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Analysis of Physico-Chemical Characteristics of Effluents from Beverage Industry in Ethiopia

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Abstract

Beverage industries are one of the most polluting industries producing huge amount of wastewater effluents. These industries have been recognized to cause pollution by discharging effluent into receiving environment especially to the nearby rivers. The aim of this study is to determine the status of waste water effluent discharge of beverage industry in Ethiopia. Samples were collected from 8 beverage industries' wastewater effluent discharge end pipe and examined for different physico-Chemical parameters such as: COD, BOD_5, TSS, ammonia, total nitrogen, PH and phosphate. The observed values were ranged between 9 - 397.5 mg/L for TSS, 0.185 - 69.7 mg/l for phosphate, 0.265 - 71 mg/l for ammonia, 226 - 1975 mg/l for COD, 15 - 576 mg/L for BOD, 4 - 86.6 mg/l for total nitrogen and 5.21 - 12.37 for PH. The finding of the study revealed that most of the beverage industries were extremely high amount of total suspended solids (TSS), BOD and COD effluent discharge were found above the Ethiopian beverage industry effluent discharge limit value. Half of the sampled beverage industries' effluent discharge of PH, total nitrogen, ammonia and phosphate were found within the limit value while the rest of the industries are still discharging their effluent above the national standard limit value. The continuous discharge of effluents into rivers without any additional treatment raises the level of pollution and toxicity, which have significantly adverse impact on the aquatic environment.

Keywords

Beverage, Wastewater, Effluent, Pollution, Physico-Chemical, Ethiopia

1. Introduction

Water pollution is serious problem globally involving the discharge of dissolved or suspended substances into groundwater, streams, rivers and oceans. A major source of pollution in developing countries is industrial activities and this has gradually increased the problem of waste disposal. Increased industrial activities have led to pollution stress on surface water both from industrial, agricultural and domestic sources [1]. The beverage industries were pin pointed as major consumers of water and became economic source in the world [2] [3]. Beer is about 95% water in composition; however, the amount of water used to produce a container of beer is far greater than the amount of water contained in the beer that is actually packaged and shipped out [4]. The bottle washing causes most of the water consumption. Modern bottle-washers need 150 - 200 ml per bottle; where as an older one consumes up to 600 ml [5].

In addition to the water used in production, wastewater generation and disposal present another improvement opportunity for brewers. Most breweries discharge 70% of their incoming water as effluent. In most cases, brewery effluent disposal costs are much higher than water supply costs. In many communities, breweries may be the largest consumer of water and the largest source of organic effluent that must be treated by the municipal treatment plant. This presents unique supply and cost concerns. When combining that cost with treatment (physical and chemical) and effluent disposal costs, brewers are presented with a reflection of the true or full cost of water [4]. The beverage industry brewing process generates large amounts of wastewater effluent and solid wastes that must be disposed of or treated in the least costly way to meet strict discharge regulations set by government entities. Brewery wastewater typically has a high biochemical oxygen demand (BOD) from all the organic components (sugars, soluble starch, ethanol, volatile fatty acids, etc). Brewery wastewater usually has temperatures ranging from 25˚C to 38˚C. The pH levels can range between 2 and 12 and are influenced by the amount and type of chemicals used in cleaning and sanitation (e.g., caustic soda, phosphoric acid, nitric acid, etc.). Nitrogen and phosphorus levels are mainly dependent on the raw material and the amount of yeast present in the effluent [6]. However, the beverage industries action without any adequate treatment facilities have led to discharge of effluents into nearby rivers.

The wastewater generation and management in beverages industries become a serious threat to freshwater bodies, aquatic biota and human health [2] [7]. The continuous discharge of effluents into streams and rivers raises the level of trace and toxic metals, which have considerably adverse effect on fresh water bodies [7] [8] [9]. In most developing countries particularly in Africa waste water discharge from beverage industry is high because the industries lacks adequate waste water treatment plants. This is the same situation in Ethiopia. According to AAEPA report [10] there are more than 2500 industries in Addis Ababa city, 90 per cent of which lack onsite waste water treatment facilities. These industries discharge waste into nearby stream courses and open ditches and the Akaki River is heavily polluted. The estimated volume of wastewater discharged from industries into the rivers at around 4.8 million·m^3 [11]. Therefore this study aims to determine the status of wastewater effluent discharge of beverage industry in

Addis Ababa city, Ethiopia.

2. Material and Methods

Study area

The study was conducted in Addis Ababa city which is the capital city of Ethiopia. It is situated 9.02 latitude and 38.75 longitude and it is located at elevation 2405 meters above sea level. Addis Ababa is the economic, industrial powerhouse and political capital of the country as well as the seat of the African union (Figure 1). However, most of its rivers are polluted due to discharge of huge amount of wastewater from industry and municipal solid and liquid wastes. Beverage industries has a great contribution for the discharge of wastewater effluent to the nearby rivers. The polluted river water is used by downstream residents to grow vegetables, which are sold and consumed by inhabitants of the city. The city's rivers are contaminated with different organic and inorganic pollutants. The shallow groundwater and springs are also contaminated [6] [10] [12].

Method of data Analysis

Sample of the beverage industries effluent was taken on effluent discharge flow from the treatment plant. The physico-chemical parameters which were examined are the following: PH, chemical oxygen demand (COD), biological oxygen dissolved (BOD), Ammonia (NH_3), total nitrogen, total suspended solids (TSS) and phosphate (PO_4^{3-}) and their comparison to wastewater quality standard according to the Ethiopian beverage effluent discharge limit value standard methods. The name of the selected factories for the analysis and their sample identification number are presented in (Table 1) and the method used for the analysis of the collected samples is also provided in (Table 2). The national Beverage's Effluent standards are attached in Appendix A.

3. Result and Discussion

The laboratory results of investigation of beverage industries' effluent for various physical and chemical parameter and comparison with the Ethiopian alcohol

Figure 1. Geographical location of the study area.

standard effluent discharge limit value is presented in (Table 3) and the graphical analysis were analyzed using MS excel data sheet.

PH and Total Suspended Solid (TSS)

The observed PH values in some of beverage industries in Addis Ababa city are shown in the Table 3 and Figure 2. The measured values indicated that the PH value of F8 (Figure 2) was above the upper limit value of 9. In addition, among eight industries, the PH value of F4 (factory four) Figure 1 was below the lower limit of 6. In general the PH value of the two factories, out of 8 factories, surpassed the countries standard limit value. The observed ranges of the values

Table 1. Name of the alcohol beverage factories effluent collection and the identification no. of samples.

Collected Sample ID (Factory ID)	Name of the Factories
1	Meskerm Liquo
2	Awash Wine
3	BGI
4	National Alcohol Meken
5	Asnak Alcohols
6	Liyu Addis Alcohols
7	Mola Maru
8	National Alcohol Mexico

Table 2. instruments or methods used for the determination of the parameters of effluents.

SI No.	Parameter	Abbreviations	Method of Analysis
1	PH	----	PH Meter
2	Chemical Oxygen Demand	COD	Titrimetric Method
3	Biological Oxygen Demand	BOD5	Microbiological Titration Method
4	Total Suspended Solid	TSS	Gravimetric Method
5	Total Nitrogen	N	Colorimetric Method
6	Ammonia	NH_3	Colorimetric Method
7	Phosphorous	PO_4^{3-}	Molybdo-Vanadophosphoric Acid Method

Table 3. Results of effluent discharge values versus the standard limit value.

Parameters	Name of the Beverage Industries								Limit Value
	Meskerm Liquor	Awash Wine	BGI	N. Alcohol Meken	Asnak Alcohol	Liyu Addis Alcohol	Mola Maru	N. Alcohol Mixico	
PH	8.175	7.97	7.34	5.21	6.275	6.83	6.785	12.37	6 - 9
TSS	108	397.5	42.5	242.5	219	143	9	108.5	50 mg/L
$PO4^3$	0.26	1.715	69.7	7.9	48	0.185	0.905	0.22	5 mg/L
NH_3	1.315	0.5	71	7.15	61	4	0.64	0.265	20 mg/l
Total Nitrogen	4	86.6	30.5	13.1	80	33.75	10	25	40 mg/l
COD	396.5	1200.5	1012	555	400	1975	176.5	226	250 mg/l
BOD	97.5	576	122	338	98	15	40.5	75	60 mg/l

were found between 5.21 - 12.37 pH (Figure 2). PH of wastewater effluent discharge of the beverage industry is generally towards basic side. Extremes of pH of wastewater are generally not acceptable as excesses of pH cause difficulties to persistence of ecological life. Water with high or low pH is not appropriate for irrigation and other agricultural purposes. Although stricter limits are often set, greater tolerance is shown towards higher pH since carbon dioxide from the atmosphere or from biological processes in healthy surface water systems tends to lower pH levels very effectively to neutral conditions. If the surface water pH shifts too far either way from the pH range of 6.5 - 7.5, sensitive fish and plant life are susceptible to loss [13].

TSS: Total suspended solids is one of the prime concern effluent discharge for the beverage industries. The study results revealed that maximum concentration of suspended solid was observed in F2 (397.5 mg/l) and the lowest observed value of 9 mg/l in F7 (Table 3) and Figure 3. Except the two factories, the measured value of suspended solid in all other six beverage industries was above the standard limit value of 50 mg/l. The observed ranges of the values were between

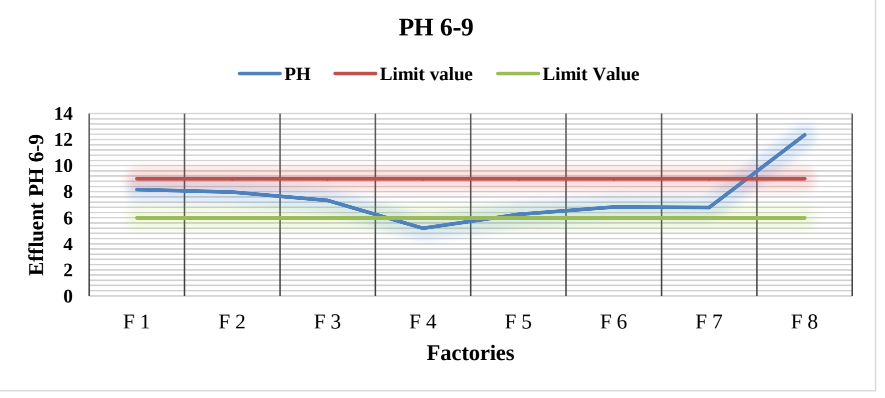

Figure 2. Comparison between effluent PH and Ethiopian beverage effluent discharge limit value.

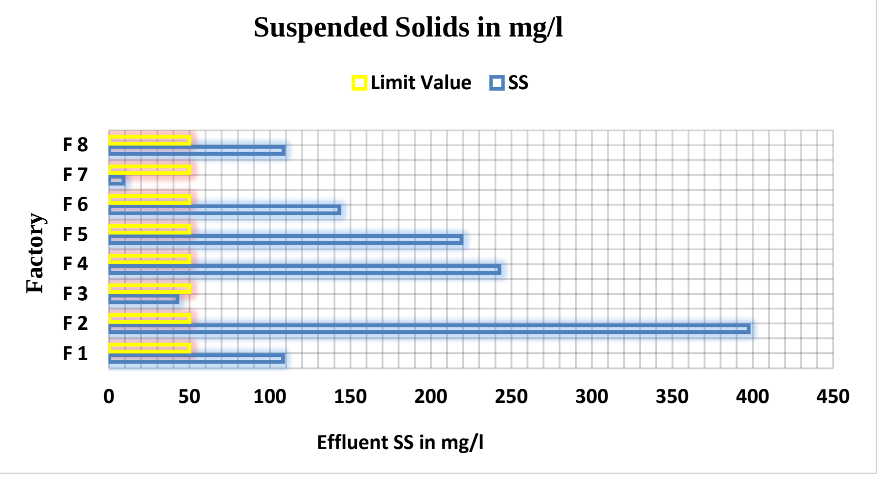

Figure 3. Comparison between effluent TSS and Ethiopian beverage effluent discharge limit value.

9 - 397.5 mg/L (Figure 3). Total suspended solids are the slice of solids that typically residues on the filter paper. Suspended solids encompass of silt, clay, fine particles of organic and inorganic matter, which is viewed as a type of pollution because water high in concentration of suspended solid may harmfully affect growth and reproduction rates of aquatic fauna and flora. Thus, it generates impact on osmoregulation of water and also lessens solubility of gasses [14].

Reactive Phosphate, Total Nitrogen and Ammonia

Phosphate: the experimental result revealed that, among eight beverage industries, the maximum concentration of phosphors was observed in F3 (69.7 mg/l) and the lowest observed value of 0.185 mg/l was found in factory 6 (Table 3) and Figure 4. Three factories were surpassed the available national standard limit value of 5 mg/l for phosphors. The observed values were ranged between 0.185 - 69.7 mg/l (Figure 4). Phosphors concentration of the other five industries was found within the limit value.

Total Nitrogen: The expermental result for total nitrogen indicated that except the two industries, the concentration of Nitrogen in others industries effluent were within (below) the standard 40 mg/l (Table 3). The maximum observed value 86.6 mg/l total nitrogen was found in F2 and the minimum 4 mg/l was in F1 (Table 3) and Figure 5. The experimental values were ranged between 4 - 86.6 mg/l (Figure 5). The high levels released by substances containing nitrogen over-stimulate plant growth. Water-based plants and algae grow too rapidly, whereupon waterways become clogged and flows are impaired. As the plants die, a disproportionately high amount of organic matter has to be broken down. If the load outstrips the natural supply of oxygen from the river, plants, fish and aerobic bacteria die and ultimately anaerobic conditions develop [13].

Total Ammonia: The study's investigation reveals the highest total ammonia concentration was found in the two industries that was extremely higher than the available national standard limit value of 20 mg/l Table 3. The maximum concentration of ammonia was 71 mg/l and the minimum observed value was found 0.265 mg/l (Figure 6). The detected values were ranged between 0.265 - 71 mg/l Figure 6. Discharging of effluent with excess amount of nitrogen, ammonia

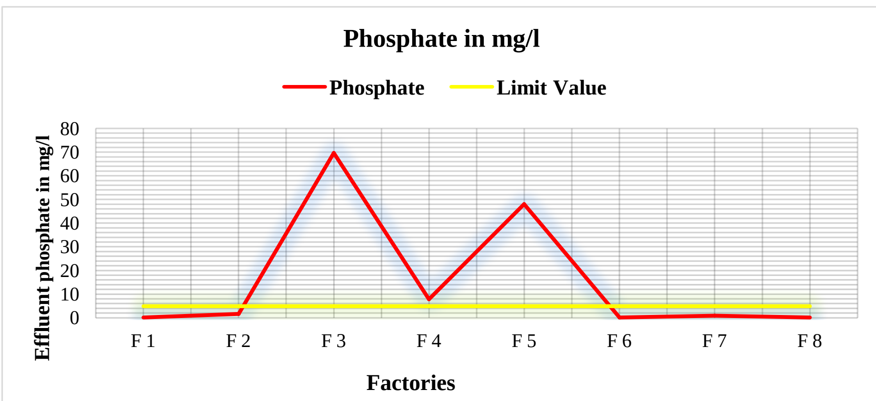

Figure 4. Comparison between effluent phosphate and Ethiopian beverage effluent discharge limit value.

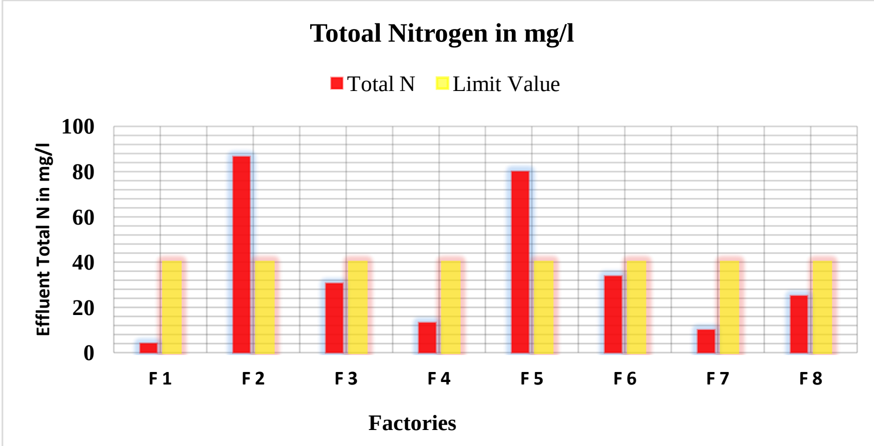

Figure 5. Comparison between effluent total nitrogen and Ethiopian beverage effluent discharge limit value.

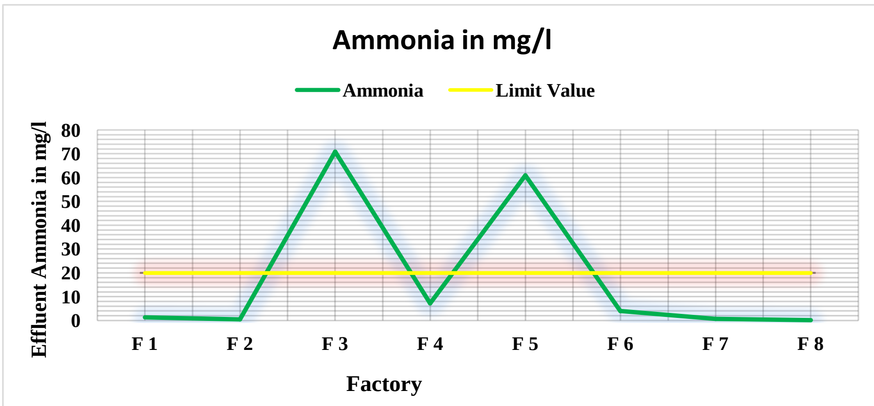

Figure 6. Comparison between effluent ammonia and Ethiopian beverage effluent discharge limit value.

and phosphors to the environment without any additional treatment is disaster. Excess of these chemicals create algal bloom in rivers and lakes that facilitate the depletion of age of the lakes. These wastes pose serious threat to associated environment including human health risks [15]. The formation of eutrophication in water bodies is also because of these chemicals.

Chemical Oxygen Demand (COD) and Biological Oxygen Demand (BOD)

It's obvious that the fineness of water quality, both COD and BOD5 were the determinant critical factors [16]. BOD and COD indicate the pollution of water by oxygen depletion [17]. The study revealed that both COD and BOD levels of the beverage industries effluent were severely higher than the standard limit value. It is noted that comparison of the laboratory results was done with the effluent standards limit values of beverage industries and it indicated that all the measured values of COD (Chemical Oxygen Demand) were above the standard of 250 mg/l, except one industry which was found within the limit value (Table 3). The Maximum COD value 1975 mg/l was found in F6 and the lowest value 226 mg/l was observed in F8 (Figure 7). The observed values were ranged between 226 - 1975 mg/l (Figure 7). Discharging of extremely high COD effluent to the water bodies may contain very high amounts of organic matter and it can cause whole diminution of dissolved oxygen leading to the mortality of aquatic organisms.

Like COD, BOD observed value of all except two beverage industries effluent discharge were extremely higher than the national standard limit value of 60 mg/l shown in the Table 3. The highest BOD Value was found in F2 (576 mg/l) and the minimum observed value was found in F7 (15 mg/l) Figure 8. The observed ranges of the values were between 15 - 576 mg/l Figure 8. Extremely high BOD effluents are well-known to deplete the oxygen content of a receiving water body which in return has adverse effect on aquatic species and aquatic chemistry.

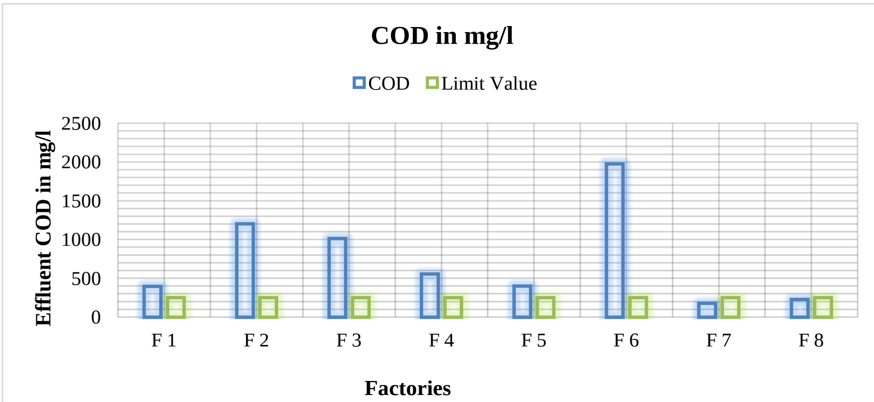

Figure 7. Comparison between effluent COD and Ethiopian beverage effluent discharge limit value.

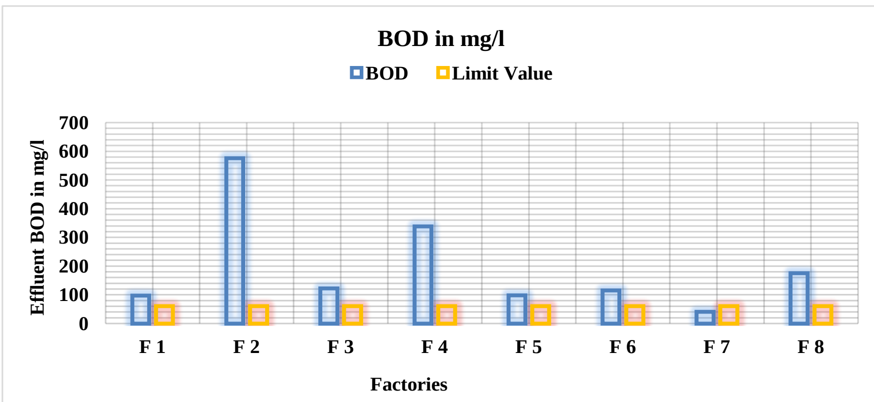

Figure 8. Comparison between effluent BOD and Ethiopian beverage effluent discharge limit value.

4. Conclusion

Beverage industries consume vast amount of water for processing their product. It is expected that due to the nature of the sector huge amount of waste water is released to the environment. Thus, this study is conducted on eight industries to analyze their physico-chemical parameters. This research illustrates that the sampled industries are releasing extremely high amount of effluent which contaminate the surrounding environment specially the nearby rivers. The BOD, COD and suspended solids are oxygen demanding components of organic matter. Most of the industries effluent is directly discharged into the nearby river and therefore the river dissolved oxygen is consumed by the pollutants released from the factories. As a result, the river water becomes contaminated and no longer support aquatic life since its oxygen content is depleted by the contaminants. To solve the problem in a sustainable way, these factories should have to apply secondary and tertiary treatment plants in good manner and follow the right procedures to treat the waste water by applying accurate amounts of chemicals, good maintenance, preparing good environmental management plan and continuous checking and evaluation before releasing their effluent to the nearby rivers.

Conflicts of interest

The authors declare no conflict of interest.

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Supporting Information

Appendix A. Ethiopian effluent discharge limit value for beverage industries (malting, brewing, distiling, production of wines and other alcoholic liquours industries).

Parameter	Limit Value
Temperature	40˚C
pH	6 - 9
BOD_5 at 20˚C	90% removal or 60 mg/l, whichever is less
COD	90% removal or 250 mg/l, whichever is less
Suspended solids	50 mg/l
Total ammonia (as N)	20 mg/l
Total nitrogen (as N)	80% removal or 40 mg/l, whichever is less
Total phosphorus (as P)	80% removal or 5 mg/l, whichever is less
Oils, fats, and grease	15 mg/l
Mineral oils at the oil trap or interceptor	20 mg/l