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CHARACTERIZATION OF BREWERY EFFLUENT FLUID

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ABSTRACT

This paper reports on the characterization of effluent fluid from different sections of a brewing plant with respect to the constituents and their toxicity level for possible classification and reuse within the system. The results showed the effluent fluids had moderate Biological Oxygen Demand (BOD) and Chemical Oxygen Demand (COD) of 40.30 mg/l and 471mg/l respectively. The suspended solids were also found as 81mg/l. From the study, it was found that there was the possibility of re-use of the effluent from bottle washing section before discharging to the environment.

Key Words: *Effluent Fluid, Biochemical Oxygen Demand, Chemical Oxygen Demand, Total Organic Carbon*.

INTRODCUTION

Brewing process is accompanied by the release of a great variety of contaminant each of which can determine the usability of the water for certain applications and can cause problems with effluent discharge. Thus, for sometime now, the brewing industry has shown increasing awareness for environmental protection and the need for sustainable production processes (Driessen and Vereijken, 2003). Implementation of ISO 14001 certification and more stringent environmental legislation have been important factors for raising awareness in the brewing industry towards effluent fluid control.Brewing effluent fluid in mostly water by weight, other materials make up only a small portion of the wastewater which has high strength of organic matter with moderately high quantity of Total Suspended Solids (TSS) concentration generated from a number of plant operations. Table 1 shows typical composition of brewing effluent. The main constituents include COD, BOD, TSS, Nitrogen and Phosphorous. The constituents of the effluent fluid are present in large quantities and may require some pretreatment before discharging the effluent fluid into a sewage system (Carl, 1988). Because of the hazards posed by these contaminants and due to the growing environmental awareness, the brewing industry has significantly increased investments in environmental protection measures (Driessen and Vereijken, 2003). Important internal drivers for the brewing industry are implementation of environmental management systems (EMS) like ISO 14001 as well as the need for establishing benchmarks for brewing process optimization.

EFFLUENT QUALITY AND ALLOWABLE STANDARDS

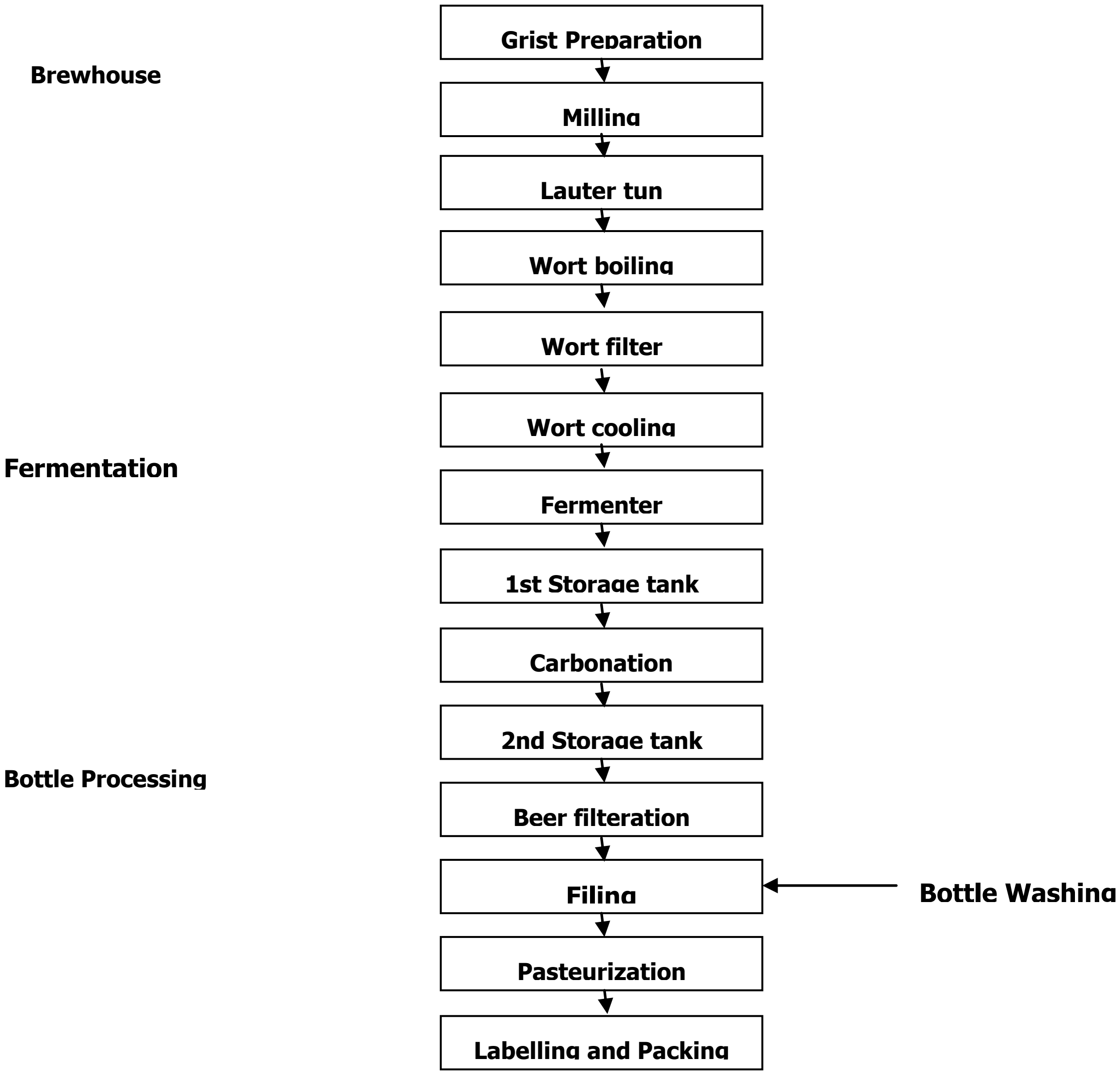

Fig. 1: Flow Diagram of a Typical Brewery Industry

Figure 1 shows a typical scheme of brewery plant. The quality and quantity of brewery effluent can fluctuate significantly as they depend on various different processes that take place within the brewery which include (raw material handling, wort preparation, fermentation, filtration, cleaning in place (CIP), packaging, etc. The amount of wastewater produced is related to the specific water consumption expressed in hecto litre (hl) of water per hecto litre (hl) of beer brewed. A part of the water is disposed with the brewery by-products and a part is lost by evaporation. As a result, the wastewater to beer ratio is often 1.2-2 hl/hl less than the water to beer ratio.

Organic component in brewery effluent (expressed as COD) is generally easily biodegradable as it mainly consists of sugar, soluble starch, ethanol, volatile fatty acids, etc. This is illustrated by the relatively high BOD/COD ratio of 0.6 – 0.7. The brewery solids (expressed as TSS) mainly consist of spent grains, kieselguhr, waste yeast and ('hot') trub. Brewery effluent pH levels are mostly determined by the amount and type of chemicals used at the CIP units (e.g. caustic soda, phosphoric acid, nitric acid, etc.). Nitrogen and phosphorus levels mainly depend on the handling of raw material and the amount of spent yeast present in the effluent. Elevated phosphorus levels can also be the result of phosphorus containing chemicals used in CIP unit. Compliance with the effluent discharge limits given in Table 1 for a brewery depends on local environmental legislation Driessen and Vereijken (2003) corroborated the work of Adeniyi (2002) that it is obvious that in case of discharging to a municipal sewer, discharge limits are less stringent than when the effluent is to be discharged into a sensitive receiving surface water body (river, lake, sea, etc.). Actual discharge limits might vary for each location, region and country.

Table 1: Typical Characteristics of Brewery Effluent and Indicative Discharge Standards (Limits) in the EU

Parameter	Brewery Effluent Composition	Typical Brewery Bend Marks	Limits (mg/l) (Discharge Standards)
Flow		2 – 8hl effluent/hl beer	
COD	2000 – 6000	0.5 – 3kg COD/hl beer	125
BOD	1200 – 3600	0.2 – 2kg BOD/hl beer	25
TSS	200 – 1000	0.1- 0.5 kg TSS/hl beer	35
T	18 – 40		
PH	4.2 – 12		
Nitrogen	25 – 80		10 – 15
Phosphorus	10 – 50		1 – 2

Source: Driessen and Vereijken, 2003.

Removal of organic compounds like (COD – Chemical Oxygen Demand) from wastewater is important to avoid creating anaerobic conditions in the receiving waters. (Driessen and vereijken, 2003). Effluent fluid is a dilute mixture of various wastes from commercial or industrial places such as the brewery, and it is essential to know its composition, quality and characteristics so as to decide on re-use, treatment and disposal. Though the effluent characteristics depend on it origin, but in general terms effluent fluid contains organic and inorganic matter and living organisms. The organic and inorganic matter may be in dissolved, suspended and colloidal state and may either be nitrogenous or nitrogen free. According to Bhatia (2005), the bacteria in the effluent converts the complex organic constituents of the effluent fluid into simpler, more stable, organic and mineral compounds.

Thus, based on their properties, the constituents of brewery effluent fluid can be classified as: physical, chemical and biological. The physical characteristics of the effluent fluids constitute the total solids content, smell or odour, colour and temperature. The important chemical characteristics of effluent fluid are determined by the pH value, chloride content, nitrogen, fat and grease content, sulphides, sulphates, dissolved oxygen, chemical oxygen demand and biochemical oxygen demand. The biological characteristics relate to the various micro-organisms found in effluent fluid, some of which may be pathogenic. However, all bacteria present in the effluent fluid are not harmful for some help to treat the wastewater and reduce the cost of treatment plants (Bhatia, 2005; Curd and Hawkes, 1975).

According to Arceivala (1998), 99.9 percent of water and 0.1 percent of solids, contained in liquid effluent is analysed to have constituents of suspended solids, colloidal solids and dissolved solids which can be determined at temperature range of 130^{o}C to 600^{o}C by weight.The essence of this paper is to characterize the effluent fluid of a brewing plant with particular reference to establishing the fluid composition. Since better characterization can lead to better water management as it is capable of improving effluent quality due to reduced contaminant and better waste water segregation.

METHODOLOGY

Samples (50cl each) were obtained from the fermentation section, bottle section, boiler section and the combined effluent stream of the brewery after which they were analyzed at the state water board laboratory in Uyo. The basic and necessary apparatus/equipment were used for the analyses and they were sterilized as the case may be. In the sample preparation, 50ml of each sample was used for hardness and alkalinity test. The samples were tested for hydrogen ion concentration level (pH) using an electronic pH meter after proper calibration. For hardness test, the colourimetric method (titration) was used, a reagent, Ethylene diamine tetracetic acid (EDTA) was used with Enchrome black as an indicator to have an end point. For alkalinity test, the procedure was repeated with hydrogen tetraoxosulphate solution, phenolphthalein and methyl orange indicator to have an end point. For spectrophotometry analysis, another 25ml of each sample was used.
The related expression in the determination of total alkalinity is given as:

$$[p] < \tfrac{1}{2}\{M\} = \{M\} - 2[p]$$

Where p = phenolphthalein indicator for end point
M = methyl indicator for end point.

(Manvelova and Synyakova, 2001).

The relationship between intensity and concentration can be represented by the following expression (Bhatia, 2005):

$$P = K \log S$$

Where P = Odour intensity
K = Constant
S = Odour concentration

Following these, each sample was diluted and incubated for five (5) days for BOD test. The dilution ratio used was 10ml to 300ml of each.

RESULTS AND DISCUSSION

Results obtained from the analysis of this work are presented in Tables 2,3 and 4. The results of some selected contaminants are also compared with admissible international standards as shown in the Figures 2 – 4.

Comparison of Biological Oxygen Demand (BOD) in Various Sections

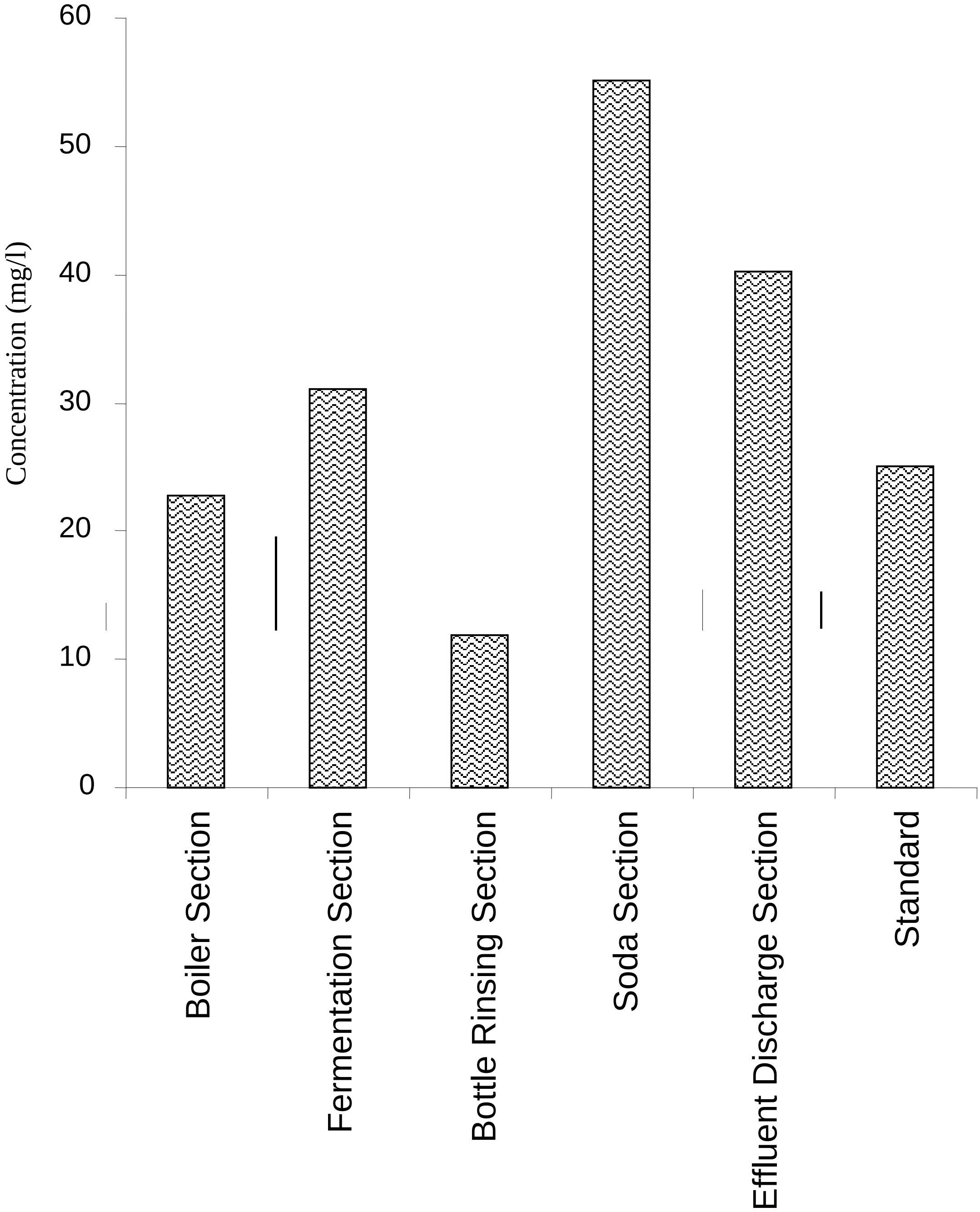

Fig. 2: Biological Oxygen Demand (BOD)

Comparison of Chemical Oxygen Demand (COD) in Various Sections

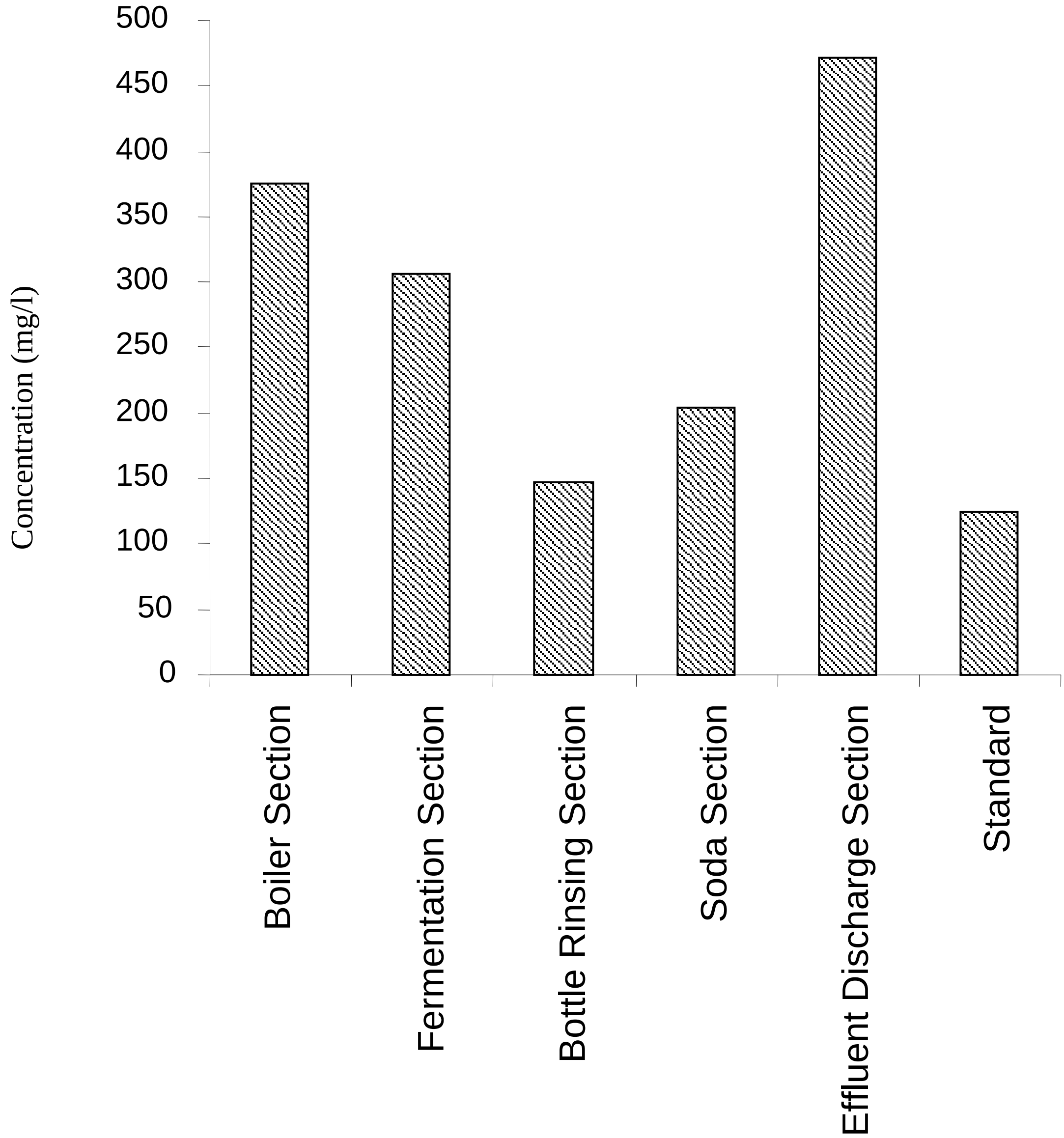

Fig. 3: Chemical Oxygen Demand (COD)

Comparison of Total Suspended Solid in Various Sections

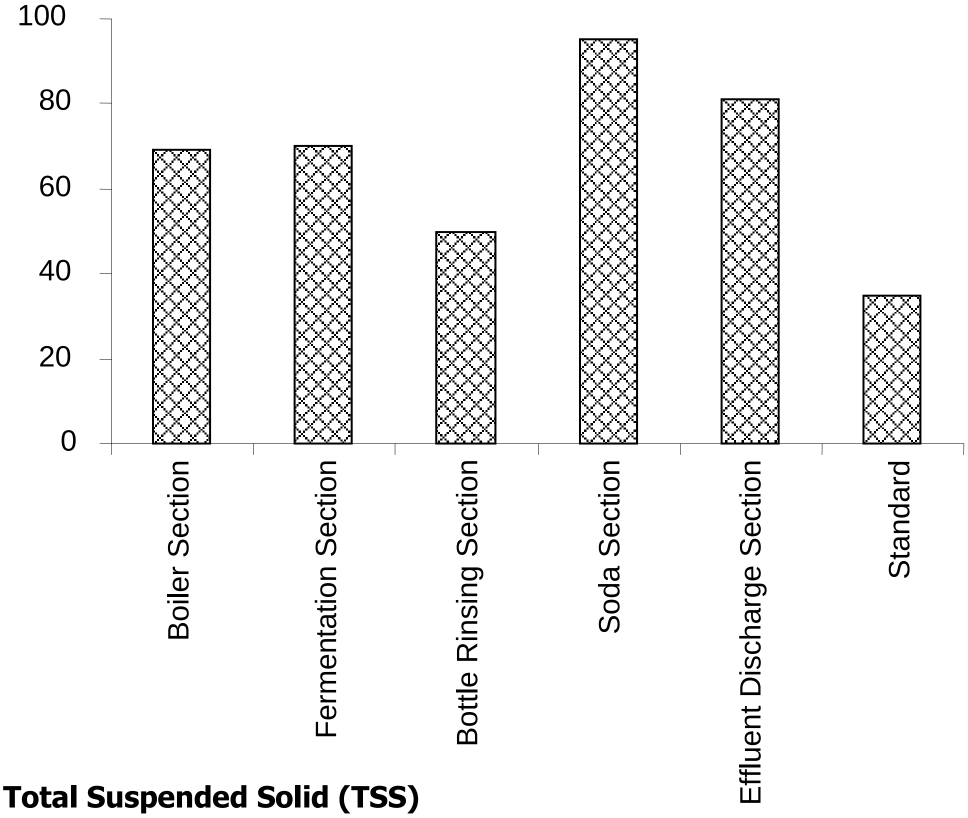

Fig. 4: Total Suspended Solid (TSS)

Table 2: Physical Characteristics of Effluent Fluids at Various Sampling Points

Parameter	Boiler Section	Fermentation Section	Bottle Rinse (Water)	Soda Section (Water)	Waste Water (Effluent)	Standard
Colour	Not too clear	Cloudy	Clear	Brown	Cloudy	
Odour	No odour	Definite odour	Threshold level	Definite odour	Threshold level	
Turbidity (mgl)	16.8	11.9	14.7	61.3	14.9	
TSS (mg/l)	69	70	50	95	81	35
TDS (mg/l)	39.3	179.2	21.4	290	38.10	

From Table 2 above, the resultS of analysis show that the samples are relatively weak solutions in the suspended and colloidal state. Colour observation indicates that the sample solutions were cloudy, clear and brownish for the various stages of the process. A solution such as the waste water has the tendency to get a little darker as putrefaction starts to occur. The changes occur as the result of gradual exhaustion of oxygen from the effluent fluid with time. According to Bhatia (2005), at increased concentration of the contaminants, effluent fluid can be harmful in the following ways:

(i) Impaired respiration to some human.

(ii) Nausa and reduction in appetite.

In term of the pH value, from the analysis result, the brewery waste water studied here tends to be alkaline. However, as time passes, pH value becomes acidic due to bacterial action by yielding acids in the wastewater. This means properly oxidized effluent should have a pH of low alkalinity. A high concentration of either an acid or alkalinity in brewery effluent fluid is indicative of industrial waste. Therefore, certain treatment methods of effluent fluid depend upon the pH value for their efficient handling.

Table 3: Chemical Characteristics of Effluent Fluids at Various Sampling Points

Parameter	Unit	Boiler Section	Fermentation Section	Bottle Rinse (Water)	Soda Section (Water)	Waste Water (Effluent)	Standard
PH		10.37	11.77	8.80	10.87	11.97	
Total Hardness	mg/l	68	96	104	166	208	
Total Alkalinity	mg/l	31.2	102	30	123.5	103.2	
Chloride	mg/l	6.2	9.8	0.3	0.7	2.4	
Sulphate	mg/l	11	37	8	8.20	17	
Phosphate	mg/l	0.386	1.149	0.185	0.223	0.462	
Nitrogen	mg/l	0.34	0.89	0.21	0.14	0.39	
DO	mg/l	20.9	32.10	12.8	48.10	18.30	
BOD	mg/l	22.80	31.10	11.90	55.10	40.30	25
COD	mg/l	376	306	147	204	471	125
Phenol	mg/l	-	-	-	-	0.018	

Moreover, inorganic and organic contaminates such as organic nitrogen indicates level of matter concentration for these fluid samples in Table 3, shows that it is weak. Phenol content for the brewery waste water even at that concentration level of 0.018mg/l, when in contact with receiving waters on disposal can cause serious taste problems in drinking water. Thus, disposal should be well guided especially without treatment. Decomposition as a function of time will reduce contaminants like suphated in that concentration into sulphides and hydrogen by anaerobic bacteria action. Hence, as long as the effluent fluid keeps degrading, the hydrogen sulphides gas so produced will cause bad odour to the wastewater. At low temperature below 25% oxygen dissolved in the wastewater is somewhat stable but exhaustible at a very slow pace (Maloney, Stein and Cornett, 1980). At the fermentation section, hardness of the fluid or wastewater is considered at the level to be appropriate at a brewery in Akwa Ibom State for brewing process. But in some circumstances or at any time these values could fluctuate due to addition of calcium to the feed water. In the interpreted wastewater stream, hardness level is expected to be somewhat higher due to mingling of the various effluent streams, with rinse water of higher hardness concentration in a larger quantity, contributes to this effect. Thus alkalinity concentration of the wastewater that is high indicates waste.

Table 4: Content of Heavy Metals in Effluent Samples

Parameter	**Concentration (mg/l)**
Iron (Fe)	0.46
Aluminium (Al)	0.118
Chromium (Cr)	0.16
Copper (Cu)	0.11
Cynanide CN)	0.76
Lead (Pb)	0.030
Zinc (Zn)	0.040
Barium (Ba)	0.31
Mercury (Hg)	0.022
Manganese (Mn)	0.017
Cadmium (Dd)	0.04

Table 4 indicates the types of heavy metals and their concentration that are found in wastewater and this indicates the presence of toxic compounds in the effluent. These are toxic to micro-organisms resulting in the malfunctioning of biological treatment plants. Generally, the concentration in the result is significant though of a fresh brewery effluent fluid, therefore, the trace level of these contaminants should be taken into consideration in the design of biological treatment plants.

Many industrial plants are required to pre-treat their wastewater before dumping it in the waste water network (Akram and Tamini, 2002). In Table 3, the COD has the highest concentration as can be seen in the graph. While nitrogen has the lowest in the boiler section. This shows that nitrogen can be eliminated to the bearest minimum to avoid contamination while because of reaction in this section COD would be high. In Table 3, total dissolved solids are the highest while phosphate is the smallest. Other parameters can be seen in the graph as represented. In Figure 3, COD is the highest in the fermentation section as shown while nitrogen is the lowest. With respect to Table 4, the interpreted waste water shows that COD has the highest concentration of 471mg/l and phenol has the lowest concentration of 0.018mg/l.

CONCLUSION AND RECOMMENDATIONS

Brewery wastewater characterization of contaminants or wastewater impurities is a guide during and after the treatment, followed by disposal at threshold limit values. The essence of this paper was to look at the relevance and importance of curtailing nuisance caused by liquid waste from process industries, such as brewery plants that emit large quantities of wastewater into surface water bodies with or without treatment or stringent discharge permit by the authorities of their location. Moreover, from the analyses result, one can determine the level of toxicity of wastewater in question as regards to reuse for aquaculture, irrigation purposes, etc. Also, the knowledge of effluent quality and quantity can become vital information that can help to improve the efficiency of plant design. Anaenobic treatment is a widely applied method for treatment of brewery effluent. Thus, it would be wise for the biological treatment of brewery wastewater.

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