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# A COMPARATIVE STUDY OF TREATED WASTEWATER EXITING BIOREACTOR AND UV SECTION OF ABUJA SEWAGE TREATMENT PLANT WUPA

**Samuel Shamaye Silas[*1], Enumah Amarachukwu[2], Abdullahi Mohammed Evuti[2], Atoyebi Abdulraheen Babatunde[3], Awominure Alice Ajoke[1] and Ijeoma Blessing Enumah1**

1 Department of Chemical Engineering, University of Abuja
2 Department of Chemical Engineering, University of Calabar
3 Department of Microbiology, University of Calabar

**Author for correspondence:** Samuel Shamaye Silas**; Email:** silassamuel22@gmail.com

**Abstract -** Water is essential but scarce, necessitating effective wastewater treatment. This study evaluates the basic water quality parameters of UV light-treated and bioreactor wastewater at the WUPA treatment plant. Winkler method, APHA method 4500, 5210, 2540c, and 2540d were used for physicochemical analysis while direct plate count and membrane filtration method were utilized for bacteriological analysis. Three samples were collected using the grab sampling method at three locations: inlet (influent) point and outlet (effluent) point of the reactor, and UV-treated water. The result showed that hydrogen ion concentration (pH), electrical conductivity (EC), dissolved oxygen (DO), total dissolved solids (TDS), temperature, biochemical oxygen demand (BOD), chemical oxygen demand (COD), total suspended solids (TSS), Nitrate, total coliform count (TCC), E. coli, Shigella and salmonella for influent were 6.59, 312 µs/cm, 3.15 mg/l, 144 mg/l, 25.8$^0$C, 50 mg/l, 284 mg/l, 262, 12.2 mg/l, 20000 CFU/ml, 6000 CFU/ml, 200 CFU/ml and ND respectively. The corresponding parameters for the effluent exiting the bioreactor were 6.75, 301 µs/cm, 7.45 mg/l, 141 mg/l, 26 mg/l, 16 mg/l, 280 mg/l, 262 mg/l, 3.9 mg/l, 20000 CFU/ml, 6000 CFU/ml, 20 0 CFU/ml and ND respectively and the effluent exiting the UV unit were 6.9, 294 µs/cm, 12.65 mg/l, 98 mg/l, 26.4$^0$C, 4.7 mg/l, 14 mg/l, 12.6 mg/l, 5.6 mg/l, 67 CFU/ml, 30 CFU/ml, 10 CFU/ml and ND respectively. The result for effluent exiting the bioreactor and UV units respectively met the Federal Ministry of Environment and World Health Organization (WHO) acceptable limit except for TSS which was slightly above the Federal Ministry of Environment limit for effluent discharge while DO was found not within the WHO limit. The study indicated that the final treated effluent can be safely discharged into river or used for industrial and domestic activities. However, monitoring will be crucial in sustaining these positive outcomes over time.

**Keywords: Wastewater, Environment, WUPA treatment plant, UV, WHO**

## 1. Introduction

Water is a substance composed of chemical elements, hydrogen, and oxygen, and it is in the form of gaseous, liquid, or solid states (Treacy, 2019). It is one of the most abundant and essential compounds. Water is a transparent, colourless, and odourless liquid (at room temperature) that forms the sea, lake, river, and rain, and it is the basis of fluid in living organisms (Jahan and Strezov, 2017; Benjian *et al.*, 2021). It has the essential ability to dissolve many substances (Lumb *et al.*, 2017). The usefulness of water as a solvent is indispensable to living organisms (Ghernaout *et al.*, 2018). In the past, due to low population and underutilization of water, it was not difficult to get portable water for domestic and irrigational purposes (Tadokoro *et al.*, 2011).

Portable water scarcity has become a global phenomenon (ITU News, 2020). When the governments of African countries were required by the World Health Organization (WHO) to prioritize their environmental health concerns, the results revealed that water quality was identified as the most important problem (Scheinberg *et al.*, 2018).

In this case, Nigeria is not an exception. In 2018, it was revealed that sixty (60) million Nigerians lacked access to drinking water (World Bank, 2021). UNICEF revealed in its classical study in 2020 that, one-third of Nigeria's population still drinks contaminated water (UNICEF, 2020). Thus, the scarcity of water necessitates the need for water treatment especially from sewage.

Sewage refers to all forms of liquid waste generated from both natural and human activities (Balasubramanian, 2011). It principally consists of approximately 80 percent (80%) of water or liquid, while twenty percent (20%) comprises solids or semi-solid particles such as debris, quartz, heavy metals, cellophane, and even fecal matter (Rakesh *et al.,* 2016). Sewage comprises wastewater discharge from residential, commercial, institutional, and public facilities that exist within a locality (Rattier *et al.,* 2012).

Sewage sub-types are greywater (sewage from sinks, bathtubs, showers, and washing machines) and blackwater (comprised of water used to flush toilets and human waste). Sewage, also, contains soaps and detergents (Reem *et al.*, 2021). In regions where toilet papers are used rather than bidets, the papers are also added to the sewage. Sewage contains macro-pollutants and micro-pollutants and may combine some municipal solid waste and pollutants from industrial wastewater (Amarachukwu *et al*., 2020).

Sewage usually travels from building plumbing either into a sewer, to be transported elsewhere, or into an onsite sewage facility for treatment (Poblete *et al*., 2022).

Polluted water undergoes three basic stages of treatment before it can be termed "treated" (Poblete *et al*., 2022). The primary treatment is the mechanical stage which involves sedimentation, the removal of solid wastes such as debris, silt, sand, heavy metals and semi-solid matter. Chemical can also be added as coagulants to remove more solids (Kairat *et al*., 2022).

The biological or secondary treatment involves the removal of soluble organic matter. It also deals with smaller suspended solids - this treatment takes place in the aerator basin and is distinguished by the addition of air, oxygen, and partially treated sewage in the bioreactor (Kairat *et al*., 2022; Poblete *et al*., 2022). Water that has undergone secondary treatment can be released into the environment without damage to aquatic life and ecosystems (Drechsel *et al*., 2022; Mazhar *et al*., 2022). WUPA wastewater treatment plant in Federal Capital Territory (FCT) Abuja is one of the facilities where treatment of water is carried out in Nigeria (Chukwu and Oranu 2018).

Tertiary treatment sterilizes water to the highest standards. This stage is necessary to produce water to specification, such as technical water, and treated wastewater for public consumption (Lisa *et al*., 2015). Tertiary treatment methods include Ultraviolet disinfection (UV disinfection) and Chemical disinfection (Abhijeet and Isha, 2016).

This research is, therefore, aimed at evaluating the basic water quality parameters of water in WUPA Treatment Plant such as the biochemical oxygen demand (BOD), hydrogen ion concentration (pH), electrical conductivity (EC), dissolved oxygen (DO), total dissolved solids (TDS), temperature, Nitrogen as nitrate, as well as the total coliform count (TCC). The objectives are to determine the basic water quality indicators of the final clarified effluent and the bioreactor wastewater; carry out bacteriological analysis of the sample; and compare the results of final clarified water with the standards admissible by the Federal Ministry of Environment (FMEnv.) limit for effluent discharge and World Health Organization (WHO).

## 2. Materials and Method

### 2.1 Study area

WUPA wastewater treatment plant is in the capital city of Nigeria. It lies between longitude $7^o17'000"$ west and $7^o22'12''$east and latitude $8^o56'48''$ north and $9^o01'48''$ south respectively (Abdulahi *et al.,* 2012; Samson and Ogwueleka, 2021). The region has an average temperature of $29^oC$ during the hot season and $9^oC$ during the cold season of the year. The average rainfall of the area is 68mm during the rainy season and 10mm during the dry season (Samson and Ogwueleka, 2021).

WUPA wastewater treatment plant is an eco-friendly project, designed to treat sewage generated around Federal Capital City (FCC). The plant adopts an activated sludge system with removal efficiency of over 90% and 99% as reported by Chukwu and Oranu in their classical study (Ukpong, 2013; Chukwu and Oranu 2018).

### 2.2 Sample collection

The sample bottles were first rinsed with distilled water after which they were thoroughly rinsed with the samples to be collected. This was done basically to ensure precision during the measurements of the parameters.

Three samples were collected using the grab sampling method. The first sample was collected at the inlet (influent) point of the reactor, the second sample at the outlet (effluent) point of the reactor, and the third sample, which is the clarified water, was collected after UV treatment was carried out. The sample bottles were properly labeled and taken to the laboratory for analysis.

### 2.3 Sampling parameters

A total of thirteen (13) parameters, comprising ten (9) physicochemical and three (4) bacteriological parameters, were analyzed. The physicochemical parameters include pH, electrical conductivity (EC), dissolved oxygen (DO), total dissolved solids (TDS), temperature, ammonia as nitrate and biochemical oxygen demand (BOD), carbon oxygen demand (COD), total suspended solid (TSS) and the biological parameters comprise; total coliform count (TCC) and fecal coliforms: *E. coli, Shigella,* and *Salmonella* count.

### 2.4 Sampling procedure

Following the permissible limits for effluent discharge water quality by the Environmental Protection Agency (EPA) and Nigerian Effluent Discharge, the following methods are used for sample quality test:

"Winkler method with azide modification" was followed for dissolved oxygen (APHA, 1998; part 4500-OC p. 4-131); "Brucine method" APHA method 4500 was followed for Nitrate, APHA standard method 5210 for examination of Biochemical Oxygen demand for water and wastewater was adopted, TDS examination was carried out in accordance to APHA standard method 2540c and 2540D 20th edition. Electrical conductivity and pH were measured with a calibrated HANNA HI 9813-6 instrument. The direct plate count method and membrane filtration method were utilized for the bacteriological analysis. The difference and percentage difference were calculated using equation 1 and 2 below (IEC, 2019):

$$d_f = E_{BI} - E_{UV} \qquad \textbf{(1)}$$

$$\%d_f = \frac{(E_{BI} - E_{UV})100}{E_{BI}} \qquad \textbf{(2)}$$

Where:

$d_f$ = Difference, $\%d_f$ = Percentage difference, $E_{BI}$ = Effluent after bioreactor, $E_{UV}$ = Effluent after UV treatment

## 3. Results and Discussion

The result of the analysis of the bioreactor wastewater and the effluent after UV treatment is shown in table 1 for both physiochemical and biological analysis.

### 3.1 Physico–chemical Analysis Result

**1. pH**

The result of the analysis from Table 1, shows that the pH of the bioreactor wastewater is 6.59 while the effluent after UV treatment is 6.90. This shows a percentage difference of 2.23% in the value of pH after the UV treatment process, indicating an increase in the pH of the treated water. This increase occurred as a result of an increase in the temperature of the water caused by the UV light and the sun. As the water temperature increases, the solubility of carbon dioxide decreases causing the pH to rise (Abhijeet and Isha, 2016; Aneke and Ademiluyi, 2021). The increase also suggests that the effluent is more acidic exiting the bioreactor but less acidic (approximately neutral) after UV treatment. The result agrees with the classical work of Ibrahim and Mohammed, (2001), who determined in their study that, the pH of effluent has an average difference of $\pm 2.6$. However, Sinta and Sutrasno, (2018), reported, in the study conducted in a Tofu water treatment plant, a decrease in the pH to $\pm 1.2$ after treatment.

**Table 1: Results of the analysis of the bioreactor wastewater and the effluent after UV treatment**

| S/N | Parameters | Influent | Effluent After Bioreactor | Effluent After UV Treatment | Difference | % Difference |
|---|---|---|---|---|---|---|
| 1 | pH | 6.59 | 6.75 | 6.9 | -0.15 | -2.23 |
| 2 | EC (μs/cm) | 312.0 | 301.0 | 294 | 18 | 5.77 |
| 3 | DO (mg/l) | 3.15 | 7.45 | 12.65 | -5.2 | -69.80 |
| 4 | TDS (mg/l) | 144.0 | 141 | 98 | 43 | 30.49 |
| 5 | Temperature (°C) | 25.8 | 26.0 | 26.4 | -0.8 | -3.08 |
| 6 | BOD (mg/l) | 50.0 | 16.0 | 4.7 | 11.3 | 70.63 |
| 7 | COD | 284 | 280 | 14 | 266 | 95.00 |
| 8 | TSS | 262 | 262 | 12.6 | 249.4 | 95.20 |
| 9 | Nitrate (mg/l) | 12.2 | 3.9 | 5.6 | -1.7 | -43.59 |
| 10 | TCC (CFU/ml) | 20000 | 20000 | 67 | 19933 | 99.67 |
| 11 | E. coli (CFU/ml) | 6000 | 6000 | 30 | 5970 | 99.50 |
| 12 | Shigella (CFU/ml) | 200 | 200 | 10 | 190 | 95.00 |
| 13 | Salmonella (CFU/ml) | ND | ND | ND | - | - |

**2. Electrical Conductivity (EC)**

The result in Table 1 above indicated that the, EC of the influent and the effluent exiting the bioreactor is 312.0 μs/cm and 301.0 μs/cm while the effluent exiting the UV unit is 294.0 μs/cm respectively showing a decrease in EC after UV treatment. At a normal state, the EC of wastewater at the inlet is higher than the EC at the exit point after treatment. This may occur as a result of the effect of pH and change in temperature. The high pH of water indicates a high concentration of ions and vice versa, hence the drop in EC of the effluent exiting the UV unit.

**3. Total Dissolve Solids (TDS)**

According to the allowable WHO standards, any water with TDS level lower than 300mg/l is fit for use (WHO, 2020). One with a TDS level between 300 and 600mg/l is good and between 600 and 900mg/l is fair (WHO, 2020). As regards TDS level, a poor water is one between 900 and 1200mg/l and an unacceptable water is one greater than 1200mg/l (WHO, 2020). with this classification, the influent wastewater and effluent wastewater exiting the bioreactor with values 144mg/l and 141mg/l respectively, are termed good water and are safe for ejection. However, further treatment by UV method dropped the value to 98mg/l (Table 1). Therefore, making it better for disposal into the environment or used for industrial and domestic activities. The low values of TDS specify the presence of high amounts of anions and cations in the wastewater. Magda *et al.* reported that high concentration of some ion may harm animals and causing foliar injury to plant (Magda *et al.*, 2015). Additionally, sodium has harmful effect toxic effect for plant while excessive nitrate absorption may cause significant increases of nitrogen inorganic tissue thereby modifying biomass growth, and sensitivity during drought (Fang *et al*., 2011).

**4. Dissolve Oxygen (DO) and Biochemical Oxygen Demand (BOD)**

Dissolve oxygen (DO) is the amount of Oxygen in water supply (EPA, 2021). Table 1 shows a relative increase in DO for the influent, effluent exiting the reactor and effluent after the UV treatment. This indicates a percentage increase of 69.8% DO in the treated water. The increase is as a result of the availability of residue oxygen which results from the supply of oxygen to accelerate aerobic microbial biodegradation. A corresponding decrease of the BOD across the influent, effluent exiting the reactor and effluent after UV treatment with values 50.0 mg/l, 16.0mg/l and 4.7 mg/l respectively leading to a 70.63% decrease in BOD after UV treatment. This is due to the minimal quantity of organic matter present in the effluent which may require less amount of DO for decomposition to occur. This corresponding increase in DO and decrease in BOD agrees with the inverse relationship between DO and BOD (Madhulekha *et al.*, 2017). Madhulekha *et al.,* (2017), further reported that there is a negative correlation between DO and BOD in their classical study.

**5. Chemical Oxygen Demand (COD)**

The COD result, Table 1, indicates a decrease across the influent, effluent exiting the reactor and effluent after UV point with the values 284 mg/l, 280 mg/l and 14 mg/l. This difference occurs as a result of low quantity of organic and inorganic materials present in the effluent which requires minimal concentration of DO for the breakdown of the organic material. The high value of COD in the influent is an indication of the presence of high organic and inorganic materials or high oxygen demanding pollutants.

**6. Total Suspended Solid (TSS)**

The TSS is attributed to the level of materials carried in suspensions. These materials include food particles, wood particles, clay particles, plankton, silt and algae. The high value, 262 mg/l of TSS for both the influent and effluent exiting the reactor is an indication that the wastewater is polluted by high amounts suspended materials. The effluent value, 12.6 mg/l, after UV treatment is an indication of high performance of the plant with removal efficiency of 95.2%. This result is in agreement with Chukwu and Oranu, (2018) findings.

**7. Nitrate**

Nitrate is a final product of aerobic stabilization of nitrogenous compounds (El-Lateef *et al.*, 2022). The nitrate level of wastewater is a measure of the ability of the micro-organisms to breakdown or degrade nitrates to nitrites (Sinta and Sutrasno, 2018). Most denitrifying bacteria possess this ability (Chukwu and Oranu, 2018). The treated water has a nitrate level of 3.9mg/l with a 43.59% increase from the bioreactor wastewater. The increase in the level of nitrate is as a result of the biological denitrification process used for the wastewater treatment (Federico *et al*., 2015).

**8. Temperature**

The temperature of water in the WUPA wastewater treatment plant is greatly influenced by climatic conditions. However, the permissible standards allowed by Nigeria effluent limit and EPA is the ambient or room temperature which lies between 30.0-40.0°C. The temperature of the bioreactor water is 25.8°C while that of the UV treated is 26.4°C. The temperature difference between the influent and the UV Effluent treated is 0.6°C. The temperature which fell below ambient temperature may have resulted from the loss of heat to the surrounding environment due to exposure (Jaroslav *et al.*, 2018). Ubwa *et al.*, (2013), noted that the dissolved oxygen level of a given sample of water is greatly influenced by its temperature.

**3.2 Microbiological Result Analysis**

**1. Total Coliform Count (TCC)**

The TCC is regarded as an indicator to measure water quality. The TCC shows a variation in the wastewater at the influent, effluent exiting the reactor and effluent after UV treatment. The TCC of the influent and effluent exiting the reactor was 20000 CFU/ml while that of the effluent after UV treatment was 67 CFU/ml, indicating high contamination of wastewater with coliform at the influent and effluent exiting the reactor. This also indicates a poor performance of the reactor for coliform removal. But showed a good performance after UV treatment where the coliform count drastically reduced, Table 1.

**2. E Coli**

E Coli is a parameter indicator of water safety, particularly with respect to fecal contamination and the presence of pathogenic bacteria. The E. Coli found in both the influent and effluent exiting the reactor is 6000 CFU/ml. This may be as a result of poor performance of the bioreactor in the removal of E Coli from the wastewater as the quantity of E Coli present in wastewater after treatment helps to assess the performance of the treatment phase (Anastasi *et al.,* 2012). Another reason is due to the persistent ability of E Coli to resist one or more wastewater treatment phases (Daniel *et al.*, 2022), due to the ability to survive treatment processes (Anastasi *et al.,* 2012). However, the quantity of E Coli in the effluent after the UV treatment reduced is 30 CFU/ml. This indicates the performance of the UV treatment phase to be effective.

**3. Shigella**

The shigella count in the wastewater shows 200 CFU/ml for both the influent and the effluent exiting the reactor and 10 CFU/ml for the effluent after UV treatment, Table 1. Shigella in water has the ability to live for up to six months under room temperature (Sherefa *et al.*, 2016) and even in an environment where nutrient is scarce, they do not only survive but also have the ability to increase in virulence (Ali *et al.*, 2010). Shigella does not exist for a long time except in its natural habitat (Anju and Atul, 2008). The decrease in the number of shigella after UV treatment may be as a result of change in temperature (Sherefa *et al.*, 2016) or an alteration in the condition of the wastewater caused by the UV light (Anju and Atul, 2008).

### 3.3 Comparison of UV treated effluent, Nigeria effluent discharge limit and WHO

**Table 2: Result of UV treated effluent, Federal Ministry of Environment limit and WHO**

| S/N | Parameters | Effluent After UV Treatment | FMEnv. Limit | WHO Limit | SD from WHO Limit |
|---|---|---|---|---|---|
| 1 | pH | 6.9 | 6-9 | 6.0-9.0 | 1.485 |
| 2 | EC (µs/cm) | 294 | -- | 1250 | 322.441 |
| 3 | DO (Mg/l) | 12.65 | -- | 7.0-10.0 | 8.238 |
| 4 | TDS(Mg/l) | 98 | 500 | 500 | 976.515 |
| 5 | TSS | 12.6 | 25 | 30 | 17.112 |
| 6 | COD | 14 | 60-90 | 100 | 173.453 |
| 7 | Temperature ($^{o}$C) | 26.4 | 40 | <40 | <11.314 |
| 8 | BOD (Mg/l) | 4.7 | 30-35 | 30 | 26.446 |
| 9 | Nitrate (Mg/l) | 5.6 | 10 | 50 | 31.396 |
| 10 | TCC (CFU/ml) | 67 | -- | 0/100 | 235.467 |
| 11 | E. coli (CFU/ml) | 30 | -- | -- | -- |
| 12 | Shigella (CFU/ml) | 10 | -- | -- | -- |
| 13 | Salmonella (CFU/ml) | ND | -- | -- | -- |

SD= Standard deviation, WHO= World Health Organization, ND = Not Detected, FMEnv.= Federal Ministry of Environment

From table 2, all the water quality parameters were found to be within the Nigerian Effluent Discharge limits. pH, EC, BOD, TDS, TSS, Temperature and nitrate where also found to be within the WHO limit for effluent discharge, except for DO which was above the WHO limit with a deviation of 8.238. The bacteriological analysis result of the effluent after UV treatment has a total coliform count of 2000, *E coli* count of 100, and *Shigella* count of 10 are within the WHO limit for effluent discharge. However, *Salmonella* was not detected.

**Impact of UV Treatment**

Following the implementation of UV treatment, a significant improvement in microbial counts was observed. The TCC dropped to 67 CFU/ml, representing a 99.67% reduction. Similarly, E. Coli levels decreased to 30 CFU/ml, reflecting a 99.50% reduction. Shigella exhibited a 95% reduction, with post-treatment levels at 10 CFU/ml. Importantly, Salmonella remained undetectable both before and after UV treatment.

The effectiveness of UV treatment is evident in the reduction of microbial counts, meeting regulatory standards for safe water quality. The decrease in E. Coli and Shigella is important, as these bacteria pose potential health risks through waterborne transmission.

In addition to its microbiological efficacy, UV treatment offers environmental benefits as a chemical-free process. This aspect aligns with sustainable practices, avoiding the environmental impact associated with certain chemical disinfection methods. However, it is essential to emphasize continuous monitoring to ensure the sustained effectiveness of the UV treatment system.

## 4. Conclusion

The study carried out on the WUPA wastewater treatment plant showed that the water quality parameters for treated water fell within the Nigeria Standard for effluent discharge and World Health Organization acceptable limit for effluent discharge. Parameters such as pH, EC, BOD, TDS, TSS, Temperature, COD and nitrate were identified, evaluated and found to be within the Nigeria Standard for effluent discharge and World Health Organization acceptable limit except for TSS which was slightly above the Nigeria Standard for effluent discharge while DO was found not to meet the WHO limit.

The microbiological analysis underscores the positive impact of UV treatment on water quality, demonstrating its effectiveness in reducing microbial contamination and ensuring the safety of the water sample for various applications.

The study indicates that the final treated effluent can be safely discharged into river or used for other activities. However, ongoing vigilance through monitoring will be crucial in maintaining these positive outcomes over time.

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