated wastewater discharge areas at low concentrations (ng L^{-1}) (Cary et al 2013; Li et al. 2015). In the other hand, other studies have reported that treated wastewater contributes to groundwater recharge downstream of wastewater treatment plants through discharge. It can constitute an effective solution for the restoration and management of aquifers threatened by seawater intrusion through managed aquifer recharge (Ouelhazi et al. 2014; Keefe et al. 2019; Hussain et al. 2019).

Impact of Wastewater Treatment Plant on Surface Water

The release of raw and ill-treated wastewater onto water courses has both short and long-term effect on the environment and human health. Freshwater sources have been negatively impacted by wastewater. Such impacts are dependent on the composition and concentration of the waste water contaminants as well as the volume and frequency of wastewater effluents entering surface water source (Akpor & Muchie, 2011).

Eutrophication of water sources may also create environmental conditions that favour the growth of toxin producing cyanobacteria, and exposure to such toxins is hazardous to human beings.

The operation of a wastewater treatment plant (WWTP) holds significant implications for both surface water bodies (Smith et al., 2018). As treated effluent is discharged into the environment, a cascade of effects can ripple through aquatic ecosystems (Johnson & Williams, 2020). Understanding the multifaceted impact on surface water is essential for effective environmental management and sustainable water resource utilization.

Impact of Wastewater Treatment Plant Effluents on Surface Water

a. Assessment of the Impact of Sewage Treatment Plant Effluents on River Wupa, Federal Capital Territory, Nigeria

Ukah, C & Ahmad, Hadiza. (2023), compare the efficiency of the output of Wupa Wastewater Treatment Plant (WWTP) with acceptable and permissible international standards and the effect on the receiving River. Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Total Suspended Solids (TSS), Total Coliform Count (TCC) and other parameters were analyzed from sampled wastewater before passing through the plant, after passing through the treatment plant and the receiving river, then compared with National permissible standards. The results of the laboratory analyses showed that the influent going to the treatment plant had BOD, COD, and TSS values of 150 mg/l, 350 mg/l, and 160.6 mg/l respectively while the effluent after the treatment processes recorded 8 mg/l, 20 mg/l, and 15.9 mg/l for the same parameters respectively. The treatment plant recorded 95% efficiency in pollutant removal when compared with National permissible standards. The study revealed that there was no adverse impact of the effluent water on the receiving water body (River Wupa) in terms of physiochemical parameters as the treated effluent from the facility conformed to the specified discharge limits for WHO, but in terms of the bacteriological parameters; values of the total coliform count (TCC) and faecal coliform (FC) were observed to be higher than that of the river at both upstream and downstream sections, which necessitates the development of a maintenance plan for the treatment plant with emphasis on proper maintenance of the unit processes of the treatment plant and UV treating the effluent properly before discharge into the receiving water body.

b. Assessment of the Efficiency of the Wupa Wastewater Treatment Plant in Removing Coliform Bacteria, particularly its Impact on Coliforms Downstream

Balogun and Ogwueleka (2021), assess the efficiency of the Wupa Wastewater Treatment Plant in removing coliform bacteria, particularly its impact on coliforms downstream. The study utilizes zebra fish liver
(ZFL) cells to explore metabolomics responses to wastewater samples collected along a flow path from the WWTP discharge point to a downstream drinking water intake. Coliforms, including Escherichia coli (E. coli), are common indicators of faecal contamination in water bodies.

The study's key findings indicate a high efficiency in the removal of both total coliforms and E. coli, with removal rates ranging from 87% to 99.98%. The highest removal efficiencies were observed in 2017. Multivariate statistical analyses revealed correlations between coliform removal efficiency and other water constituents. These findings shed light on the biological effects of wastewater effluent on aquatic ecosystems and emphasize the importance of wastewater treatment in safeguarding water quality and public health. The research contributes to the advancement of understanding in the field of wastewater treatment's impact on microbial contamination in water bodies, offering insights into the efficacy of the Wupa Wastewater Treatment Plant's processes in removing coliform bacteria.

c. Evaluation of Performance Efficiency of the Wupa Wastewater Treatment Plant, Located in Idu Industrial Area of Abuja

Saidu et al. (2019), evaluate the performance efficiency of the Wupa Wastewater Treatment Plant, located in the Idu-lndustrial Area of Abuja. The research focuses on assessing the treatment process's effectiveness in removing various contaminants from wastewater. Samples were collected at different stages of the treatment process, including raw influents, primary effluents, and final treated effluents. The study analyses both the physicochemical and bacteriological characteristics of these samples using established methods.

The research's findings reveal important insights into the quality of effluents produced by the Wupa Wastewater Treatment Plant. For example, the average concentrations of dissolved oxygen (DO), biochemical oxygen demand (BOD5), chemical oxygen demand (COD), total suspended solids (TSS), total dissolved solids (TDS), ammonia-nitrogen (NH4-N), nitrate-nitrogen (NO3-N), and phosphate-phosphorus (PO4-P) were determined in the final effluent. The study shows that some of these parameters exhibit significant removal efficiencies, such as BOD5 (87.28%), COD (85.88%), and TSS (91.44%).

Moreover, the study assesses the impact of the treated effluent on the downstream water quality of the Wupa River. While some parameters showed slight increases downstream, the research confirms that the treated effluent did not have a significantly adverse effect on the receiving water body's physicochemical characteristics. The study contributes to understanding of wastewater treatment plant performance and its implications for water quality downstream.

d. Evaluation of the Impact of Wastewater Treatment Plant (WWTP) Effluent on the Quality of Downstream **Drinking Water Sources**

Zhen et al. (2018), evaluate the impact of wastewater treatment plant (WWTP) effluent on the quality of downstream drinking water sources. The research focuses on using a zebra fish liver (ZFL) cell-based metabolomics approach to understand the biological effects of contaminants from a WWTP discharge point to a drinking water treatment plant (DWTP) intake. The study's main objective is to explore how the presence of contaminants in wastewater effluents affects downstream water quality and, subsequently, public health. Zebra fish liver cells were exposed to water samples collected at various points along the flow path from the WWTP discharge to the DWTP intake. The researchers used metabolomics techniques to analyse both hydrophilic and lipophilic metabolites in the ZFL cell extracts. This approach allows for the identification of specific metabolomics changes that result from exposure to complex pollutant mixtures present in wastewater effluents.

The study's key findings reveal that as wastewater effluent travels downstream, distinct shifts occur in the metabolite profiles of the exposed ZFL cells. While the effects on hydrophilic metabolites tend to decrease downstream of the WWTP, the effects on lipophilic metabolites increase closer to the DWTP intake. This suggests that certain bioactive compounds in the watershed, other than those originating from the WWTP, contribute to downstream contamination.

The metabolomics analysis also provides insights into the biological effects of WWTP effluent exposure on ZFL cells. These effects include disrupted energy metabolism, altered amino acid concentrations, and changes in lipid metabolism pathways. The research underscores the potential of cell-based metabolomics as a valuable tool for understanding the complex impacts of contaminants on aquatic ecosystems and public health.

The study emphasizes the importance of comprehensive wastewater management practices to safeguard downstream water sources and protect the quality of drinking water. By combining innovative analytical methods with traditional water quality assessments, this research contributes to advancing our understanding of the ecological and human health implications of wastewater discharge and its subsequent influence on water sources.

3.0 METHODOLOGY

Study Area

The Zhidu community, located within the Idu Industrial Layout of the Federal Capital Territory, Abuja, has an estimated population of 5,000 residents, the majority of whom live below the poverty line of $1.20 per day. The primary water sources for the community are the Zhidu River, an extension of the Wupa River, and local boreholes. The study area is geographically positioned between 7° 17' 00" and 7° 22' 12" longitude and 8° 56' 48" and 9° 01' 48" latitude. With an average temperature of 29°C and annual rainfall ranging from 10 to 68 mm, the region provides suitable conditions for examining water quality. The

Wupa Wastewater Treatment Plant (WWTP), utilizing an oxidation ditch system, is designed to manage wastewater from Abuja City. This research will analyze the plant's treatment parameters and assess its efficiency in removing pollutants, focusing particularly on microbiological factors and selected heavy metals.

Materials

Plastic sample bottles 2000ml and 1000ml, Wagtech Palintest test kit, HACH Hardness test kit, Conductivity meter, DO meter, Lovibond turbidity water test (tintometer group), pH Meter, Titrimetric apparatus: burette, measuring cylinder, stirring rod, beaker, test tube, etc. Membrane filtration: membrane filter, filter holder, incubator, agar medium, etc. Gravimetric apparatus: weighing balance, oven, filter paper, etc. Reagent: nitratest powder, nitratest tablet, nitricol tablet, ammonia No. 1 and No. 2 tablets, phosphate No. 1 LR and No. 2 LR tablets, hardness 1 buffer solution and hardness 2 indicator solutions, EDTA, potassium K tablet, etc. Clinical hand gloves, Water sample: surface

Data Collection

Five (5) water samples was randomly collected during raining season and dry season, from one (1) Wupa Treatment Plant Effluent and four (4) surface water sources downstream (Wupa River) in Zhidu Settlement for physicochemical, bacteriological and some heavy metal analysis. The samples were collected in a precleaned and sterilized bottle with stopper, the bottle and cap were rinsed three times with sample water and then fill within one to two inches from the top, filled as carefully as possible without air bubbles, clinical hand gloves were used to avoid contamination (Abinandan et al., 2014). Five litres of water samples were collected for physico-chemical and microbial analysis, while two litres for analysis of heavy metals at National Water Resources Institute (NWRI) Mando, Kaduna. Each sample was transported to the laboratory soon after collection and bottles are marked with the source location.

Experimental Procedures

Among all the physicochemical & bacteriological parameters experiment carries out, only five (5) will be explained here, while the following table shows the result for all.

Biological Oxygen Demand (BOD5)

- **i.** Collect a representative water sample and ensure that it is free from any air bubbles.
- **ii.** Fill a 300 mL glass BOD bottle with a portion of the water sample.
- **iii.** Repeat step 2 with another 300 mL glass BOD bottle.
- **iv.** Measure the initial dissolved oxygen (DOi) concentration of one of the bottles using a
- **v.** DO meter.
- **vi.** Incubate both bottles in dark at 20°C for 5 days.
- **vii.** After 5 days, measure the final dissolve oxygen (DO5) concentration of one of the bottles using a DO meter. **viii.** Calculate BOD5 using the formula:

$$D0\mathbf{5} = \frac{D0i \;--\; D05}{P}$$

Where, $D0i$ is the initial DO Concentration

DO_5 is the final DO concentration and

P is the volume taken from the sample / volume of the bottle (300 ml)

Chemical Oxygen Demand (COD)

i. Collect a representative water sample and ensure that it is free from any air bubbles.

ii. Add a known excess amount of a strong oxidizing agent, such as potassium dichromate, to the water sample. iii. Heat the mixture at a specific temperature (usually 150 – 160oc) for a specific duration (typically 2 hours) under acidic conditions to oxidize the organic compounds in the water sample. iv. Measure the amount of oxygen consumed by the oxidant using a colorimetric analysis or titration method.

v. Calculate COD using the formula:

$$\frac{\text{Amount of oxidant added X volume of oxidant equivalent weight of oxygen}}{\text{Volume of water sample}} \quad COD =$$

vi. Read and record the results: Once the measurement is complete, the turbid meter will display the turbidity value. Take note of the reading and record it for further analysis or documentation.

vii. Clean and store the instrument: After use, clean the turbid meter according to the manufacturer's instructions to prevent contamination and damage. Store it in a safe place for future use.

Total Suspended Solid (TSS)

Collect a representative water sample and ensure that it is free from any air bubbles.

i. Weigh a pre-weighed filter of a specified pore size.
ii. Filter a known volume of the water sample through the filter.
iii. Dry the filter in an oven to remove all water on the filter.
iv. Weigh the filter again after drying. vi. Calculate TSS using the formula: may interfere with the filtration process. This can be done using a filtration apparatus or by allowing the sample to settle and carefully decanting the supernatant.

iii. membrane filter on the filter holder, ensuring that it is properly positioned and securely attached.
iv. Filtration Process: Pour the water sample onto the membrane filter, allowing it to pass through the filter under gentle vacuum or pressure. The filter will retain the bacteria present in the sample while allowing the water to pass through.
v. Membrane Filtration: Prepare the membrane filtration apparatus by assembling the filtration unit, including the filter holder and membrane filter. Place the
vi. Incubation: Transfer the membrane filter onto a suitable growth medium, such as M-FC agar without rosolic acid, which is commonly used for faecal coliform enumeration. Incubate the filter at the appropriate temperature (usually

Weight of filter drying - weight of pre-weighed filter 44.5°C) for 24 hours.

$$TSS = \frac{\text{Weight of filter drying - weight of pre-weighed filter}}{\text{Volume of water sample}}$$

Faecal Coliform

i. Sample Collection: Collect a representative water sample and ensure that it is free from any air bubbles.
ii. Sample Preparation: If necessary, filter the water sample to remove any large particles or debris that

vii. Colony Counting: After the incubation period, visually examine the membrane filter for the presence of characteristic faecal coliform colonies. Count the colonies using a colony counter or by manually counting under appropriate lighting conditions.
viii. Calculation: Calculate the number of faecal coliform bacteria present in the original water sample based on the number of colonies counted and the dilution factor.

Total Coliform

i. Sample Collection: Collect a representative water sample from the source of interest, and ensure that it is free from any air bubbles
ii. Sample Preparation: If necessary, filter the water sample to remove any large particles or debris that may interfere with the filtration process.
iii. Membrane Filtration: Use a sterile membrane filter with a pore size of 0.45 micrometres (pm) or smaller. Place the filter on a filtration apparatus, such as a filter funnel or vacuum filtration system. Pour the water sample onto the filter, allowing it to pass through and retain any bacteria present on the filter.
iv. Incubation: Transfer the filter onto a selective agar medium that supports the growth of coliform bacteria, such as m-Endo LES agar. Incubate the agar plates at the appropriate

temperature (usually 35-37°C) for a specified period of time (typically 24-48 hours) to allow the coliform bacteria to grow and form visible colonies.

v. Colony Counting: After the incubation period, visually inspect the agar plates for the presence of coliform colonies. Count the number of colonies that exhibit typical coliform characteristics, such as red or pink coloration on mEndo LES agar. Record the colony count as the total coliform count.

Hypotheses Testing

The paired t-test is a statistical tool that is used to compare means from the same group at different times. It was employed to compare the means of the amount of the physiochemical parameters analysis results of water samples collected in the two seasons (raining and dry season) under the following assumptions:

1. Normality: The data were normally distributed, as confirmed by the ShapiroWilk test.
2. Dependence: The samples were dependent, as the data were collected from the same participants.
3. Homogeneity of variance: The variances of the two groups were equal, as confirmed by Levene's test.

Paired T-Test Procedure

i. Calculation of the mean and standard deviation: The mean and standard deviation of the differences were calculated as presented in the formular.

$$t = \frac{\Sigma d}{\sqrt{\frac{n(\Sigma d^2) - (\Sigma d)^2}{n-1}}}$$

Where d: difference par paired value, n: number of samples

ii. Performing the paired t-test:
Statistical software package (Excel) was used to perform the paired ttest. The test calculated the tstatistic, degrees of freedom, and pvalue.

iii. Interpret the results: If the p-value is below your chosen significance level (e.g., 0.05), reject the null hypothesis that the means of the two seasons are equal. This indicates a statistically significant difference between means of number of residues in samples for the two seasons.

4.0 DISCUSSION OF RESULTS

Table 4.1: *Summary of analysis for wet season*

Parameters	Sample A	Sample B	Sample C	Sample D	Sample E	WHO	NESREA
pH	7.43	7.47	6.9	7.1	7.76	6.5-8.5	6-9
Temperature (°C)	28.3	27.1	28.2	26	28	Ambient	Ambient
EC (µS/cm)	445.4	1007	980	1000	978		1000
TDS (mg/L)	172	2014	1962	2003	1955	500-1000	2000
TSS (mg/L)	7	653	609	700	639	10-30	30
Turbidity (NTU)	4.67	152	139	141	122	5	10
Sulphate (mg/L)	5.34	23	25	22	20	200	290
Nitrate (mg/L)	0.8	57	57	51	58	50	10
Total phosphorous (mg/L)	0	49	42	39	36	1.0-2.0	2
Fluoride (mg/L)	0.55	0.75	1.01	1.2	0.9		
Total coliform (cfu/100 ml)	tntc	tntc	tntc	tntc	tntc	200-1000	400
Feacal coliform (cfu/100 ml)	2678	tntc	tntc	tntc	tntc	200-1000	NT
BOD (mg/L)	2.9	36	36	36	36	10-30	30
COD (mg/L)	0.4	40	40	41	41	50-125	80
DO (mg/L)	8.39	0.49	0.029	0.029	0.029	5	5
Iron mg/L	0.00	54	38	29	32	0.05-0.3	1
Lead mg/L	0.00	11	7	7	5	0.1	0.01
Copper mg/L	0.011	9	9	9	9	0.05-1.5	1
Zinc (mg/L)	1.6	10	8.9	8.45	7.8	0.5-5	2

BOD; Biological Oxygen Demand, COD; Chemical Oxygen Demand, DO; Dissolved Oxygen, NT; Not detectable. TNTC; Too Numerous to Count, EC; Electrical conductivity, TDS; Total Dissolved Solids, TSS; Total Suspended Solids

4.4 Comparison of the World Health Organization-WHO to the National Environmental and Regulations Enforcement Agency-NESREA Standards

Table 4.3: Standards for WHO and NESREA

Parameters	WHO	NESREA
pH	6.5-8.5	6-9
Temperature (°C)	Ambient	Ambient
EC (µS/cm)		1000
TDS (mg/L)	500-1000	2000
TSS (mg/L)	10-30	30
Turbidity (NTU)	5	10
Sulphate (mg/L)	200	290
Nitrate (mg/L)	50	10
Total phosphorous (mg/L)	1.0-2.0	2
Fluoride (mg/L)		
Total coliform (cfu/100 ml)	200-1000	400
Feacal coliform (cfu/100 ml)	200-1000	NT
BOD (mg/L)	10-30	30
COD (mg/L)	50-125	80
DO (mg/L)	5	5
Iron mg/L	0.05-0.3	1
Lead mg/L	0.1	0.01
Copper mg/L	0.05-1.5	1
Zinc (mg/L)	0.5-5	2

BOD; Biological Oxygen Demand, COD; Chemical Oxygen Demand, DO; Dissolved Oxygen, NT; Not detectable, TNTC; Too Numerous to Count, EC; Electrical conductivity, TDS; Total Dissolved Solids, TSS; Total Suspended Solids

The sources of primary data embraced by this research were analysis of water samples that were collected from the sites, these include; the effluent from the Wupa treatment plant-sample A, surface (river) water samples (sample B, sample C, sample D and sample E) down-stream (after the facility).

From the procedures of laboratory analysis, physicochemical and biological parameters of the WWTP effluent and the receiving surface water were analyzed with four heavy metals also was considered. The following results were obtained from the various water samples, a total of five (5) water samples were collected from different locations within the study area and analyzed. These include the effluent water samples from outlet of WWTP (Sample A), surface water samples (sample B, sample C, sample D and sample E) down-stream (after the facility) for wet and dry season show in Table 4.1 and Table 4.2 above.

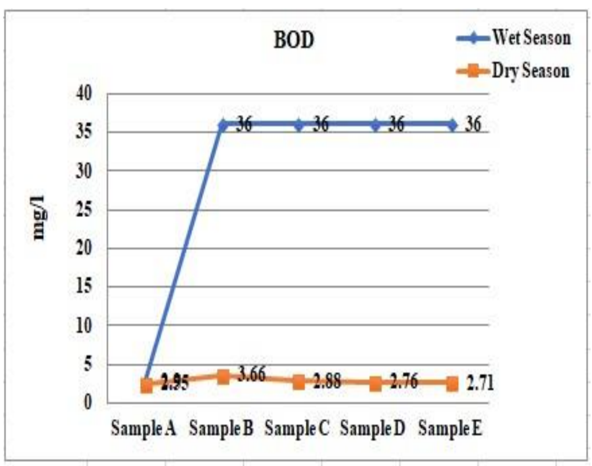
Biological Oxygen Demand (BOD)

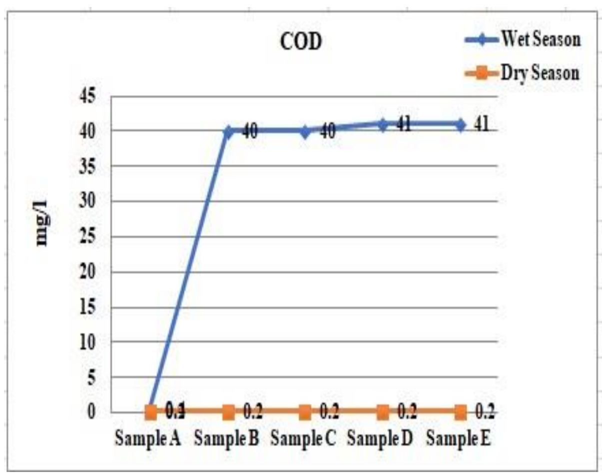
The biological oxygen demand (BOD) of the water (surface) samples generally varied from 36 to 41 mg/L during the wet season, throughout the study period with the treated effluent sample ranging between 2.9 mg/L for the wet season and 2.55 mg/L for the dry season (Table 4.1 and Table 4.2). The values obtained in wet season were higher than the environmental standards (WHO and NESREA), leading to oxygen depletion, eutrophication and imbalance of aquatic food web. Also impact the aquatic biodiversity, leading to loss of sensitive species, decline in reproduction habitat destruction and proliferation of tolerant species. The increased of BOD concentrations during wet season could be attributed to run-off washed into water body. The values of the BOD for dry season fell within the recommended limits as stated in
points

Chemical Oxygen Demand (COD)

The chemical oxygen demand (COD) of the wet season surface water samples generally varied from 40 to 41 mg/L throughout the study period with the treated effluent samples ranging between 0.4 mg/L (wet season) and 0.2 mg/L (dry season) as analyzed in Table 4.1 and 4.2. The values obtained in all surface water samples for wet seasons were higher than the dry season and within the environmental standards of WHO (50-125 mg/L) and NESREA (50 mg/L). Higher levels of COD were observed upstream and downstream of the discharge points in wet season. The increased of COD concentrations during wet season could be attributed to run-off washed into water body.

This is undesirable since continuous discharge of effluent has impacted the receiving water body to some extent and this may have negative effects on the quality of the freshwater and subsequently cause harm to the aquatic life especially fish, downstream (Morrison et al., 2001).





the WHO (10 -30 mg/L) and NESREA (30 mg/L) guidelines.

Figure 1.0: *BOD variation for 5 sampling*

Figure 2.0: *COD variation for 5 sampling points*

Total Suspended Solids (TSS)

The total suspended solid (TSS) profile of the treated effluent from the Wupa WWTP and receiving water body samples vary significantly and ranged from 609 to 700 mg/L during wet season (due to runoff) as analyzed in Table 4.1; 8 to 16 mg/L during dry season (Table 4.2) for the surface water. The treated effluent in particular had TSS ranges of 7mg/L for the wet season to 5mg/L for the dry season and these fell within the allowed limits of 10 to 30 mg/L (WHO) and 50mg/L (NESREA) illustrated in Figure 4.4. These TSS concentrations automatically influenced the quality of the water body, providing optimal light penetration, stable habitat, pollution regulation and balanced hydrological processes amongst others. Elevated TSS (surface water during wet season of points B, C, D and E) can be toxic to freshwater animals by causing habitat degradation, reduced light penetration, depletion, impaired feeding. oxygen mechanism, disrupt aquatic food web and long term biodiversity -causing sensitive species to become locally extinct due to unfavorable conditions.

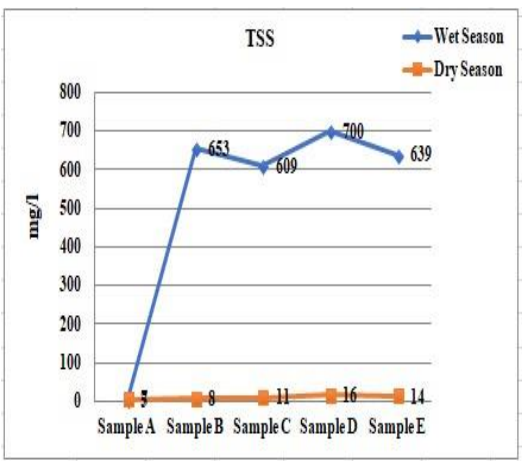


Figure 3.0: *TSS variation for 5 sampling points*

Table 4.2: *Summary of analysis for dry season*

Parameters	Sample A	Sample B	Sample C	Sample D	Sample E	WHO	NESREA
pH	7.2	7.3	7.4	7.4	7.4	6.5-8.5	6-9
Temperature (℃)	23.2	23.2	23.4	23.2	23.2	Ambient	Ambient
EC (µS/cm)	333	283	243	240	240		1000
TDS (mg/L)	166	141	121	119	122	500-1000	2000
TSS (mg/L)	5	8	11	16	14	10-30	50
Turbidity (NTU)	4.97	3.54	2.57	2.33	2.39	5	10
Sulphate (mg/L)	5.40	5.70	6.00	5.64	5.55	200	290
Nitrate (mg/L)	0.80	0.86	9.40	8.78	8.88	50	10
Total Phosphorus (mg/L)	0	0	0	0	0	1.0-2.0	2.0
Fluoride (mg/L)	0.51	0.52	0.54	0.54	0.54		
Total Coliform (cfu/100mL)	tntc	tntc	tntc	tntc	tntc	200-1000	400
Feacal Coliform (cfu/100mL)	tntc	tntc	tntc	tntc	tntc	200-1000	NT
BOD (mg/L)	2.55	3.66	2.88	2.76	2.71	10-30	30
COD (mg/L)	0.2	0.2	0.2	0.2	0.2	50-125	80
DO (mg/L)	8.35	11.3	11.7	11.20	11.21	5	5
Iron (mg/L)	0.00	0.00	0.00	0.00	0.00	0.05-0.3	0.3
Lead (mg/L)	0.00	0.00	0.00	0.00	0.00	0.1	0.01
Copper(mg/L)	0.014	0.013	0.012	0.011	0.012	0.05-1.5	1
Zinc(mg/L)	1.8	1.9	2.0	2.1	1.94	0.5-5	2.0

BOD; Biological Oxygen Demand, COD; Chemical Oxygen Demand, DO; Dissolved Oxygen, NT; Not detectable. TNTC; Too Numerous to Count, EC; Electrical conductivity, TDS; Total Dissolved Solids, TSS; Total Suspended Solids

Total Coliform

Total coliform counts are TNTC, confirming severe microbiological pollution. This indicates contamination from untreated or inadequately treated wastewater and runoff during wet season also amplifying the microbial pollution, making the water unsafe for most uses by the Zhidu settlement.

Feacal Coliform

The high level (TNTC) of pathogenic indicators (Salmonella, Shigella) in surface water and WWTP effluent samples suggest that the WWTP's effluent may be untreated or inadequately treated for harmful bacteria. However, this could also be a function of runoff during wet season.

The National Environmental Standard and Regulations Enforcement Agency and the World Health Organization's (WHO) guidelines provide a comprehensive overview of fundamental parameters crucial in evaluating water quality. From table 4.3, both standards converge on specific aspects, notably the agreed upon pH range of 6.5 to 8.5, serving as a consensus on acceptable acidity levels in drinking water. This alignment signifies a shared understanding of the importance of pH in ensuring safe water for consumption.

However, notable discrepancies arise in other metrics. For instance, while NESREA sets a specific limit of 10.0 NTU for turbidity, WHO does not explicitly define a threshold of 5.0 NTU, suggesting potential variations in approaches regarding water clarity regulation. Moreover, distinctions are evident in the regulation of conductivity and Total Dissolved Solids (TDS). NESREA specifies maximum limits of 1000 uS/cm for conductivity and 1000 mg/L for TDS, emphasizing the importance of controlling dissolved solids in water. In contrast, WHO's guidelines lack a defined upper limit for conductivity, signaling a divergence in regulatory specifications. Additionally, variations exist in acceptable levels of nitrate, sulphate concentrations between the two standards while fluoride concentrations had no define limits, with WHO often proposing more stringent limits compared to NESREA. These disparities underline differing regulatory perspectives and thresholds, providing insights into the nuances of water quality assessment and the variations in permissible limits outlined by these regulatory bodies.

Self-Purification Potential of Wupa River

Self-purification potential is imperative and was assessed based on the variations observed at the sampling points. This is an indication that the river possesses high self- purification potential. Thus, Wupa River has a fair assimilative capacity both in the rainy (wet) and dry seasons that can withstand some level of unexpected spills from the plant. This ability to undergo self-purification is aided by the presence of rock outcrops and boulders along the river channel.

Summary of findings

The study evaluated the impact of the Wupa Wastewater Treatment Plant (WWTP) effluent on the Wupa River in the Zhidu settlement by analyzing physical, chemical, microbiological parameters, and heavy metals to assess water quality suitability for consumption. The analysis revealed significant findings across different seasons and parameters.

The examination of physical parameters showed that surface water had a slightly alkaline pH, ranging from 7.76 in the wet season to 7.4 in the dry season, while the WWTP effluent exhibited a neutral pH range of 7.2 to 7.43. Turbidity levels were consistently higher in surface water during the wet season, indicating a higher concentration of suspended particles, including organic matter and possibly other contaminants.

High turbidity values exceeded the World Health Organization (WHO) limit of 5.0 NTU, making the water aesthetically poor and unsafe for consumption. Total Dissolved Solids (TDS) also exceeded WHO and NESREA limits of 500–1000 mg/L at certain points during the wet season, particularly at sampling point B, raising concerns about the water's taste and suitability for consumption.

Chemical parameters revealed that Dissolved Oxygen (DO) levels in surface water fluctuated significantly, ranging from 0.049 mg/L in the wet season to 11.21 mg/L in the dry season. In contrast, the WWTP effluent demonstrated stable DO levels between 8.35 and 8.39 mg/L. Concentrations of heavy metals, including iron, copper, and zinc, varied between surface water and effluent. Zinc levels at the discharge point were particularly notable, contributing to higher conductivity values, which occasionally exceeded WHO standards during the wet season.

Microbiological analyses showed the presence of total coliforms in both surface water and effluent, with pathogenic indicators such as Salmonella and Shigella detected. This indicates that the treatment processes at the WWTP were insufficient to eliminate harmful microorganisms, raising concerns about the microbiological safety of the water.

The study highlighted the vulnerability of surface water to external influences, including anthropogenic activities and surface runoff, particularly during the season. While some parameters, such as pH and conductivity during the dry season, fell within WHO and NESREA limits, others, such as turbidity, TDS, and microbiological indicators, exceeded acceptable levels. These findings emphasize the need for improved treatment processes, alignment of local water quality standards with international benchmarks, and continuous monitoring of water quality. The research provides a foundation for understanding the interplay between effluents and water sources, guiding future interventions to enhance water resource management in the Zhidu settlement.

Result of Paired Sample t-test for Difference of Means of the Amount / Concentration of Samples Analysis Results for Rainy and Dry Season

From Table 4.4, the paired sample t-test result shows significant variation in the presence of the water quality parameter from the samples collected at designated locations.

A total number of 17 water quality parameters were tested for significant difference of the amount present during the raining and dry seasons, and sixteen were revealed to have significant difference the seasons. The details are presented as follow

Table 4.4: Paired T-test Result Difference Mean

	Raining season		Dry season		
Parameters	Mean	Standard Deviation	Mean	Standard Deviation	t-value
pH	1.991404	0.045989	0.99279	0.012247	-0.08237
Temperature (°C)	3.314404	0.035847	3.145869	0.003834	10.91254
EC (µs/cm)	6.738904	0.357955	5.581586	0.144589	5.299936
TDS (mg/L)	7.103528	1.093531	4.892147	0.145076	4.058539
TSS (mg/L)	5.570058	2.02658	2.299684	0.46728	4.409224
Turbidity (NTU)	4.251314	1.514701	1.114949	0.315907	3.919922
Sulphate (mg/L)	2.823274	0.646808	1.730651	0.040187	3.946314
Nitrate (mg/L)	3.171046	1.898099	1.244604	1.30736	2.888145
Total Phosphorus (mg/L)	2.975314	1.667128	0	0	3.990698
Fluoride (mg/L)	-0.15972	0.298771	-0.63517	0.026889	3.330668
BOD (mg/L)	3.079757	1.126445	1.060705	0.139395	4.24453
COD (mg/L)	2.777722	2.065053	-1.60944	0	4.750478
DO (mg/L)	-1.84154	2.533842	2.367875	0.138456	-3.54369
Iron (mg/L)	2.89192	1.633862	0	0	3.95782
Lead (mg/L)	1.579831	0.926553	0	0	3.812637
Copper(mg/L)	0.855808	2.999499	-4.39341	0.091389	3.823594
Zinc (mg/L)	1.829386	0.585612	0.665483	0.003303	3.590428

Biological Oxygen Demand (BOD); Chemical Oxygen Demand (COD); Dissolved Oxygen (DO); Too Numerous to Count (TNTC); Not Count (NT); Electrical conductivity (EC); Total Dissolved Solids (TDS); Total Suspended Solids (TSS).Note: ($P<0.05$), df = 4, t-critical = 2.7764

5.0 CONCLUSION

From the study, it is concluded that there exists a seasonal variation in the water quality of Wupa river. In conclusion, this study provides valuable insights into the complex dynamics of water quality in Zhidu, focusing on the impact of the WWTP. The analysis of physical, chemical, and microbiological parameters with four heavy metals in surface water sources indicated that the WWTP is generally effective and helps in preventing pollution of surface water sources downstream its discharge point(s).

The study assessed the impact of WWTP effluents on Wupa river. The findings confirmed that all the physicochemical parameters and heavy metals (Fe, Cu, Pb, and Zn) of the effluent examined were within the World Health organization (WHO) and National Environmental Standard and Regulations Enforcement Agency (NESREA), except for biological parameters which were higher than the required amount.

RECOMMENDATION

The recommendations provided below suggest improvements that can be made by the government and WWTP authorities and in future developments of WWTPs in Nigeria to ensure sustained effective removal of pollutants in wastewaters. The recommendations are as follows:

There must be continuous monitoring of the efficiency of the wastewater treatment plant so as to ensure sustained adherence to standardized permissible standards. Looking at the advantages of sewage treatment plant to human health and environment, there is need for a deliberate policy by the government to construct more sewage treatment plants in our states and local government areas.

Surrounding communities can also increase their voice within the network through political participation, such as voting for new political officials, writing and petitioning to legislators, and rallying at town hall meetings. Forming these coalitions could increase communication, foster a more inclusive atmosphere, and advance opportunities for further discussion between different actors in the WWT (wastewater treatment) network. It also has the ability to remind WWTPs of their responsibilities and hold government officials accountable to their constituents. All of these recommendations offer more promising and effective steps to address the omnipresent issue of fence-line community marginalization.

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