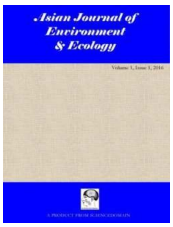

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# Assessment of Effects of Brewery Waste Water Discharge and Self Purification Potential of "Rafin Giya" Stream in Kudenda Industrial Layout, Kaduna Nigeria

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***Authors' contributions***

*This work was carried out in collaboration between both authors. Author UM designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Author PCO managed the analyses of the study and wrote the general structure and final draft of the article. Both authors read and approved the final manuscript.*

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## ABSTRACT

Flowing surface water bodies have natural capacities to purify themselves from pollutions that come into them from external sources. The impact of the effluents of a brewing industry located in Kaduna on Rafin Giya stream and its self-purification potential were investigated. The brewery wastewater effluents were collected and analysed for some physicochemical parameters for a period of 27 days to determine the level of constituents, toxicity level and suitability for its discharge into receiving water body. Water samples were also collected from five points at 200 m interval along the stream covering the upstream and the downstream. The physicochemical parameters determined include: pH, Temperature, Electrical conductivity (EC), Turbidity, Total suspended solids (TSS), Total dissolved solids (TDS), Biological Oxygen Demand ($BOD_5$), Chemical Oxygen Demand (COD), Chlorides and Coliform. The average values of these parameters for the brewery effluents were 3.79, 29.09℃, 1011.8 µs/cm, 6.09 NTU , 1048.9 mg/L, 826.9 mg/L, 1128.8 mg/L,

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2122.1 mg/L, 573.5 mg/L and 1 MPN in respectively. Most of these parameters were found to be higher than the limits set by the National Environmental Standards and Regulations Enforcement Agency (NESREA) in Nigeria for industrial wastewater discharge into receiving water bodies. The physicochemical parameters determined for the stream water also include: pH, Temperature, Total suspended solids (TSS), Turbidity, Chlorides, Biological Oxygen Demand ($BOD_5$), Dissolved oxygen (DO), Electrical conductivity (EC), Total dissolved solids (TDS) and coliform. The values obtained at a point upstream, the brewery effluent discharge point and three points downstream at 200 m intervals were 6.4, 4.0, 4.8, & 4.9; 27℃, 31° C, 31℃, 31℃, & 30℃; 3.8 NTU, 8.1 NTU, 8.0 NTU, 7.8 NTU, & 7.1 NTU; 730 mg/l, 1490 mg/l, 1420 mg/l, & 1340 mg/l; 270 µs/cm, 1480 µs/cm, 1480 µs/cm, 1450 µs/cm, & 1400 µs/cm; 100 mg/l, 1680 mg/l, 1550 mg/l, 1430 mg/l & 12000 mg/l; 14.6 mg/l, 2.8 mg/l, 3.9 mg/l, 4.8 mg/l, & 6.4 mg/l, for pH, Temperature, Turbidity, Electrical conductivity, BOD, and DO respectively. The corresponding self-purification potential exhibited by the stream over a distance of study were found to be 76.6%, 90 .0%, 25.0%, 53.5%, 93.7%, 8.3%, 43.8%, 19.3%, 54.5% and 100% for the parameters respectively. This trend of results compare favourably with literature values on flowing rivers. These results therefore suggested that the brewery wastewater have great pollution impact on the stream water and therefore making it unsuitable for human consumption. The pollution absorbance potential of the stream is low as a result of its low volume and flow rate, although gradual self-purification was observed, it is recommended that careless disposal of such contaminants should be discouraged with strict enforcement of existing legislation and regular monitoring.

*Keywords: Impact assessment; brewery effluent; water pollution; physicochemical parameters; self-purification potential.*

## 1. INTRODUCTION

Industrial, agricultural, domestic and several other human activities have become sources of environmental pollution that cause several health hazards to man. These environmental pollutions include air pollutions from industrial gaseous effluents, exhaust gases from motorists as a result of burning fossil fuels and the indiscriminate burning of bush and solid waste [1]. Water bodies which support aquatic and human lives are also being polluted by discharging untreated industrial wastewater, domestic wastewater and agricultural wash off chemicals into them [2,3,4]. The world's supply of freshwater is limited and threatened by pollution from various human activities. Flowing surface water bodies have natural capacities to purify themselves from pollutions that come into them from external sources [3]. As estimated by WHO [5], "within the next 50 years, more than 40% of the world's population will live in countries facing water stress or water scarcity". Worldwide water bodies are primary means for disposal of wastewater, especially the effluents from industrial, municipal sewage and agricultural practices that are near them. This effluent can alter the physical, chemical, and biological nature of receiving water body [6]. Wastewater effluents are composed mainly of either organic, inorganic matter or both and toxic substance depending on it source. Contamination of the environment by effluent is viewed as an international problem because of the effect on the ecosystem in most countries. In Nigeria, the situation is no better by the activities of most industries and populace towards waste disposal and management which usually leads to the increasing level of pollution of the environment [7]. Such is the case of the industrial wastewater effluents discharge into streams in Kaduna which eventually enter into river Kaduna which is the major surface water body that supplies water for the production of portable water to Kaduna metropolis and environs. The pollution absorbance potential and capacity of river/stream self-purification are important indicators for the river/stream health. Water bodies in flowing state normally have the capacities to purify itself from the contamination of external sources discharge into it [8]. Self-purification process of water involves physical, chemical and biological processes that occur simultaneously which enable the water body to recover its natural state over a certain distance [9]. The purification process greatly depends on absorption and dissolution of atmospheric oxygen from the water body surface. This absorbed and dissolved oxygen (DO) is necessary for the growth of bacteria to break down the biological and chemical pollutants thereby reducing its strength for a period of time. Other natural factors on which self-purification of water bodies depends include the water velocity, depth, discharge and temperature. The

turbulence flow of water bodies helps the river/stream to be very clean because of the natural capacity to absorb and digest pollutants at a very high rate [10]. Stagnant water bodies tend to become septic because of the low rate of oxygen absorption. Most public health diseases such as cholera, diarrhea and ulcer have been recorded as a result of drinking of contaminated water [5]. Thus there is a need to assess the quality of industrial wastewaters being discharged into receiving surface water bodies so as to ascertain compliant with national standard limits for industrial wastewater quality by National Environmental Standards and Regulations Enforcement Agency [11] in order to prevent water pollution and the likely ecological imbalance and associated public health hazards [12].

## 2. MATERIALS AND METHODS

### 2.1 Description of Study Area

The stream "Rafin giya" is located in Kudenda, industrial area of Kaduna Nigeria. The discharge point of the brewery wastewater effluent into the stream is situated at Latitude $10^0$ 28.043' N, Longitude 7° 23.194' E and elevation 592.3m above sea level. The map of the "rafin giya" stream in kudenda and the picture of the wastewater sampling location along the stream are shown in Figs. 1- 2.

### 2.2 Sampling

During this study, sampling of the brewery wastewater effluents was conducted for a period of 27 days within the late dry season and early rainy season. The study area is characterized by two main climatic seasons; the dry and rain seasons. The dry season starts about early October and ends about middle April. The rain season starts about middle April to about early October. The wastewater samples were collected daily from the brewery discharge point into the stream. The samples were collected in new plastic containers which were pre-cleaned by washing with non-ionic detergents, rinsed in tap water and distilled water before sampling. The containers were rinsed thoroughly with the wastewater sample before being filled with the wastewater and taken for physicochemical analysis. The temperatures of the samples were taken at the point of collection using portable digital thermometer and the samples were then transported in cooler boxes.

Similarly, samples were collected over a distance of 1 km along the stream and analysed. The samples were collected at 5 different points, $S_1$: a point upstream, $S_2$: the brewery effluent discharge point, and three points $S_3$, $S_4$, and $S_5$ downstream, all at 200 m distance intervals to each other.

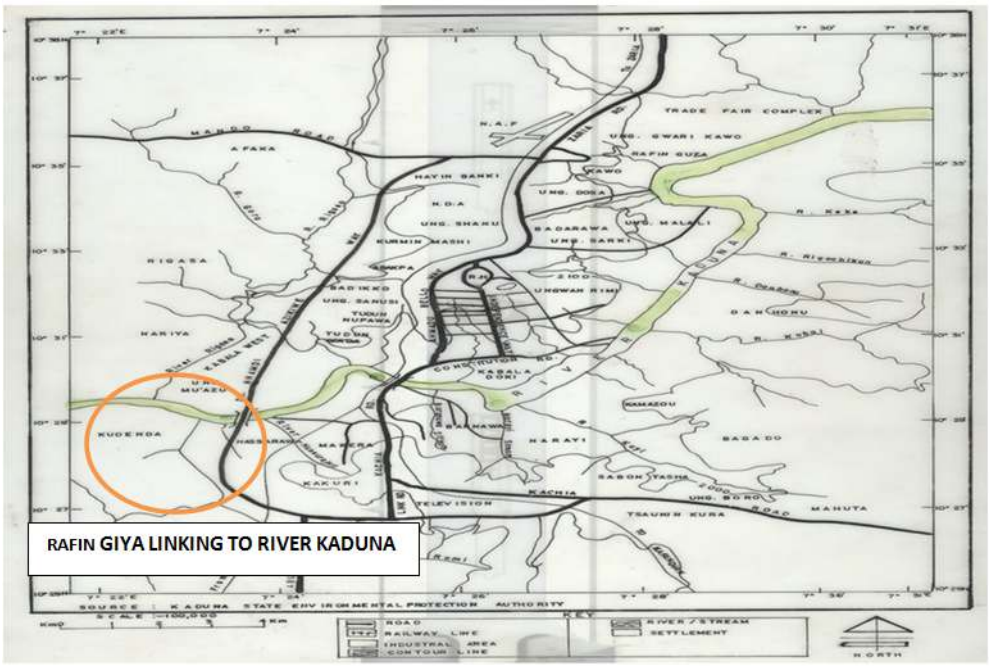


**Fig. 1. Map of Kudenda industrial layout Kaduna**

**Fig. 2. Stream water sampling at brewery wastewater effluent discharge point**

## 2.3 Physicochemical Analysis

The Physicochemical parameters were analysed as per the method of wastewater Quality described in "Standard methods for the examination of water and wastewater American Public Health Association [13]. These include: Total Suspended Solids (TSS), Total Dissolved Solids (TDS), Turbidity, Chemical Oxygen Demand (COD), Biological Oxygen Demand ($BOD_5$), Dissolved oxygen (DO), Electric-Conductivity (EC), pH, Chlorides, and coliform count.

## 3. RESULTS AND DISCUSSION

The results of the analysis of the physicochemical properties of the wastewater samples are presented in Tables 1-5.

The pH regimes of the wastewater ranged from 2.2 to 7.7, while mean pH for a period of 27days and the mean pH was 3.79 which is far outside the NESREA limit as stated in Table 5. The brewery wastewater effluent pH increased the pH of the stream from 6.4 to 4.2 which is acidic. pH range of 6.5 to 8.5 is the recommended for drinking water and water meant for full contact recreation respectively (WHO [5]). This values of pH of the brewery effluents indicated high acidity of the wastewater which causes ecological problems such as soil erosion along the stream and also seriously detrimental to aquatic, animal and human health. The temperature of wastewater ranged from 27℃ to 35.5℃ and the mean temperature was found to be 29.7℃ and this has increased the stream temperature from 27℃ to 31℃ at the wastewater discharge point. Although the temperature is within the set limits, this increase may however reduce solubility of oxygen and amplify odour due to anaerobic reaction.

Total suspended solids and turbidity gives a measure of the water clarity. The turbidity of the wastewater ranged from 4.6 to 7.2 NTU for the period of the study; and the mean value was 6.09 NTU. The range of the TSS measured for the wastewater is 1000 to 1200 mg/L and the mean value is 1048.9 mg/l which is far higher than the limit recommended by NESREA. The wastewater increased the TSS of the stream from 200 mg/l to 1600 mg/l. Excessive turbidity in water can cause problem with water purification processes such as flocculation and filtration, which may increase treatment cost. High turbid waters are often associated with the possibility of microbiological contamination, and also affect the sights of aquatic creatures.

Total dissolved solids (TDS) are the measure of total inorganic salts and other substances that are dissolved in water. TDS is a good indicator of electrical conductivity of the wastewater which is the measurement of the ability of a solution to carry electric current since this ability depends on ions in solution. The range of the total dissolved solid is 600 to 1100 mg/L and the mean value measured for the wastewater samples is 826.9 mg/L which falls within NESREA limits. The TDS of the stream water was increased from 730 mg/l to 1490 mg/l. The electrical conductivities of the wastewater samples ranged from 700µs/cm to 1630 µs/cm and the mean value was 1011.8 µs/cm. Although there is no specified limit by NESREA for EC, the mean value exceeded the recommended WHO limit of 900 µs/cm. The wastewater increased the EC of the stream from 270 µs/cm to 1480 µs/cm. Electrical conductivity is a useful indicator of mineralization and salinity or total salt in a water sample. High EC can also increase the corrosive nature of the wastewater. Thus, the parameter gives concern and it makes the wastewater unsuitable for direct discharge into water bodies. The range of the chloride contents values for the wastewater recorded was 500.2 mg/l to 646.1 mg/l and the mean value is 573.5 mg/l. The chlorides contents are also a good indicator of electrical conductivity of the wastewater since it depends on the dissolved chemical compounds present in water. The higher the chloride content, the higher the conductivity in the water samples. The measured chloride content also exceeded the NESREA limit for industrial wastewater discharge into receiving water bodies.

**Table 1. Physicochemical properties of wastewater effluent of a brewing industry, Kaduna**

| Sampling time / Parameter | Day 1 | Day 2 | Day 3 | Day 4 | Day 5 | Day 6 | Day 7 | Day 8 | Day 9 | Day 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| pH | 2.6 | 4.2 | 7.7 | 7.2 | 2.3 | 2.2 | 2.3 | 2.3 | 2.4 | 2.4 |
| Temperature (℃) | 31 | 29.2 | 28.1 | 32 | 35.5 | 27.2 | 29 | 27.6 | 27 | 27.1 |
| TSS (mg/L) | 1200 | 1200 | 1000 | 1000 | 1000 | 1000 | 1000 | 1000 | 1000 | 1000 |
| Turbidity (NTU) | 7.2 | 6.5 | 4.6 | 5.7 | 5.0 | 6.2 | 6.1 | 6.0 | 6.2 | 6.1 |
| Chloride (mg/L) | 631.9 | 639 | 646.1 | 639 | 631.9 | 624.8 | 603.5 | 608.5 | 582.2 | 575.1 |
| $BOD_5$ (mg/L) | 1650 | 1250 | 1805 | 1110 | 1300 | 990 | 1200 | 900 | 1500 | 900 |
| COD (mg/L) | 3102 | 2350 | 3393.4 | 2086.8 | 2444 | 1861.2 | 2256 | 1692 | 2828 | 1692 |
| EC (µs/cm) | 1470 | 1180 | 1630 | 1120 | 960 | 1020 | 1000 | 1000 | 940 | 980 |
| TDS (mg/L) | 760 | 600 | 1100 | 1000 | 720 | 960 | 920 | 880 | 800 | 880 |
| Coliform (*E-coli*/100 ml) | - | 1 | - | - | 2 | 1 | - | 1 | - | 2 |

**Table 2. Physicochemical properties of wastewater effluent of a brewing industry, Kaduna**

| Sampling time / Parameter | Day 11 | Day 12 | Day 13 | Day 1 4 | Day 15 | Day 16 | Day 17 | Day 18 | Day 19 | Day 20 |
|---|---|---|---|---|---|---|---|---|---|---|
| pH | 2.3 | 2.8 | 2.4 | 2.8 | 3.9 | 4.8 | 4.8 | 4.8 | 4.8 | 4.7 |
| Temperature (℃) | 30 | 29.2 | 30 | 29 | 29 | 29 | 29 | 31 | 30 | 29 |
| TSS (mg/L) | 1000 | 1200 | 1000 | 1000 | 1000 | 1000 | 1100 | 1100 | 1120 | 1200 |
| Turbidity (NTU) | 6.0 | 6.0 | 6.2 | 6.5 | 6.3 | 6.4 | 6.5 | 6.5 | 6.6 | 6.6 |
| Chloride (mg/L) | 575.1 | 568 | 568 | 568 | 568 | 560.9 | 553.8 | 500.2 | 550.1 | 513.5 |
| $BOD_5$ (mg/L) | 1000 | 890 | 800 | 1110 | 900 | 905 | 910 | 900 | 905 | 906 |
| COD (mg/L) | 1880 | 1673.2 | 1504 | 2086.8 | 1692 | 1701.4 | 1710.8 | 1692 | 1701.4 | 1703.28 |
| EC (µs/cm) | 870 | 902 | 890 | 900 | 800 | 770 | 710 | 715 | 716 | 700 |
| TDS (mg/L) | 780 | 860 | 560 | 860 | 870 | 600 | 670 | 675 | 782 | 778 |
| Coliform (*E-coli*/100 ml) | 0 | 1 | 1 | 2 | 2 | 2 | 1 | 1 | 2 | 2 |

**Table 3. Physicochemical properties of wastewater effluent of a brewing industry, Kaduna**

| Sampling time / Parameter | Day 21 | Day 22 | Day 23 | Day 24 | Day 25 | Day 26 | Day 27 |
|---|---|---|---|---|---|---|---|
| pH | 2.6 | 4.2 | 7.7 | 7.2 | 2.3 | 2.2 | 2.3 |
| Temperature (℃) | 31 | 29.2 | 28.1 | 32 | 35.5 | 27.2 | 29 |
| TSS (mg/L) | 1200 | 1000 | 1000 | 1000 | 1000 | 1000 | 1000 |
| Turbidity (NTU) | 7.2 | 6.5 | 4.6 | 5.7 | 5.0 | 6.2 | 6.1 |
| Chloride (mg/L) | 631.9 | 639 | 646.1 | 639 | 631.9 | 624.8 | 603.5 |
| $BOD_5$ (mg/L) | 1000 | 1250 | 1005 | 1110 | 1300 | 990 | 1200 |
| COD (mg/L) | 3102 | 2350 | 3393.4 | 2086.8 | 2444 | 1861.2 | 2256 |
| EC (µs/cm) | 1470 | 1180 | 1330 | 1120 | 960 | 1020 | 1000 |
| TDS (mg/L) | 960 | 600 | 1100 | 1000 | 720 | 960 | 930 |
| Coliform (*E-coli*/100 ml) | 2 | 0 | 0 | 1 | 0 | 1 | 1 |

**Table 4. Range and mean values of the physicochemical parameters of wastewater**

| Parameter | Range | Mean | NESREA limit |
|---|---|---|---|
| pH | 2.2 – 7.7 | 3.79 | 6-9 |
| Temperature: ℃ | 27 – 35.5 | 29.7 | < 40 |
| TSS: mg/L | 1000 – 1200 | 1048.9 | 30 |
| Turbidity: NTU | 4.6 – 7.2 | 6.09 | 25 |
| Chloride: mg/L | 500.2 – 646.1 | 573.5 | 600 |
| $BOD_5$ : mg/L | 800 – 1805 | 1128.8 | 30 |
| COD: mg/L | 1504 – 3393.4 | 2122.1 | 80 |
| EC: µS/cm | 700 – 1630 | 1011.8 | NOT SPECIFIED |
| TDS: mg/L | 600 – 1100 | 826.9 | 2000 |
| Coliform: (*E-coli*/100 ml) | 0 – 2 | 1 | 400 |

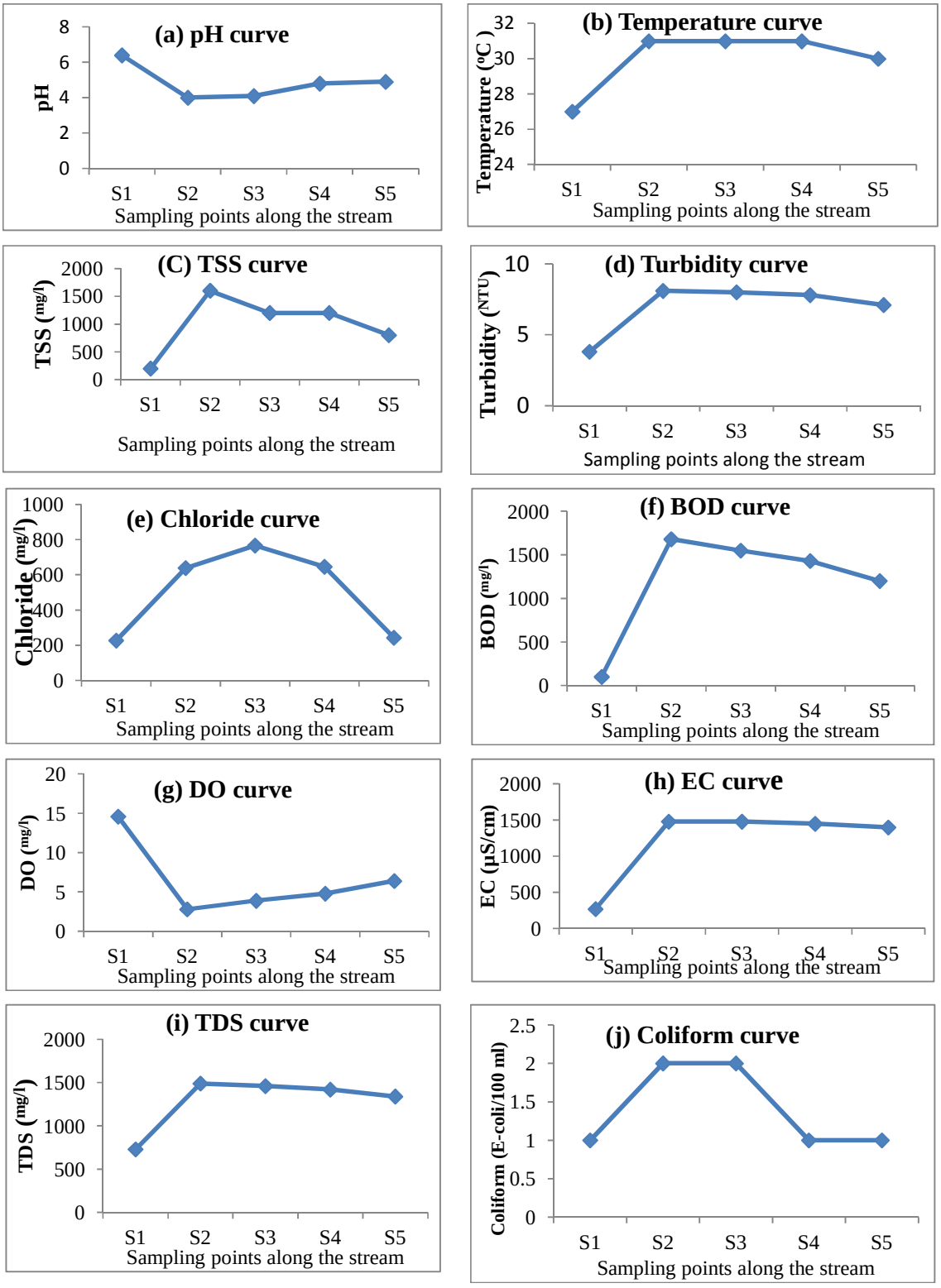


**Fig. 3. Graphical representation of the self-purification potential in "Rafin Giya" stream, Kudenda, Kaduna**

**Table 5. Physicochemical properties of the stream water**

| Parameter | $S_1$ | $S_2$ | $S_3$ | $S_4$ | $S_5$ | % self-purification potential |
|---|---|---|---|---|---|---|
| pH | 6.4 | 4.0 | 4.1 | 4.8 | 4.9 | 76.6 |
| Temperature: ℃ | 27 | 31 | 31 | 31 | 30 | 90 |
| TSS : mg/L | 200 | 1600 | 1200 | 1200 | 800 | 25 |
| Turbidity: NTU | 3.8 | 8.1 | 8.0 | 7.8 | 7.1 | 53.5 |
| Chloride: mg/L | 227.2 | 639 | 766.8 | 646.1 | 242.5 | 93.7 |
| $BOD_5$ : mg/L | 100 | 1680 | 1550 | 1430 | 1200 | 8.3 |
| DO: mg/L | 14.6 | 2.8 | 3.9 | 4.8 | 6.4 | 43.8 |
| EC: µS/cm | 270 | 1480 | 1480 | 1450 | 1400 | 19.3 |
| TDS: mg/L | 730 | 1490 | 1460 | 1420 | 1340 | 54.5 |
| Coliform (*E-coli*/100 ml) | 1 | 2 | 2 | 1 | 1 | 100 |

The range of total coliform measured was 0 to 2 *E-coli*/100 ml and the mean value is 0.7 *E-coli*/100 ml. The NESREA limit is 400 *E-coli*/100 ml, thus the waste water meet up with the discharge regulation of total coliform. The coliform count is a measure of the microbial activities as they oxidized the organic constituents in the wastewater and multiply in number. It is an indicator of possible presence of pathogenic micro-organisms.

The risk to consumers of infection from drinking polluted waters strongly depends on the presence of pathogenic organism present in the water.

The BOD and COD concentrations of the wastewater samples were measured, as the two are important tests of the relative oxygen-depletion effect of a wastewater pollutant. The Biological oxygen demand (BOD) of the wastewater samples varied from 800 mg/l to 1805 mg/l with a mean value of 1128.8 mg/l indicating higher level of BOD than the NESREA limit. The chemical oxygen demand (COD) of the wastewater samples varied from 1504 to 3393.4 mg/l throughout the study period which also indicated higher levels of COD than NESREA limit. This has greatly polluted the stream water which indicated that the brewery wastewater requires further treatment before being discharged into the stream. The trend of the result compare favourably with previous studies on flowing streams and rivers [3].

The water quality parameters analysed have shown that the stream pollution absorbance potential is low as compared to the brewery wastewater loading causing serious pollution effect on the stream. The dissolved oxygen (DO) and other water quality parameters of the stream water measured covering a distance of 1 km upstream to downstream the brewery wastewater discharge point along the stream however indicated that the stream has a self-purification effort as shown in Fig. 3.

## 4. CONCLUSION

This study was aimed to evaluate the impact of brewery wastewater effluent on the quality of stream “rafin giya” water in Kudenda industrial area of Kaduna and to determine the self-purification effort of the stream. This study has revealed that with the exception of temperature, total dissolved solids and total coliform, all other physicochemical parameters of the brewery wastewater measured which include pH, TSS, turbidity, conductivity, BOD, COD, and Chlorides levels are very high than the NESREA limits for industrial wastewater discharge and thus have caused high pollution effects on the stream. The analyses have also shown that the stream pollution absorbance potential is low compared to the brewery wastewater loading. The self-purification potential exhibited by the stream over a distance of 1 km were found to be 76.6%, 90 .0%, 25.0%, 53.5%, 93.7%, 8.3%, 43.8%, 19.3%, 54.5% and 100% for pH, Temperature, Turbidity, Electrical conductivity, BOD, and DO respectively. Although the stream exhibited gradual self-purification potential; there was a high pollution impact on the stream river by the brewery wastewater. It is thereby recommended the discharge of such highly polluted wastewater should be discouraged with strict enforcement of existing legislation and regular monitoring. Further work will address the kinetics and modelling of the stream’s self purification and pollutants absorptive capacity.

## COMPETING INTERESTS

Authors have declared that no competing interests exist.

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