Journal of Science and Sustainable Development (JSSD), 2024, 12(2), 47-54

ISSN: 2304-2702 (print); 2414-4479 (online)
DOI: https://doi.org/10.20372/au.jssd.12.2.2024.0518

RESEARCH PAPER

Physicochemical Analysis of Wastewater as Performance Evaluation of Wastewater Treatment Plant of Debre Berhan Dashen Brewery

Balkew Zewge*, Wubshet Sileshi and Bezuayehu Tadesse

Department of Chemistry, Debre Berhan University, College of Natural and Computational Science, Debre Berhan, Ethiopia;
***Corresponding Author:** Email: balkewzewge47@gmail.com*

Abstract

Currently, the evaluation of the performance of wastewater treatment plants (WWTP) of every industry in Ethiopia attracts great attention because of the increase in industrialization and consequently increase in environmental pollution. This study was conducted to evaluate the efficiency of the wastewater treatment plant of Debre Berhan Dashen Brewery by analyzing the physicochemical parameters of the wastewater discharged from the brewery. Wastewater samples were collected from the influent and outlet of each treatment unit. The pollutant removal efficiency of each treatment unit was evaluated. In addition, the major physicochemical parameter values of the wastewater samples were analyzed using standard methods. The results showed that the influent had the mean value of pH(10.95±0.83), temperature (29.5±0.93 ^{o}C), EC (3203±1.05 µS/cm), COD (6133±1.63 mg/L), BOD5 (2304±3.96 mg/L), TDS(2737±5.61 mg/L), TSS (866±1.32mg/L), NH4-N (15.6±0.03 mg/L) and NO3-N (16.3±0.07 mg/L) and the final effluent had a mean value of pH(7.85±0.15), temperature (26.97±1.07 oC), EC (2160±1.83 µS/cm), COD (835.0±2.23 mg/L), BOD5 (192±8.0 mg/L), TDS (1119.5±7.6 mg/L), TSS (268±1.22 mg/L), NH4-N (11.3±0.06 mg/L) and NO3-N (6.96±0.67 mg/L). The value of COD, TSS, and BOD were higher than the national industrial wastewater discharge limits set by EEPA 2003. Thus, the Debre Berhan Dashen brewery waste treatment plant needs improvement so as to meet the standard limit and minimize environmental pollution.

Keywords: COD, BOD, TSS, wastewater, treatment plant

Introduction

Ecological and human disasters can arise from the discharge of industrial wastes causing the degradation of ecosystems and human health (Chala et al., 2012; Alebel, 2014). Human activities on rivers and their ecosystem affect one or more of the five attributes of watersheds and streams: water quality, habitat structure, stream flow patterns, sources of energy and nutrients, and biotic interactions (Kebede, 2018; Andargachew and Samuel, 2013). Compromised environmental quality as a result of effluent discharge from industrial sectors has become a serious environmental concern for many countries especially in developing nations like Ethiopia (Chala et al., 2012).

In Ethiopia, the large and medium-scale manufacturing sub-sectors are dominated by four consumer goods-producing industrial groups, like food and beverage, chemical, textile, leather, and shoe groups are the main industrial sectors that contribute to the national and local economic activities in the country (Alebel, 2014). Breweries are the conventional industries in the agro and food sector using cost-effective techniques to manufacture the best quality beer. During the process of beer brewing, beer mainly passes through three very important chemical and biochemical reactions (mashing, boiling, fermentation, and maturation) and three solid-liquid separations (wort separation, wort clarification and rough beer clarification) (Chala et. al., 2012).

Wastewater is one of the major waste products of brewery operations. Untreated effluents typically contain suspended solids (TSS) from 200- 1000 mg/L, biochemical oxygen demand (BOD) from 1,200-3,600 mg/L chemical oxygen demand (COD) from (2,000-6,000 mg/l) and nitrogen (N) in range (25-80 mg/l) (Kebede, 2018). Phosphorus (P) can be present at concentrations of (10-50 mg/l). The effluent pH can also vary from 3 to 12 depending on the use of acid and alkaline cleaning agents as well the temperature average becomes about 30 ℃ but can fluctuate from (18-40℃) (Kebede, 2018; Choi, 2016).

The wastewater treatment system employed at Debre Berhan Dashen Brewery is UASB with a re-aeration system. A prerequisite for the successful operation of a UASB system is the presence of well-settling (granular) sludge, which can stand the up-flow velocity of the wastewater and is retained in the reactor. In the UASB processes, the wastewater to be treated is introduced at the bottom of the reactor. The treated effluent from the system is released through the canal and farmers use it for different activities and irrigation purposes before mixing with a tributary of the Beresa River. However, no study has been conducted on the performance evaluation of its treatment plant and the quality of treated wastewater released to the surrounding environment. The main objective of this study was to evaluate the performance of the treatment plant and analyze the physicochemical parameters: Temperature, pH, electrical conductivity (EC), chemical oxygen demand (COD), Biological oxygen demand (BOD), total dissolved solids (TDS), total suspended solids (TSS), Nitrate-nitrogen (NO3- N), and Ammonium Nitrogen (NH4+-N) of the effluent released to the environment.

Materials and methods

Description of Study Areas

The study was conducted at Debre Berhan Dashen Brewery Share Company. Debre Berhan City is found in the North Shoa Zone, Amhara Regional State, Ethiopia (Figure 1). The area is located 120 km north of Addis Ababa. It has latitude and longitude of 9°41′N, 39o32′E and an elevation of 2840 meters above sea level. The brewery officially started production on November 15, 2015 and is located at 09 Keble, North part of Debre Berhan city. The GPS (UTM), location of the factory is Northing 106908.94 and Easting 558472.03 an altitude of 2822.21 meters above sea level. The annual production capacity of the brewery is approximately 2,000,000 hectoliters of bottled brand and drought beers.

The factory produces a substantial volume of wastewater approximately 1680 m3/day. The wastewater treatment system employed at Dashen Brewery is a UASB reactor coupled with an aeration tank. The treated effluent from the system is released to the surrounding agricultural area and then discharged to the nearby Beresa River. Physicochemical analysis and removal efficiency of the treatment plant was done by taking the sample from four parts of the treatment plant (the initial point of discharge, influent tank effluent, buffer tank effluent, bioreactor effluent and final effluent).

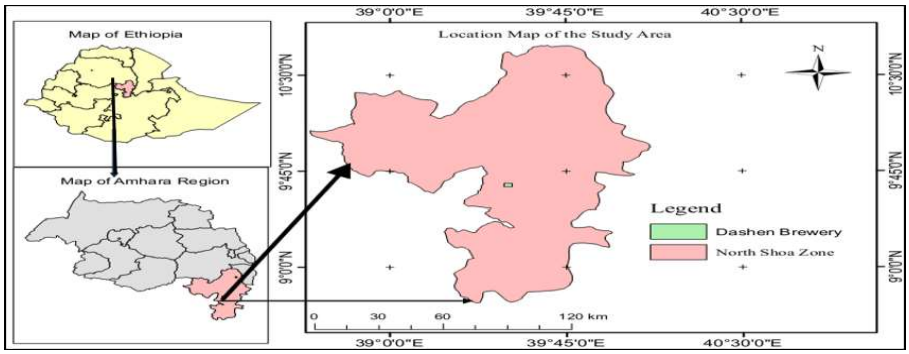

Figure 1. Map of Debre Berhan Dashen Brewery

Materials

The materials which were used during conducting this study were polypropylene bottles for collecting the brewery wastewater samples, an incubator, a Digital pH meter (pH and Temperature Meter HM PH-80 and PH-200), a BOD meter, DRB 200 Reactor, a Conductivity meter (LFF330 SET model), HACH spectrophotometer model DR/5000, HACH spectrophotometer model DR/3900, HACH spectrophotometer (HACH DR/900 Model, Loveland, CO, USA).

Wastewater sampling and preservation

Wastewater samples were collected from Debre Berhan Dashen Brewery at each outlet, while wastewater was discharged into the environment. The Wastewater Treatment Plant (WWTP) of the brewery consists of four main units namely: influent tank, equalization (buffer), anaerobic effluent tank (UASB reactor) and post-aeration tank (SBR) (Figure 2). The wastewater samples were collected from the inlet point and an outlet of each treatment unit and at the final discharge point. Samples were collected between 08:00 and 11:00 AM during the dry season. Considering the variability of the nature of brewery effluent, a snap sampling method was used (Firew et. al., 2018). Five rounds (forty-five) of samples were taken for the analysis of physicochemical parameters. Each wastewater sample was taken using cleaned polyethylene bottles stored in an ice box until transported to the laboratory.

Figure 2. Wastewater Sample collection from the outlet of treatment plants

Physicochemical Analysis

Physicochemical Parameters such as Temperature, biological oxygen demand (BOD5) total suspended solids (TSS), total dissolved solids (TDS), electrical conductivity (EC), and chemical oxygen demand (COD), were analyzed in the Debre Berhan Dashen Brewery Water and Wastewater treatment laboratory. Ammonium Nitrogen NH4-N and Nitrate-nitrogen NO3-N were analyzed in Horticoop Ethiopia water and soil laboratory at Bishoftu, Oromia Regional State, Ethiopia).

The pH and temperature were measured by digital temperature and pH measuring electrode (pH and Temperature Meter HM pH-80 and pH-200 model). Total Dissolved Solid (TDS) and conductivity (EC) were measured by a digital conductivity meter (LFF330 SET model). Nitrate-nitrogen (NO3-N) and Ammonium Nitrogen (NH4+-N) were determined using a spectrophotometer (HACH

DR/3900 Model, Loveland, CO, USA) according to the manufacturer's instructions. The TSS of the sample was determined using Whatman No.1 filter paper. A filter paper was weighed initially and then filter 50 ml of the sample was, the filter paper with wet TSS was oven-dried at 100oC. TSS was calculated thus: TSS (mg/l) = (final- initial weight)/volume of sample (Ogbu et. al., 2016).

The Biological Oxygen Demand (BOD) was determined as the difference between the initial oxygen concentration in the sample and concentration after 5 days of incubation in BOD bottles at 20 ℃ using the Oxi-Trop BOD system method (APHA, 2005). The Chemical Oxygen Demand (COD) was determined by the colorimetric determination method using the HACH DR/900 spectrophotometer.

Pollutant Removal Efficiency of each treatment plant

The pollutant removal efficiency of each treatment unit of the plant was evaluated from the difference in pollutant concentration in the influent and effluent from each unit, using the following formula:

Removal Efficiency (%) = [(Ci – Ce)/Ci] x100…. (Enitan et. al., 2015).

Where Ci = is the concentration of the waste material in the influent
Ce = is the concentration of the waste material in the effluent

Results and discussions

Analysis of physicochemical parameters

The average physicochemical parameters results obtained from the laboratory analysis of raw brewery wastewater and each treatment unit are summarized in Table 1. Comparison of the mean value of the parameters in the raw effluent with that in effluent from the influent tank indicated (Table 1) a significant difference ($p<0.05$) only for the parameters NO3-N and NH4-N.

Table 1. Physicochemical parameters values. The data are presented as mean+ SD, n=7

Parameters	Units	Mean ± Standard deviation				
		Brewery raw wastewater	Influent tank Effluent	Equalization tank Effluent	Anaerobic (UASB) reactor Effluent	Post-aeration (SBR) tank Effluent
pH	-	10.95±0.83	10.86±1.02	8.27±1.54	7.44±0.25	7.85±0.15
T	^{o}C	29.5±0.93	27.25±0.26	27.19±1.43	28.33±1.20	26.97±1.07
EC	µS /cm	3203±1.5	3092±8.6	2956± 3.8	2383±4.15	2160±1.83
TDS	mg/l	2737±5.61	2540±1.1	2160±3.61	1406±2.17	1199.5±7.6
COD	mg/l	6133±1.63	6017±1.81	5825±1825	971±2.51	835±2.23
BOD_5	mg/l	2304±3.96	2259±4.15	2105±4.56	288±1.12	192±8.0
TSS	mg/l	866±1.32	714±1.12	546±9.6	342±6.6	268±1.22
H_4-N	mg/l	15.6±0.03	14.2±0.02	14.0±0.04	15.7±0.04	11.3±0.06
NO_3-N	mg/l	16.3±0.07	14.3±0.12	12.6±0.25	5.06±0.89	6.96±0.67

The determined temperature, electrical conductivity (EC) and total dissolved solids (TDS) in this study were 26.97± 1.07 ^{o}C, 2160 ± 1.83µS /cm and 1199.5 ± 7.6 respectively (Table 1). These values are higher than the WHO standard (Ogbu et. al., 2016). The results of the analysis showed that the quality of the brewery discharge from the treatment plant does not meet the effluent standards in terms of COD and BOD_5. The effluent had average COD and BOD_5 values of 6133 ± 1.63mg/l and 2304.3 ± 3.96 mg/l respectively as indicated in Table 1. Which were above the standard reported values (Abimbola et. Al., 2014). The higher organic masses in the wastewater resulted from the alcohol from drip beer, dissolved carbohydrates and a high content of suspended solids such as malt, spent grain and surplus yeast could possibly be the causes of high COD and BOD5 in the discharge (Firew et. al., 2018). The nitrogen content was NH_4-N and NO_3-N in the wastewater were 15.6±0.03 mg/l and 16.3 ± 0.07 mg/l, respectively as shown in Table 1, which were in the effluent standards range (Firew et. al., 2018). The sources of the nitrogen might be the malt processing followed by the hydrolysis of protein for NH_4-N and NO_3-N (Firew et. al., 2018).

The obtained TSS value was 866 ±1.32 mg/l within the range of the reported value (Geoffrey et. al., 2011; Gangagni et. al.,2007). Malt processing, packaging and possible label pulp from the bottle washer could be the cause of TSS in the wastewater. The analysis also showed a pH value of 10.95±0.83 which was within the wide range (4-12) reported value (Teklit, 2018). The wide range in pH of wastewater might be due to the batch-processing nature of the brewery and the amount and type of chemicals (e.g. caustic soda, phosphoric acid, nitric acid, etc.) used at the CIP units (Teklit, 2018).

Performance Efficiency of Each Treatment Unit

The recorded physicochemical parameter values of each treatment unit (after their respective retention time) are depicted in Table 2. The removal efficiencies of the influent tank with 5 minutes retention time was pH (0.82%), T(^{o}C) (7.6 %), COD (1.89%), BOD_5 (1.95%), TSS (17.6%), TDS (7.2%), TP (4.21), NH_4-N(8.9%), and NO_3-N (12.26%) (Table 2).

The retention time in the equalization tank is 3 hrs with an average flow of volume of 720 m^3. This step time is required to obtain sufficient hydraulic peak shaving and sufficient rubbing out of peaks in pH and the organic load (COD, BOD, and TSS). In addition, the complex organic material will hydrolyze partially to sugars, amino acids and fatty acids (acidification), Firew et. al., 2018). The comparison of the average values of effluent from the influent tank with that of the equalization tank showed a significant decrease in pollutants ($p<0.05$) only for pH, TDS, TSS, EC, TP and NO_3-N (Table 2).

Table 2. Removal Efficiency of each treatment unit of the system

Parameters	units	Percentage Removal (%)			
		Influent tank Effluent	Equalization tank Effluent	Anaerobic (UASB) reactor Effluent	Post aeration tank Effluent (SBR)
pH	-	0.82	23.84	10.03	0.51
T	^{O}C	7.60	0.20	-4.19	0.45
EC	µS/cm	3.50	10.86	19.40	9.40
TDS	mg/l	7.20	14.96	34.90	14.70
COD	mg/l	1.89	3.18	83.32	4.97
BOD_5	mg/l	1.95	6.18	86.30	4.24
TSS	mg/l	17.55	23.50	37.40	21.60
NH_4-N	mg/l	8.90	1.42	-1.02	28
NO_3-N	mg/l	12.26	11.89	59.80	-37.50

The average equalization tank removal efficiencies were pH (23.84%), T (0.2%), COD (3.18%), BOD5 (6.18%), TSS (23.55%), TDS (14.96%), EC (10.86), NO3-N(11.89%) and NH4-N(1.42%) (Table 2). Relatively higher removal efficiencies of equalization tank for Hawasa St. Georgis brewery than the present study for TSS, NH4N, and NO3-N, but lower efficiencies for EC, TDS, COD and BOD5 than reported values Gulnur et. al., 2018; Firew *et. al.*, 2018).

The retention time in the UASB tank is 6 hrs. on average 700 m3 of waste flows. After the wastewater passed over the UASB reactor, the values of most pollutants decreased and comparisons of the measured value in this unit with the equalization tank indicated significant differences ($p<0.05$) for COD, BOD5, NO3-N and NH3-N (Table 1). The percentage treatment efficiency of the UASB reactor was for pH (10.03%), T (-4.19) BOD5 (86.3%), COD (83.32%), TSS (37.4%), NO3-N (59.8%), EC (19.4%), TDS (34.9%), SO4(34.8%), TP (28.7) and NH4-N (-1.02%) (Table 1). The UASB reactor removal efficiency for BOD5 and COD was 86.38% and 83.32% respectively which has low efficiency compared to the reported efficiency of UASB reactor BOD5 (94.6%), COD (91.2%) (Avinash et.al., 2013). The increment in the concentration of ammonia is related to the anaerobic conversion of organic matter and protein-containing compounds (Fuerhacker *et. al*., 2000). Nitrate-reducing bacteria may also be involved in anaerobic digestion, reducing NO3- to ammonium (NH4+). This increment amount of ammonia nitrogen in the rector may lead to decreases in the removal efficiency of ammonia nitrogen in the reactor. Also in anaerobic systems, the low removal efficiency of nutrients is expected because organic nitrogen is hydrolyzed to ammonia which is difficult to remove in anaerobic processes (Ferew *et. al*., 2018).

The anaerobic effluent flows to the re-aeration tank where it is post-aerated in order to remove odor compounds mainly H2S from the anaerobic effluent and further reduction of organic matter. In comparisons of mean differences of pollutants in effluent from the UASB reactor with effluent from the post-aeration tank reactor, there were significant differences ($p<0.05$) (Table 2).

Physicochemical characteristics of the treatment plant effluent and overall removal efficiency

The results of the physicochemical analysis and overall removal efficiency of the wastewater treatment plant are presented in Table 3. The mean values of some parameters were within the acceptable ranges of the discharge limits of EEPA, 2003).

Table 3. Physicochemical parameter values showing before treatment, after treatment and overall removal efficiency of the treatment plant.

Parameters	Mean (Before treatment)	Mean (After treatment)	Overall Removal efficiency	EEPA (2003) Discharge limits
pH	10.95±0.83	7.85±0.15	28.31	6-9
T (^{O}C)	29.5±0.93	26.97±1.07	8.6	40
EC (µS /cm)	3203±1.5	2160±1.83	32.6	1000
TDS (mg/l)	2737±5.61	1199.5±7.6	56.17	80
COD (mg/l)	6133±1.63	835±2.23	86.38	250
BOD_5 (mg/l)	2304±3.96	192±8.0	91.7	60
TSS (mg/l)	866±1.32	268±1.22	69.05	50
NH_4-N (mg/l)	15.6±0.023	11.3±0.06	27.56	20
NO_3-N (mg/)	16.3±0.07	6.96±0.67	57.3	10

The Brewery effluent had a mean pH, temperature, NH4-N, NO3-N, SO42-, 7.85±0.145, 26.97±1.07 oC, 11.3±0.06 mg/l, 6.96±0.67 mg/l,8.48±0.71 mg/l, respectively (Table 3), which were within the set limit of Ethiopian Environmental Protection Authority (EEPA, 2003). The mean value BOD5 (192±80 mg/l), COD (835±123 mg/l), TDS (1199.5±76 mg/l), TSS (268±122 mg/l), EC (2160±183 µS /cm), TP (29.33±0.12 mg/l) were higher than the acceptable ranges of the discharge limits set, (EEPA, 2003).

In general, the assessment of this study indicated that Debre Berhan Dashen Brewery discharged partially treated wastewater. The disposal of partially treated or untreated effluent into the environment can cause severe pollution problems since the effluents contain organic compounds that require oxygen for degradation (Geoffrey *et. al*., 2011). For example, the levels of COD and BOD above the standard limit in water are typically signs of low water quality and possible threats to human health and the environment and effluent that contain excessive nutrients like nitrogen and phosphorus could also result in algae bloom and cause a disturbance in the water body ecosystem. The Debre Berhan Dashen Brewery effluent must be monitored and controlled efficiently in order to safeguard the public health and environmental concerns in the surrounding area. Therefore, the concerned bodies need to check continuously and give advice to the owners to improve the wastewater treatment plant efficiency.

Conclusion

The result of the analyzed physicochemical parameters of the effluent revealed that the parameters pH, Temperature, NH4-N, NO3-N and SO42- meet the permissible limit set by EEPA, 2003. However, the values of BOD5, COD, TDS, TSS, EC and TP of the final effluent were above the range of the standard discharge limit. This indicates that the wastewater was partially treated and the ineffectiveness of the Debre Berhan Dashen Brewery wastewater treatment plant. From the result of this study, it is recommended that improving the efficiency of the treatment plant units or implementing additional treatment plants should be needed. The municipality office should prevent the release of properly untreated wastes into the environment. It is also recommended that further studies should be conducted on the heavy metal analysis of the effluent. That will be very important for the full assessment of the wastewater and the efficiency of the treatment plant. It is also recommended that monitoring programs should be implemented for the discharge of effluent to address all actions that have been identified to have potentially significant environmental impact.

Conflict of interest

The authors declare no conflict of interest.

Acknowledgment

The authors would like to thank the management of Debre Berhan Dashen Brewery for allowing the laboratory and instruments.

Funding

The authors declare no financial support

References

Abimbola, M. E., Feroz, M. S., Josiah, A. and Faizal, B.(2014). Assessment of Brewery Effluent Composition from a Beer Producing Industry in Kwazulu-Natal, South Africa. Fresenius Env. Bulletin.23,693-701.

Alebel, A. (2014). Does ISO 14001 accreditation reduce the environmental impact of industries: A case study in Addis Ababa, Ethiopia. Open J. of Water Pollution and Treatment. 1, 21-33.

Andargachew, B., and Samuel, S. (2013).The Effects of Dashen Brewery Wastewater Treatment Effluent on the Bacteriological and Physicochemical Quality of Shinta River in Gondar, North West Ethiopia, World Environment, 3, 29-36

APHA. (2005). Standard Methods for the Examination of Water and Wastewater, twenty-first ed. American Public Health Association. APHA: Washington, DC.

Avinash, K. S., Sharma , M.P., and Sharwan, K.(2013). Performance Evaluation of Brewery Waste Water Treatment Plant. IJEPR. 2, 105 -111.

Chala, D., Amanuel, A., Mengesha, D., Adinew, G., Metadel, A., Asha, E., and Mesfin,G. (2012). Performance evaluation of a brewery wastewater treatment plant in Ethiopia: Implications for wetland ecosystem management. Science policy and management for sustainable use. 3, 27.

Choi, H. J. (2016). Parametric study of brewery wastewater effluent treatment using Chlorella vulgaris microalgae, Environ. Eng. Res. 21, 401-408.

EEPA,(2003). Guideline Ambient Environment Standards for Ethiopia. Prepared by EPA and UNIDO under ESDI project US/ETH/99/068/Ethiopia. Addis Ababa.

Enitan, A., Adeyemo, J., Kumari, S., Swalaha, F.M. and Bux, F. (2015). Characterization of Brewery Wastewater Composition. Int. J. Env. Chem. Eco. Geo. and Geoph. Eng. 9: 1073-1076.

Firew, T., Daniel, F. and Solomon, S.S. (2018). Performance Assessment of Wastewater Treatment Plant of Hawassa St. George Brewery, Hawassa, Ethiopia. J. Appl. Sci. Environ. Manage. 22, 1285-1292.

Fuerhacker,M., Bauer, H., Ellinger,R., Sree, U., Schmid, H., Zibuschka, F. and Puxbaum, H. (2000). Approach for a novel control strategy for simultaneous nitrification/ denitrification in activated sludge reactors. 9, 2499-2506.

Gangagni, R. A., Sasi, K. R. T., Surya, P.S., Vanajakshi, J. J., and Sarma, P.N.(2007). pH regulation of alkaline wastewater with carbon dioxide: A case study of treatment of brewery wastewater in UASB reactor coupled with absorber. Bioresource Technology. 98, 2131–2136.

Geoffrey, S. S., John. C., Sunny, E. I., Evans, T. M., Sehliselo, N., Lubinda, F. W. and Allex, E. A.(2011).The treatment of brewery wastewater for reuse: State of the art. Desalination. 273 , 235–247.

Gulnur, C., and Nur, S.O.(2006). Performance assessment of a wastewater treatment plant treating weak campus wastewater.28, 185-197.

Kebede, T. B. (2018). Wastewater treatment in brewery industry, Review." IJEDR, .6, 1-7.

Ogbu, K. C., Ebenebe, C. I., and Abajue, M. C. (2016). Physico-Chemical Characteristics of Ama Brewery Effluent and Its Receiving Ajali River In Udi, Enugu State, Nigeria. 3, 2392 – 2399.

Teklit, B. K. (2018). Wastewater treatment in brewery industry, Review. IJEDR, 6, 2321-9939.