Characterization of Brewery Wastewater Composition

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Abstract**—**Industries produce millions of cubic meters of effluent every year and the wastewater produced may be released into the surrounding water bodies, treated on-site or at municipal treatment plants. The determination of organic matter in the wastewater generated is very important to avoid any negative effect on the aquatic ecosystem. The scope of the present work is to assess the physicochemical composition of the wastewater produced from one of the brewery industry in South Africa. This is to estimate the environmental impact of its discharge into the receiving water bodies or the municipal treatment plant. The parameters monitored for the quantitative analysis of brewery wastewater include biological oxygen demand (BOD_5), chemical oxygen demand (COD), total suspended solids, volatile suspended solids, ammonia, total oxidized nitrogen, nitrate, nitrite, phosphorus and alkalinity content. In average, the COD concentration of the brewery effluent was 5340.97 mg/l with average pH values of 4.0 to 6.7. The BOD_5 and the solids content of the wastewater from the brewery industry were high. This means that the effluent is very rich in organic content and its discharge into the water bodies or the municipal treatment plant could cause environmental pollution or damage the treatment plant. In addition, there were variations in the wastewater composition throughout the monitoring period. This might be as a result of different activities that take place during the production process, as well as the effects of peak period of beer production on the water usage.

Keywords**—**Brewery wastewater, environmental pollution, industrial effluents, physicochemical composition.

I. Introduction

PRODUCTION of beer includes blending and fermentation of maize, malt and sorghum grits using yeast, which requires large volumes of water as the primary raw material. Traditionally, the amount of water needed to brew beer is several times the volume actually brewed. For instance, an average water consumption of 6.0 hectoliters is required to produce one hectoliter of clear beer [1]. Large volumes of water are being used by the industry for production of beer for two distinct purposes; as the main ingredient of the beer itself and as part of the brewing process for steam raising, cooling, and washing of floors, packaging, cleaning of the brew house during and after the end of each batch operation. The amount of wastewater that is being discharged from the industry after the production of beer, also contributes to this large volume of water [2].

With the competing demand on water resources and water reuse, discharge of industrial effluents into the aquatic environment has become an important issue [2]-[6]. Much attention has been placed on the impact of industrial wastewater on water bodies worldwide due to accumulation of organic and inorganic suspended matter, nitrite, nitrate as well as soluble phosphorus in the water bodies [7]-[9]. Due to recent environmental pollution problems that have emerged, monitoring and controlling of quality of liquid effluents being discharged into natural water bodies or municipal treatment plants, especially by the industry has become an important aspect of environmental research area [5], [6]. Thus, the aim of this study was to monitor and characterize the composition of brewery wastewater in South Africa. This will serve as database for the industry and the local authority, as well as to assess of the degree of compliance by the industries to the local legislative guidelines for effluent disposal.

II. Materials and Methods

A. Wastewater Sample Collection

Pre-screened brewery wastewater samples from the combined wastewater stream of a breweries industry in South Africa were collected in one liter sterile glass bottles and transported to the laboratory at 4°C for analysis. Physicochemical analyses were carried out within 48 hours of sample collection, with necessary preservation techniques adapted from Standard Methods [10].

B. Wastewater Characterization

Brewery wastewater samples were analyzed for parameters such as Total Dissolved Solids (TDS), Total Suspended Solids (TSS), Volatile Suspended Solids (VSS), Total Solids (TS), Volatile Solids (VS), temperature, pH, Oxidation-Reduction Potential (ORP), alkalinity, Total Chemical Oxygen Demand (TCOD), Soluble Chemical Oxygen Demand (SCOD), BOD5, conductivity (mS/cm), crude protein, sulphates, orthophosphate, ammonia, Total Oxidized Nitrogen (TON), nitrite and nitrates according to Standard Methods for Examination of Water and Wastewater [10]. The TS and TSS were determined gravimetrically by drying well homogenized samples respectively at 103°C for 24 h. The VS and VSS fractions were determined gravimetrically by incineration in muffle furnace at 550°C for 1 h [10]. Alkalinity was measured by potentiometric titration using 0.02N H_2SO_4 to an end-point pH value of 4.5.

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C. Conventional and Instrumental Methods for Samples Analysis

Total dissolved solids, conductivity (mS/cm) and oxidation-reduction potential were measured using calibrated electrode (YSI 556MPS, Yellow Springs, USA). The pH and temperature were measured using a pH meter (Beckman pH 211 Microprocessor, USA). The pH was an indicator of the process stability, while the conductivity was an indicator of production of total dissolved solids. The BOD_5 measurement was done using the respirometric method for five days (OxiTop TS 606/2-i system). The COD concentration in the wastewater was determined by close refluxing according to the standard method 5220D [10]. Microwave digester (Milestone Start D, Sorisole, Italy) was first used to digest the samples at 150°C for 2 h in COD vials containing the digestion solution (0–15,000 mg COD/L). Then, COD concentration was measured using an Aquakem Gallery discrete autoanalyser (Thermo Scientific, UK). The protein concentration was analyzed using a UV/VIS Spectrophotometer (Merck, Spectroquant Pharo 300, and Germany) according to the protocol of [11]. Sulphates, orthophosphate, ammonia, total oxidised nitrogen, nitrite, and nitrates were measured using Thermo Gallery photometric analyser (Thermo Scientific, UK) [10].

D. Analytical Quality Assurance and Statistical Analysis

Both reagent and sample blanks were used for all the methods that required the use of spectrophotometer and Aquakem Gallery discrete auto analyzer. Standard solutions were prepared for the analysis of COD and protein content. Instruments were first calibrated before using standard solutions. The data obtained was used to calculate mean, ranges, and standard deviations. Graphs and data analysis were performed using GraphPad Prism v5.0 software package.

E. Estimation of Pollutant Removal Efficiency

The organic load, nutrient and suspended solid removal efficiency of the UASB reactor were calculated using (1).

$$\text{Removal efficiency (\%)} = \frac{C_{\text{influent}} \times C_{\text{effluent}}}{C_{\text{influent}}} \times 100 \quad (1)$$

where, $C_{influent}$ = initial parameter concentration and $C_{effluent}$ = final parameter concentration.

III. Results and Discussion

A. Assessment of Brewery Wastewater Composition

The results of the physicochemical analysis and the summary of the statistical analysis of the brewery wastewater composition investigated are shown in Table I. The results showed that the effluent produced from the brewery industry did not meet the discharge limit for wastewater disposal to water bodies according to the European Union (EU) discharge limits [12], although, the local effluent discharge standards do vary from one location, region and country to another. Table I shows the South Africa National Water Act, No 36 of 1998, wastewater discharge standards from the Department of Water Affairs (DWA) 2010 guidelines [13]. However, the standard limits are less stringent when the effluents are to be discharged to a municipal wastewater treatment plant [14].

The results of the analysis indicated that the quality of the brewery wastewater from the plant did not meet the discharge standards in terms of total and soluble COD content of wastewater, as well as the BOD_5. The trends and variability of the values plus large standard deviations from the means shows that the pollution level of the wastewater is high. The average and standard deviation of the total and soluble COD values were 5340.97 ± 2265 mg/L and 3902.28 ± 1644 mg/L respectively. The trends of total and soluble COD during the courses of the brewery wastewater composition monitoring showed fluctuation in the strength and composition of the brewery wastewater with the range being between 1096.41 to 8926.08 mg/L for TCOD and 1178.64 to 5847.74 mg/L for SCOD.

The variations in the COD concentration for each week could be as a result of variation in the activities and housekeeping practices of the brewery plant, which could cause serious environmental impact and closure of the production plant by the municipal authority, if not checked. The observed values are within the range reported for some brewery wastewater plants as shown in Table II [15]–[18]. Further work on the characterization of brewery wastewater during the monitoring period could be found in the literature [19].

The BOD_5 values range between 1609-3980 mg/L with the mean value of 3215.27 mg/L and a standard deviation of ± 870.92 (Table I). Low COD: BOD_5 ratios of 1.932 ± 0.543 obtained in this study were in accord with past reports, which suggested that the wastewater content is biodegradable [20], [21]. Effluent from the brewery plant is regarded as a biodegradable industrial wastewater and the COD concentration of brewery effluent that is more than 800 mg/L has been reported to be more suitable for treatment using anaerobic digestion technology [16], [21].

IV. Conclusions

The results of this study showed that the quality of wastewater from this brewery plant is high in COD, BOD_5, TSS, ammonia and protein content and does not meet the required effluent regulatory standards. Therefore, there is a need to treat the brewery wastewater in order to protect the environment and reduce the cost of penalties that the industry may incur when it discharges effluent into the municipal wastewater treatment plants. From the results, the COD: BOD_5 ratio indicated that the effluent is high in organic matter which is highly biodegradable. This is the type of wastewater that can be treated by anaerobic treatment system.

TABLE I
SUMMARY OF BREWERY WASTEWATER COMPOSITION FROM THE STUDIED BREWERY PLANT AND THE SOUTH AFRICA (S.A) AND THE EU STANDARD LIMITS [19]

Parameters	Range	Average value*	SA Discharge limits	EU Discharge Limits [12]
Temperature (˚C)	24-30.5	27.90 ± 2.23	< 44	-
pH	4.6-7.3	6.0 ± 1.44	Between 5.0 and 9.5	-
Total COD	1096.41- 8926.08	5340.97 ± 2265	75	125
Soluble COD	1178.64 - 5847.74	3902.28 ± 1644	-	-
BOD_5	1609 – 3980	3215.27 ± 870.92	Determined by the treatment capacity of the receiving sewerage treatment plant	25
TS	1289 – 12248	5698.11±2749.06	-	-
VS	1832 – 4634	3257.33± 1074.34	-	-
TSS	530 – 3728	1826.74± 972.46	25	35
VSS	804 -1278	1090.86 ± 182.74	-	-
	961-1483	1281.60	1000	-
Crude protein	61.67-754.42	273.47 ± 233.63	-	-
Orthophosphates	7.51 -74.10	23.71 ± 21.88	10	1-2
TON	0 - 5.36	1.81 ± 1.66	-	-
NH_3-N	0.48 - 13.05	8.62 ± 10.40	3	-
Nitrate	1.14 -11.55	4.30 ± 3.41	15	-
Nitrite	0-0.24	0.37 ± 0.18	15	-
ORP (mV)	-27.1 to -84.9	-47.80	-	-
Conductivity (mS/cm)	1.044-1.622	1.52	70-150	-
Alkalinity (mg $CaCO_3$/ L)	500- 10000	2450.33± 3034.19	-	-

*An average of 14 samples ± std deviation. * All parameters are in mg/L except otherwise stated

TABLE II
REPORTED BREWERY WASTEWATER CHARACTERIZATION FROM THE LITERATURE AND THE EFFICIENCY OF THE UASB REACTOR [16]

Parameter	Units	This study	[17]	[22]	[18]	[23]	[24]	[15]
pH	-	4.6-7.3	3.30-6.30	6.3-6.9	3-12	7.2	-	11.97
Temperature	ºC	24-30.5	25-35	-	18-40	-	-	-
COD	mg/L	1096-8926	8240 ≥ 20000	910-1900	2000-6000	4000	1120-1500	471
TSS	mg/L	530 – 3728	2020-5940	140-320	2901-3000	1300	10-60ml/l	81
VSS	mg/L	804 -1278	-	90-180	-	-	-	-
TS	mg/L	1289–12248	5100-8750	1300-2000	5100-8750	-	-	-
NH_4-N	mg/L	0.48 - 13.05	-	2.2-7.0	-	15	-	-
TN	mg/L	0 - 5.36	0.0196-0.0336	17-36	-	15	30-100	0.39
TP	mg/L	-	16-124	8.4-17	-	-	10-30	0.462
CODremoval	%	79	57	80	-	80	-	-

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