Research Journal of

Microbiology

ISSN 1816-4935

Academic
Journals Inc.

www.academicjournals.com

Research Journal of Microbiology 9 (5): 239-245, 2014
ISSN 1816-4935 / DOI: 10.3923/jm.2014.239.245

Microbial Impacts of Brewery Effluent Discharge on Sissa River: A Case Study of Kaase in Kumasi, Ghana

[1]Samuel Fosu Gyasi, [2]Eugene Appiah-Effah and [1]Andrew Nkansah
[1]Department of Environmental Engineering, University of Energy and Natural Resource, Sunyani, Ghana
[2]Department of Civil Engineering, Kwame Nkrumah University of Science and Technology, Kumasi, Ghana

Corresponding Author: Samuel Fosu Gyasi, Department of Environmental Engineering, University of Energy and Natural Resource, Sunyani, Ghana Tel: +233268189473/233243034733

ABSTRACT

Industries are major sources of pollution in all environments. Based on the type of industry, various kinds of pollutants can be discharged directly or indirectly into the environment. In this study, effluent discharge from brewery were collected and compared with values recorded for its receiving stream. Parameters investigated included Total Suspended Solids (TDS), Biological Oxygen Demand (BOD_5), Chemical Oxygen Demand (COD), total ammonia, nitrates and phosphates. ANOVA and Dunnet's Multiple Test were used for the analyses of these parameters. Besides, microbial parameters in the form of total/faecal coliform, total viable count, faecal enterococci, *E. coli* and *Salmonella*, were sampled and analysed using the Most Probable Number (MPN) method. With the exception of the pH, all the parameters measured from the brewery effluent site as well as in the river indicated higher levels than those permitted by the GSA and WHO. The study revealed that effluent from the waste treatment plant from the brewery was technically efficient with respect to most of the physicochemical parameters. This could, however, not be said for their microbial counterpart as levels of biological indicators of pollution all exceed the WHO and GEPA recommendations. It is, therefore, being recommended that the brewery authorities as well as the EPA of Ghana must ensure that the brewery effluents meet quality standards. This action is urgently warranted as high level pollution of the industrial effluents cause's environmental problems which will affect plant, animal and human life.

Key words: Brewery, Sissa river, Kumasi, pollution, microbial, discharge

INTRODUCTION

Industries are major sources of pollution in all environments. Based on the type of industry, various kinds of pollutants can be discharged directly or indirectly into the environment (Tilt, 2013). Waste water from industry may include sanitary waste of employees, processing waste from manufacturing plants, water emanating from washing the factory floor as well as those utilized in various cooling systems (Awaleh and Soubaneh, 2014). This may vary widely depending on the size of the industry and what is being produced.

Brewery effluent is the resulting liquid flow from a wastewater treatment system of a brewery factory. The quality of brewery effluent can fluctuate significantly as it depends on various different processes that take place within the brewery and that the organic components in brewery effluent are generally easily biodegradable since these mainly consists of sugars, soluble starch, ethanol, volatile fatty acids as well as solids which are mainly spent grains, waste yeast and trub (Driessen and Vereijeken, 2003). It has been reported that untreated brewery effluent typically contained suspended solids (10-60 mg L^{-1}), Biological Oxygen Demand (BOD) (1000-1500 mg L^{-1}), Chemical Oxygen Demand (COD) (800-3000 mg L^{-1}), nitrogen (30-100 mg L^{-1}) and phosphorus (10-30 mg L^{-1}) (Orhue *et al.*, 2005). However, not all of the organic materials are dissolved in the effluent hence some organic materials will remain as particulate (http://www.energystar.gov /ia/business/industry/LBNL-50934.pdf).

In all these activities, there is the production of large quantities of waste which needs to be treated before discharge. Study has shown that, the quality and the kind of waste produced depend on a large extent on the frequency of production and cleaning of the vessels employed in production (Gamper-Rabindran and Finger, 2013). When these wastes are not effectively treated before discharge, they could pollute the receiving waters accepting these discharges. It is an undeniable fact that the water resources of our planet, a basic and most important of our existence, are the most threatened aspect in life existence. In 1978, the UN reported consumable water levels at 2.7% of earth's water with ground water being a major contributor. Present estimates quantify consumable water levels at 1% of the earth's water resources and ground water levels are increasingly being threatened by pollution directly and indirectly (Kumar and Suneetha, 2014). Sustainable utilization of the earth's water is defined as the use of water resources which imposes no cost what so ever on future generations, either through depletion of the resource or through a reduction in its quality (Ekhaise and Anyasi, 2005).

Guinness Ghana Breweries (GGBL) is a Ghanaian brewery based at the Kaase Industrial Area in Kumasi. They are listed on the stock index of the Ghana Stock Exchange, called the GSE All-Share Index, established in 1991. When production started at its inception, the company produced only Guinness Foreign Extra Stout, popularly known as 'Guinness'. It had a primary depot linked to chain of stores across the country particularly in the south. In 1988/89 another brand, this time non-alcoholic beverage, 'Malta Guinness' was introduced and that became an instant hit capturing almost 70% of beverage market. Effluent from these breweries is emptied into drainage channels after treatment which ends up in the Sissa River. This river serves as a source of drinking water for many inhabitants downstream. On the look of things, the river seem polluted but so far no empirical study has been done to verify the relatively high standard of effluent quality reported by the company. As a result, this study has set as its main objective to analysis the quality of effluent discharge into receiving waters to ascertain the effluent quality level.

MATERIALS AND METHODS

Study area: Kaase within the Kumasi Metropolis in the Ashanti Region of Ghana (Fig. 1b) was chosen for this study. This is because this vicinity is where GGBL (G) in Fig. 1, is sited and thus will be first the line of receiving pollutants from the brewery. Within the vicinity of Kaase lies the Sissa river which serves as a source of drinking water for some communities downstream, few kilometers away.

Sampling points: With the help of a Global Position System (GPS), different sampling points were taken from where effluents from the Guinness Brewery Limited (GBL) exits the company's waste treatment plant and 3 other points along the Sissa River was selected (Fig. 1). These include sampling point where effluent from the brewery exit the factory floor (G) and point (B) along the stream just before the effluent joins the stream, as well as points A and C which are 50 meters before and after the effluent has joined the stream, respectively.

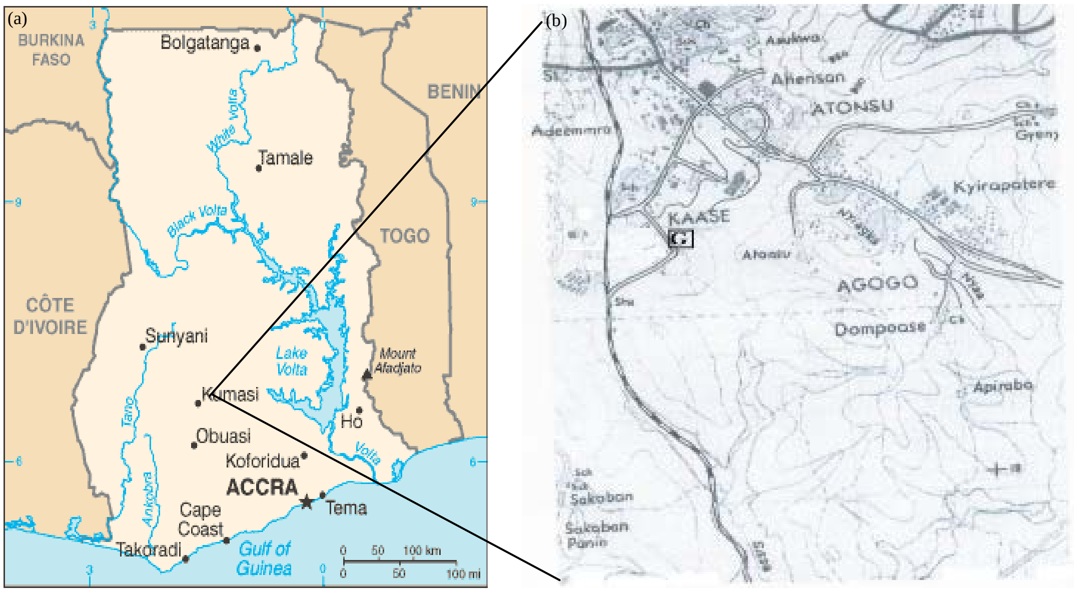

Fig. 1(a-b): Administration Map of Ghana (a) Kumasi in the Ashanti region and that of portions of Kumasi (b) Ashanti Region of Ghana showing the study area (Kaase). The Location of the brewery is marked G

Sampling: With the help of a labeled 500 mL transparent sterile sampling bottles, effluent from the factory floor (G) and water samples from the stream along the other 3 designated points were collected. Conductivity, total dissolved solids, pH, temperature and turbidity were measured *in-situ* using PC 300 Waterproof Handheld pH/Conductivity/TDS/Temperature meter. Another set of samples was collected in similar sterile labeled bottles for microbial analysis. These were tightly covered, stored in a cool ice chest and hurriedly transported to the laboratory for analysis. Data was collected between September-December, 2013.

Laboratory analysis: Physico-chemical analysis of the water samples were carried out in the laboratory by instrument and non-instrumental methods. Parameters investigated include Total Suspended Solids (TDS), Biological Oxygen Demand (BOD_5), Chemical Oxygen Demand (COD), total ammonia, nitrates and phosphates. These were analysed using the standard procedure mentioned in AWWA/APHA (1992). Microbiological parameters were also sampled and these were limited to total/faecal coliform, total viable count, faecal enterococci, *E. coli* and *Salmonella*. These microbial parameters were determined using Most Probable Number (MPN) method.

Data analysis: Data for both physicochemical parameters and microbial counterparts were compared between means of parameters collected from the brewery effluent and that of the means of water samples collected from the different portions of the stream using one way ANOVA followed by Dunnets Multiple Test (GraphPad prism 6.0) [www.graphpad.com/scientific-software/prism/].

RESULTS

Analysis of results based on some physicochemical parameters with respect to temperature and pH between effluents from the brewery and that of water samples collected from the 4 different

Table 1: Comparative analysis of some physicochemical parameters of effluents from brewery into the sissa river

Parameter	Effluent (G)	Mid Points (B)	Upstream (A)	Downstream(C)	WHO	GEPA
pH	7.933±0.5472	7.337 ± 0.2815^{ns}	7.19 ± 0.07^{ns}	7.28 ± 0.1929^{ns}	6.5-8.5	6.0-9.0
Temperature (°C)	25.67±2.739	25.6 ± 2.623^{ns}	25.63 ± 2.695^{ns}	25.7 ± 2.606^{ns}	-	3
Turbidity (mg L^{-1})	17.17±6.414	100.7 ± 60.08^{ns}	49.43 ± 17.01^{ns}	92.8 ± 63.68^{ns}	5	-
Conductivity (mg L^{-1})	2105±198.6	1612 ± 550.5^{ns}	514.0 ± 122.3^{ns}	$1018\pm794^{*}$	-	-
Total Dissolved Solids (TDS) (mg L^{-1})	1053±98.73	806.3 ± 279^{ns}	257.0 ± 60.13^{ns}	$509\pm396.9^{**}$	1000	-
Total Suspended Solids (TSS) (mg L^{-1})	51.0±34.39	223.7 ± 293.6^{ns}	100.7 ± 61.71^{ns}	$177.7\pm206.7^{***}$	-	-
BOD5 (mg L^{-1})	183.0+133.2	301 ± 432.1^{ns}	41.0 ± 42.46^{ns}	$244.0\pm373.3^{**}$	10	50
COD (mg L^{-1})	576.0±748.6	976 ± 1427^{ns}	138.7 ± 150.6^{ns}	783.3 ± 1229^{ns}	20	250
NH3	3.167±2.454	4.800 ± 2.750^{ns}	5.0 ± 6.843^{ns}	5.267 ± 6.634^{ns}	5	1
NO3	21.90 ± 3.017	15.1 ± 0.08544^{ns}	45.67 ± 39.18^{ns}	75.67 ± 60.14^{ns}	1.5	-
PO4	27.3±0.1	21.01 ± 19.39^{ns}	11.11 ± 11.17^{ns}	11.64 ± 10.76^{ns}	1	-

SD: Standard Deviation, N: 3, Effluent (G): Effluents from the exit points of the brewery waste treatment plant, Mid points (B): Points along the Sissa stream just before effluents from the brewery joins the stream, Upstream (A): About 100 m above mid points (B): Whiles Downstream (C): About 100 m after midpoint B, Ns: Not significant ($p>0.05$) *Significant ($p< 0.05$), **Significant ($p<0.005$), ***Significant ($p<0.001$) at 95% confidence of interval

sampling points along the stream did not show any significant difference ($p>0.05$). Means of these sampled parameters also fell within the World Health Organization (WHO) and Ghana Environmental Protection Agency (GEPA) permissible guidelines for drinking water (i.e., 6.5-8.5b and 6.0-9-0, respectively) as shown in the Table 1. Turbidity measurements for effluent from the brewery were also assessed as part of the study and the analysis of the results showed that the brewery effluent recorded the lowest mean turbidity value (17.17 NTU) with a standard deviation 6.411 (Table 1).

Water samples from point B were the most turbid (100.7±60.08 NTU) and all the samples exceeded the WHO/GEPA recommendations of 5 NTU for drinking water as shown in Table 1. The difference of the means turbidity between the brewery effluents and that of the different water samples were however not statistically significant ($p>0.05$).

The analysis of the mean electrical conductivity of the effluent discharge from the brewery showed that electrical conductivity of the effluent discharge from the stream was high (2105±198.6 mg L^{-1}) and exceeded levels recorded for water samples collected at sampling point C (1018±794 mg L^{-1}). This difference was statistically significant as shown in Table 1. The analysis of the Total Dissolved Solids (TDS) showed that, mean TDS for the brewery effluent was high (1053 mg L^{-1}) with a standard deviation of 98.73 compared to mean TDS of water collected downstream after effluents have joined the stream (509 mg L^{-1}) with the standard deviation being 396 ($p>0.005$) (Table 1).

Total suspended solids for both effluents from the brewery and that of water collected from the stream were assessed during the study. Results of the analysis of the samples showed that levels of this parameter were very high downstream (C) (177.7±206.6 mg L^{-1}) compared to that of the effluents from the brewery (51.0±34.39 mg L^{-1}) as shown in Table 1. The difference was statistically significant ($p>0.0001$). The analysis of demand for oxygen showed that the Biological Oxygen Demand (BOD_5) of the brewery effluent was lowers (183 mg L^{-1}) than that of water sample collected downstream (244 mg L^{-1}) (Table 1). This difference was not only significant ($p>0.005$) but also exceeded both GEPA/WHO recommendations for drinking water. Similar analytical trend was found with Chemical Oxygen Demand (COD), although, the difference was not statistically significant ($p<0.005$) as shown in Table 1. The nutrient contents of the effluents from the brewery and that of the stream were also analysed with respect to total ammonia present and the results

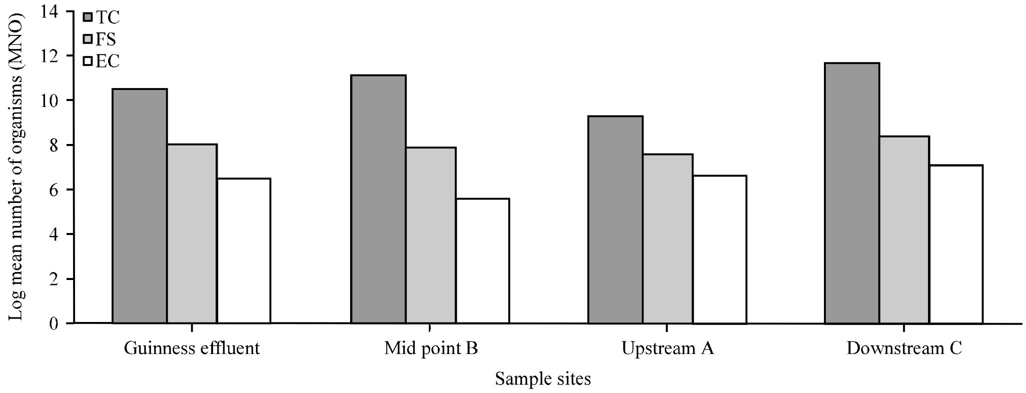

Fig. 2: Graph of mean log number of microorganisms and different sampling locations. WHO/GSA: World Health Organization and Ghana Standard Authority Acceptable guidelines for total coliform numbers in drinking water = 0.00 CFU/100 mL, TC: Total coliform, FC: Feacal coliform, EC: *E. coli*

showed that, level of this parameter was low in the effluent (3.167±2.454 mg L^{-1}) compared to water collected downstream (5.267±6.634 mg L^{-1}) (Table 1). This was also seen with the level of nitrates in the effluents (21.90±3.017 mg L^{-1}) compared to water collected downstream (75.67±60.14 mg L^{-1}) as shown in Table 1.

The amount of total phosphate analysed for the effluents from the brewery was however higher (27.3 mg L^{-1}) with a standard deviation of 0.1 compared with all the levels recorded in water collected from the stream (A = 21.01±19.39 mg L^{-1}; B = 11.11±11.17 mg L^{-1} and C = 11.64±10.76 mg L^{-1}) (Table 1). The difference between levels of phosphates recorded from the effluent discharge was also not statistically significant compared to any of the levels recorded in water collected across the 3 points in the stream as shown in Table 1.

Microbial quality analysis was also carried out for all the water samples collected from the effluent from the brewery and the 3 different sampling points (A, B and C) along the Sissa River as shown in Fig. 1b. Results of the study with respect to total coliform count of the samples showed that water from downstream C was the most polluted (log of mean 11.66 cfu/100 mL), whiles water from upstream A of the stream was least polluted (mean of log 7.62 cfu/100 mL) as shown in Fig. 2. Total coliform counts from effluents from the brewery and that of midpoint B were also high, lying between sampling point downstream C and upstream A (Fig. 2). All of these values exceeded the WHO and GSA guidelines for drinking water as shown in Fig. 2.

Faecal streptococci was employed as microbial pollution markers for all the water samples collected during the study. Analysis of the results showed that, none of the source of water collected for the study met the WHO/GEPA permissible guidelines for drinking water (Fig. 2). Water samples collected during the study revealed that water samples collected from downstream C was the most polluted with respect to faecal coliform numbers (mean log of 8.39 CFU/100 mL), followed by the effluent from the brewery (mean log of 7.96 CFU/100 mL) as shown in Fig. 2.

The study also assessed the level of pollution of water from all the sampling points with respect to *E. coli* count. The analysis of the results showed that, these were all polluted. *E. coli* numbers from the stream (downstream C) once again was the most polluted which was closely followed by effluent from the brewery and that of upstream A as shown in Fig. 2.

DISCUSSION

This is the very first time effluent discharge from the brewery is being monitored by an independent researcher to assess the efficiency of the waste treatment plant and the subsequent health implication on the downstream consumers. The non significance difference between the pH and temperature of the brewery effluent with respect to levels recorded from the 3 sampling points along the stream offered a great relief as extremes of pH could lead to an unsafe working environment, affect biological treatment systems and damage the sewer network due corrosion. In addition, pH extremes could affect the availability of plants nutrients, as well as bring about heavy metal pollution and growth of algae as well as microbial proliferation. This was consistent with a study conducted by a group of workers in Nigeria, published in 2005 where effluents discharge from brewery recorded a pH levels that fell within recommended values (Orhue *et al*., 2005).

High temperatures recorded could contribute to oxygen depletion in 2 ways. First, relatively small increase in temperature kills certain species of fish and increases the rate of decay. In addition to this, high temperatures raise the metabolic rate of surviving fish, leading to increase in oxygen consumption which will invariably lead to oxygen depletion (Sharda *et al*., 2013). This was in line with the present study. The significantly high electrical conductivity and Total Dissolved Solids (TDS) of effluent from the brewery compared to water collected from downstream point C of the Sissa River quite worrying. Total Dissolved Solids (TDS) defined as the quantity of dissolved material in water, depend mainly on the solubility of rocks and soils that come into contact with water. As the level of TDS rises, the conductivity will also increase. Discharges to water could change the conductivity depending on the discharge type. A failing sewage system could raise the conductivity because of the presence of chloride, phosphate and nitrate. On the other hand, an oil spill would lower the conductivity because oil does not conduct electrical current very well (Nirgude *et al*., 2013). This implies that the high conductivity measured was indication of the effluents from the brewery being rich in salts. This is not good for irrigation, drinking and washing purposes and this was in agreement with the present study.

The significantly higher BOD_5 of the effluent from the brewery compared to downstream point C of the river could be attributed to the inefficiency of the waste treatment plant. The results based on BOD_5 suggest that the brewery is discharging organic pollutants into the stream leading to eutrophication and the promotion of the growth of algae (Safari *et al*., 2013). Research has further shown that, the concentration of biological oxygen demand (BOD_5) in wastewater treatment plant effluents could significantly influence the dissolved oxygen rate in receiving water bodies and this was consistent with our study.

The study reported relatively high bacteria pollution level and this development obviously could not be ignored. This is a matter of great concern as the riparian communities that depend on the river as sources of drinking water downstream could be at very high risk of infection and diarrheal related diseases. This study has shown that the effluent parameters from the treatment plant at the brewery did not meet both the WHO and the GSA standards. In a related study conducted by Garcia-Armisen *et al*. (2014) in Belgium, results of the study showed that, analysis per season revealed allochthonous bacteria brought by WWTPs effluents triggered changes in community microbial composition, eventually followed by rapid post-disturbance return to the original composition as observed with 1 month. This observation was consistent with the present study.

CONCLUSION

The study revealed that effluent from the waste treatment plant from the brewery was technically efficient with respect to most of the physicochemical parameters. This could however not be said for their microbial counterpart as levels of biological indicators of pollution all exceed the

WHO and GEPA recommendations. It is therefore being recommended that the brewery authorities as well as the EPA of Ghana must ensure that the brewery effluents meet quality standards. This action is urgently warranted as high level pollution of the industrial effluents cause's environmental problems which will affect plant, animal and human life.

REFERENCES

AWWA/APHA, 1992. Standard Methods for Examination of Water and Wastewater. 18th Edn., American Water Works Association, American Public Health Association, Washington, DC., USA.

Awaleh, M.O. and Y.D. Soubaneh, 2014. Waste water treatment in chemical industries: The concept and current technologies. Hydrol. Curr. Res., Vol. 5. 10.4172/2157-7587.1000164

Driessen, W. and T. Vereijeken, 2003. Recent developments in biological treatment of brewery effluent. The Institute and Guide of Brewery Convention, Livingstone, Zambia, March 2003.

Ekhaise, F.O. and C.C. Anyasi, 2005. Influence of breweries effluent discharge on the microbiological and physicochemical quality of Ikpoba River, Nigeria. Afr. J. Biotechnol., 4: 1062-1065.

Gamper-Rabindran, S. and S.R. Finger, 2013. Does industry self-regulation reduce pollution? Responsible care in the chemical industry. J. Regul. Econ., 43: 1-30.

Garcia-Armisen, T., O. Inceoglu, N.K. Ouattara, A. Anzil, M.A. Verbanck, N. Brion and P. Servais, 2014. Seasonal variations and resilience of bacterial communities in a sewage polluted urban river. PLoS ONE, Vol. 9. 10.1371/journal.pone.0092579

Kumar, P.G. and V. Suneetha, 2014. A cocktail enzyme: Pectinase from fruit industrial dump sites: A review. Res. J. Pharm. Biol. Chem. Sci., 5: 1252-1258.

Nirgude, N.T., S. Shukla and A.Venkatachalam, 2013. Physico-chemical analysis of some industrial effluents from vapi industrial area, Gujarat, India. J. Chem., 6: 68-72.

Orhue, R.E., A.U. Osaigbovo and D.E. Vwioko, 2005. Growth of maize (*Zea mays* L.) and changes in some chemical properties of an ultisol amended with brewery effluent. Afr. J. Biotechnol., 4: 973-978.

Safari, G.H., K. Yetilmezsoy, A.H. Mahvi and M. Zarrabi, 2013. Post-treatment of secondary wastewater treatment plant effluent using a two-stage fluidized bed bioreactor system. J. Environ. Health Sci. Eng., Vol. 11. 10.1186/2052-336X-11-10

Sharda, A.K. M.P. Sharma and S. Kumar, 2013. Performance evaluation of brewery waste water treatment plant. Int. J. Eng. Pract. Res., 2: 105-111.

Tilt, B., 2013. Industrial pollution and environmental health in rural China: Risk, uncertainty and individualization. China Q., 214: 283-301.