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Water quality assessment of a wastewater treatment plant in a Ghanaian Beverage Industry

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The research is aimed at assessing the performance of the wastewater (excluding sewage) treatment plant in a Ghanaian beverage industry. Sixteen (16) water quality parameters were analyzed by collecting influent and effluent wastewater samples of the treatment plant for a year and their average values were compared with EPA (Ghana) guidelines for beverage industries discharging into water bodies. Most of the effluent wastewater pollutant content met the set guidelines, while others were unacceptable. However, the ability of the wastewater treatment plant to effectively deal with key pollutant such as BOD (93%), Ammonia (82%) and COD (82%) suggests that the treatment plant is efficient. In order to improve on the final effluent quality, sand filters may be introduced after the Sequential Batch Reactor II before final discharge into the environment.

Key words: EPA guidelines, de-sludging, environment, sand filters, wastewater.

INTRODUCTION

The importance of water in all facets of life cannot be over emphasized. It is vital for consumption, health and dignity. It is a fundamental resource for human development, especially residential area location. The development of any city has practically taken place near some source of water supply (Rangwala et al., 2007). The ever increasing levels of pollutants and complexity of effluents from municipality and industry, demand effective technologies to reduce pollutants to the desired levels. The use of current wastewater treatment technologies for such reclamation is progressively failing to meet required treatment levels. Advanced wastewater treatment technologies are essential for the treatment of industrial wastewater to protect public health and to meet water quality criteria for the aquatic environment and for water recycling and reuse (Agyemang, 2010).

The protection of receiving waters is essential to prevent eutrophication and oxygen depletion in order to sustain fish and other aquatic life. Discharge of untreated effluent wastewaters into water bodies may put at risk riparian communities that depend on these waters for domestic and personal use (Tchobanologous et al., 2003). Though treated wastewater may not comply with drinking water standards, contacts with water carrying

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high pathogenic loads may potentially lead to the transmission of enteric infections (Kamala and Kanth Rao, 2002).

The wastewater treatment plant discharges close to 500 m^3/day of treated effluent to an open channel that leads to the Atonsu stream. Downstream are a number of riparian communities that rely on the stream for bathing, cooking, drinking, irrigation and cleaning. The main objective of the study is to conduct an assessment on the quality of the treated wastewater effluent that is discharged into the Atonsu stream. This objective was achieved through physical, chemical and biological analysis of the effluents and the standards compared with EPA (Ghana).

METHODOLOGY

Wastewater sources

Wastewater (excluding blackwater and urine) generated in the plant is channeled into a central concrete drain that leads to the pre-treatment tank of the treatment plant. Sources of wastewater generated in the plant includes wastewater generated from cleaning the production floors, washing of process equipment (mixing tanks, storage vessels, holding tanks, etc.), washing and rinsing of beverage bottles, washing and cleaning laboratory floors and equipment and wastewater generated from the kitchen.

Wastewater treatment plant

The wastewater treatment plant is the batch type and consists of four main components; the pre-treatment tank, balancing equalizing and neutralization basin, the sequential batch reactor I and sequential batch reactor II. Figure 1 presents the layout of the wastewater treatment process at the beverage plant.

Pre-treatment tank

The pre-treatment tank is an underground rectangular concrete tank with the capacity of 280 m^3 and consists of three main sections. The first section removes wastewater constituents that are likely to cause operational problems during the treatment process. This includes screening for the removal of debris, crown corks, straws, rags, grit and flotation for the removal of small quantities of oil and grease. The second section is the neutralization basin and is equipped with an automatic pH meter that corrects the pH of the wastewater by dosing sulphuric acid when it is necessary. It also contains mechanical agitators which continuously stir the wastewater to ensure a uniform pH within the chamber. The third section is the neutralized tank and is equipped with submersible pumps to automatically pump the wastewater when it gets to a set maximum limit.

Balancing neutralizing and equalizing basin

The balancing, neutralization and equalization basin receives preliminary treated wastewater from the pre-treatment tank and is automatically controlled. It is circular in shape, has a capacity of 780 m^3 and is made of stainless steel. The basin serves to neutralize the wastewater pumped from the pre-treatment tank and to receive and balance shocks such as high pH and temperature levels. The basin has a retention time of 8 h. From the basin water is pumped to the sequential batch reactor I for subsequent treatment to be effected.

Sequential batch reactor I

The sequential batch reactor I is circular in shape, has a capacity of 780 m^3 and is made of stainless steel. The reactor contains bacteria employed to feed on the high concentration of organic and inorganic compounds present in the wastewater. The bacteria convert the colloidal and dissolved carbonaceous organic matter into various gases and cell tissue. The resulting cell tissue is removed from the treated wastewater by gravity settling. The reactor is automatically operated and desludging is done periodically. Wastewater is retained for 8 h.

Sequential batch reactor II

From the sequential batch reactor I, wastewater is pumped to the sequential batch reactor II for further treatment to be effected. The sequential batch reactor II is also circular in shape, has a capacity of 780 m^3 and is made of stainless steel. The second reactor is employed to further breakdown organic and inorganic compounds present in the wastewater by the use of bacteria. It is automatically operated and desludging is done periodically. Treated effluent wastewater is finally discharged into the Atonsu stream.

Wastewater sampling and analysis

Sampling was done monthly starting from August 2009 to July 2010. Twenty-four (24) samples representing twelve (12) influent and twelve (12) effluent samples were analysed. Temperature of the samples was measured *in-situ*. Parameters that were analyzed include BOD, COD, turbidity, colour, pH, temperature, total dissolved solids, total suspended solids, conductivity, coliforms, nutrients and trace metals. Table 1 presents the methods and instruments used for the water quality analysis.

RESULTS AND DISCUSSION

Wastewater characteristics

The mean value of each water quality parameter considered for both influent and effluent wastewater samples have been computed and tabulated (Table 2) as well as the standard deviation and standard errors of 95% confidence interval.

Temperature

The temperature of the influent wastewater to the treatment plant ranged from 47 to 50°C and with a mean of 48.2°C. The effluent temperature ranged from 28 to 30°C. The drop in the effluent temperature could be due to heat losses by convection to the atmosphere and conduction to the walls of the receiving treatment tanks. A drop in temperature is paramount to aiding bacterial

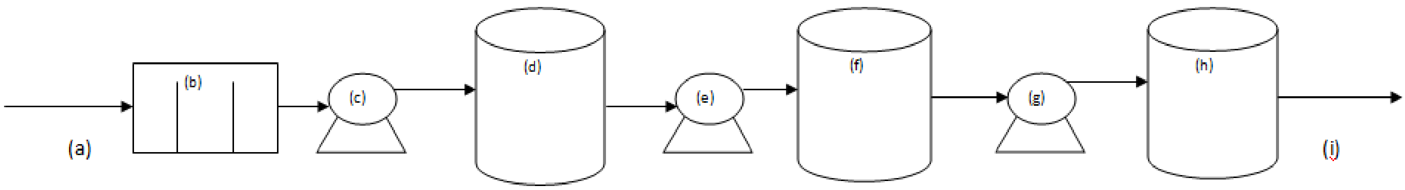

Figure 1. Layout of wastewater treatment process at the Beverage Plant. (a) Influent wastewater (b) Pre-treatment tank (c) Centrifugal pump (d) Balancing equalizing neutralizing basin (e) Centrifugal pump (f) Sequential batch reactor I (g) Centrifugal pump (h) Sequential batch reactor II (i) Effluent wastewater.

Table 1. Methods and instruments used for water quality analysis.

Parameter	Method used	Instrument used
BOD	Winkler modification	-
COD	Closed Tube method	-
Turbidity	APHA Standard method (USEPA)	HACH Model 2100P Turbidimeter
	Cyberscan PC 300 Series	Cyberscan PC 300 Series
Total dissolved solids	Cyberscan PC 300 Series	Cyberscan PC 300 Series
Total suspended solids	Gravimetric method	-
Ammonia-Nitrogen	Titrimetric method	Micro Kjeldhal method
Sulphates	-	HACH Type DREL/2010 Spectrophotometer
Trace metals	-	A.A.S 220 model
Temperature	-	Thermometer
pH	-	Cyberscan PC 300 series pH meter
Colour	-	Nesselerizer
Coliforms	Membrane Filtration method	Membrane filter
DO	-	Oximeter

activities in the treatment tanks. The mean effluent temperature of 29°C was below the EPA Ghana guideline of 30°C.

pH

All the influent wastewater samples analyzed were alkaline. The mean pH value was 11.3 and was in the range of 10.8 to 11.6. The mean pH values of the effluent wastewater ranged from 7.9 to 8.9 and were all within EPA Ghana guideline range of 6 to 9. The decrease in the pH value of the effluent wastewater indicates that some form of treatment had been achieved. The decrease in the effluent pH value could be attributed to the dosing of sulphuric acid to the influent wastewater at the pre-treatment section of the treatment process, in order for biological processes to be effected**.**

Conductivity

Generally conductivity of water is determined to ascertain the ability of the waters to conduct electrical current. The mean influent conductivity value ranged between 1750 and 1999 µS/cm and was 1750 µS/cm. The high influent conductivity values may be attributed to the high concentration of dissolved ions present in the wastewater during the bottles washing stage of the bottle preparation process. Mean effluent conductivity was 842.8 µS/cm in a range from 923 to 756 µS/cm. Even though the drop in conductivity shows some amount of ion removal, the conductivity levels of the effluents wastewater were unsatisfactory compared to EPA (Ghana) guideline value of 750 µS/cm.

Turbidity

Turbidity, a measure of the light transmitting properties of wastewater, is a test used to indicate the quality of wastewater discharges with respect to colloidal and residual suspended matter. High levels of turbidity in industrial effluents contribute large amounts of suspended solids to receiving waters. The mean influent turbidity value was in the range of 39 and 57 NTU and

Table 2. Wastewater characteristics.

Parameter	Mean Influent	Mean Effluent	EPA Ghana (2000)
Temperature (°C)	48.2±0.7	28.3±0.3	30
TDS (mg/l)	862.2±56.1	839.8±59.3	<1000
Conductivity (µS/cm)	1750.1±100.6	842.8±58.8	750
Colour (TCU)	77.8±36.0	100±41.3	100
TSS (mg/l)	87.7±27.8	176.7±114.3	<50
Turbidity (mg/l)	46.8±3.8	94.8±67.8	75
DO (mg/l)	3.6±0.6	5.7±0.6	<1
pH	11.3±0.2	8.5±0.3	6-9
BOD (mg/l)	1116.8±192.7	49.8±32.9	<50
COD (mg/l)	3114.2±252.7	569.2±115.9	<250
NH_3-N (mg/l)	11.5±1.1	2.1±0.3	1.0
Sulphate (mg/l)	60.6±24.2	177.7±17.7	250
Cadmium (mg/l)	0.0±0.0	0.0±0.0	<0.02
Copper (mg/l)	0.0±0.0	0.00±0.0	1
Lead (mg/l)	0.0±0.0	0.0±0.0	<1
Coliforms (mg/l)	5466.7±1952.5	15850±6377.1	400

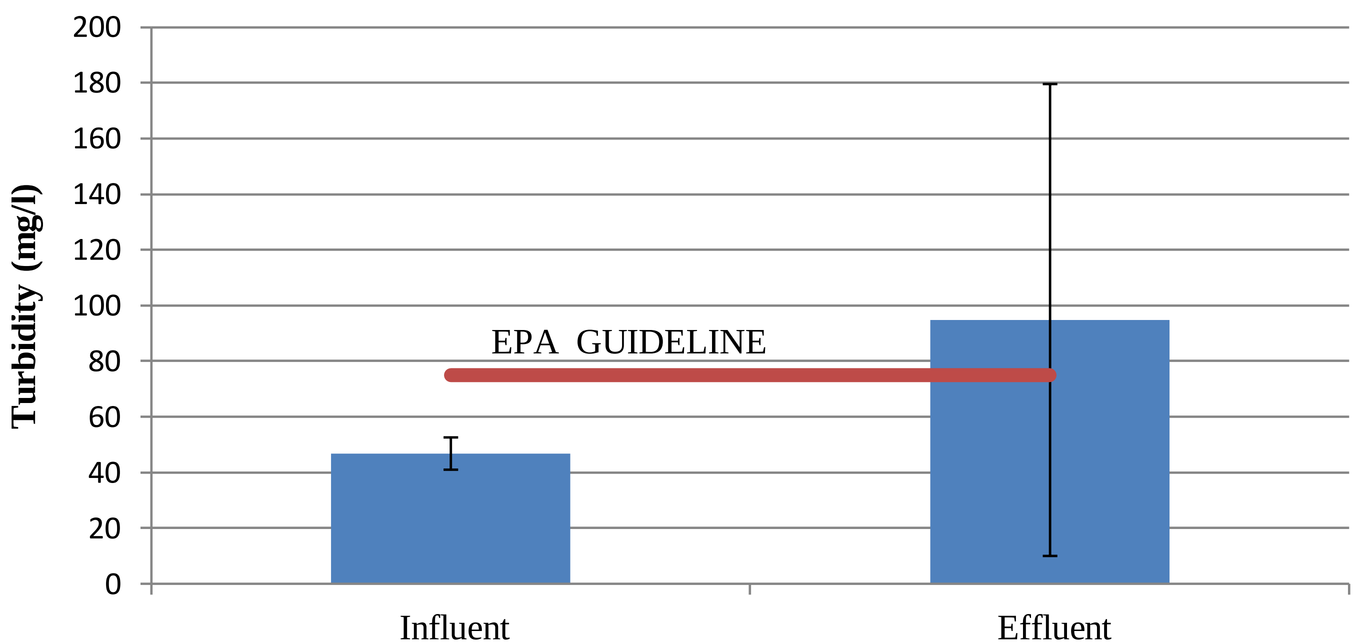

Figure 2. Influent and effluent turbidity and EPA guideline.

was 46.8 NTU. The final effluent turbidity value was in the range of 32 and 225 NTU. The mean effluent turbidity value of 94.8 NTU was above the EPA Ghana guideline value of 75 NTU. The mean effluent turbidity value could be attributed to incomplete sludge settlement during the sedimentation stage of SBR. Figure 2 is a plot of the mean influent and effluent turbidity results and the EPA Ghana guideline.

Colour

Various beverage processing activities such as production floor cleaning and bottle washing impart considerable amount of colour to water. Mean colour value for the influent wastewater ranged from 25 to 150 TCU respectively with the mean of 77.8 TCU. The mean final effluent colour was 100 TCU and ranged between 60 to 180 TCU. Mean effluent colour value was consistent with EPA guideline of 100 TCU. However, some high effluent values of colour recorded during the effluent sampling time could be attributed to incomplete sludge settlement during the sedimentation stage of sequential batch reactor.

Dissolved Oxygen (DO)

Dissolved oxygen is required for the respiration of aerobic microorganism as well as all other aerobic life forms. Mean influent DO ranged from 1.8 to 4.8 mg/l and was 3.6 mg/l. Mean effluent DO was 5.7 mg/l and ranged from 4.8 to 6.4 mg/l. The increase in the effluent DO may be attributed to the infusion of air by blowers during the wastewater treatment period. Both the influent and effluent DO values were consistent and above the EPA Ghana guideline value of 1 mg/l. Figure 3 is a plot of the average influent and effluent DO results and the EPA Ghana guidelines.

Total dissolved solids (TDS)

Total dissolved solids consist of both the organic and inorganic molecules and ions present in the true solution of the water. Mean influent TDS value ranged from 771 to 991 mg/l and was 862.2 mg/l. Mean effluent TDS value was 839.9 mg/l and ranged from 720 to 923 mg/l. It was noted that both average influent and effluent TDS results were consistent with the EPA Ghana guideline for beverage industries discharging into water bodies.

Total suspended solids (TSS)

The mean influent TSS value ranged from 44 to 144 mg/l and was 87.7 mg/l. The mean effluent TSS value ranged from 71 to 380 mg/l and was 176.7 mg/l. The mean effluent value of 176.7 mg/l was more than the EPA Ghana guideline value of 50 mg/l. The high mean effluent TSS value could be attributed to incomplete sludge settlement during the sedimentation stage of SBR. Figure 4 is a plot of the average influent and effluent TSS results and the EPA Ghana guideline.

Biochemical Oxygen demand

The influent BOD concentration of the treatment plant ranged from 700 to 1504 mg/l, with a mean of 1116.8 mg/l. The high values of BOD in the influent wastewater may be attributed to the high concentration of the organic matter content in the wastewater. The mean effluent BOD concentration was 49.8 mg/l and in the range of 19 to 120 mg/l. Figure 5 is a plot of the average influent and effluent BOD results and the EPA Ghana guideline. The result of the average effluent signifies that the biological method is able to treat the wastewater by means of biodegradation of organic matter. It is noted that the release of excess amounts of organic matter into receiving waters could result in a significant depletion of oxygen and subsequent mortality of fishes and other oxygen dependent aquatic or marine organism. The percentage removal achieved was 93%.

Chemical Oxygen demand (COD)

The mean influent COD value ranged between 2466 mg/l to 3760 mg/l and was 3114.2 mg/l. The mean effluent COD was between 450 mg/l and 856 mg/l respectively with a value of 569.2 mg/l. Even though all the effluent COD values were low as compared to the influent values none met the EPA Ghana guideline value of 250 mg/l. The effluent values could be attributed to the presence of sulphides, sulphites, thiosulphate and chlorides that cause interferences to COD. The removal efficiency was 82%.

Ammonia-Nitrogen (NH_3-N)

The mean influent ammonia value ranged from 9.1 mg/l to 15 mg/l and was 11.5 mg/l. The mean effluent value was 2.1 mg/l and ranged from 1.7 mg/l to 2.8 mg/l. The initial rise in ammonia of the influent quality could be due to the presence of ammonia is a by-product of anaerobic digestion whilst the fall in the effluent values could be due to nitrification and de-nitrification processes. The percentage removal achieved was 82%. The average effluent result was above EPA Ghana set guideline.

Sulphates

Mean influent sulphate concentration ranged from 30 to 150 mg/l and was 60.6 mg/l. Also the mean effluent sulphate concentration was 117.7 mg/l and ranged from 80 to 130 mg/l. Both influent and effluent sulphate concentration results obtained during the sampling period were in the range of EPA Ghana set guideline of 250 mg/l. The increase in the sulphate concentration of the effluent wastewater could be attributed to the dosing of sulphuric acid during the wastewater pre-treatment stage in order to bring the pH down for biological activities to be effected.

Cadmium

The mean influent cadmium concentration was 0.0 mg/l and the effluent cadmium concentration 0.0 mg/l. The effluent quality is acceptable according to EPA Ghana

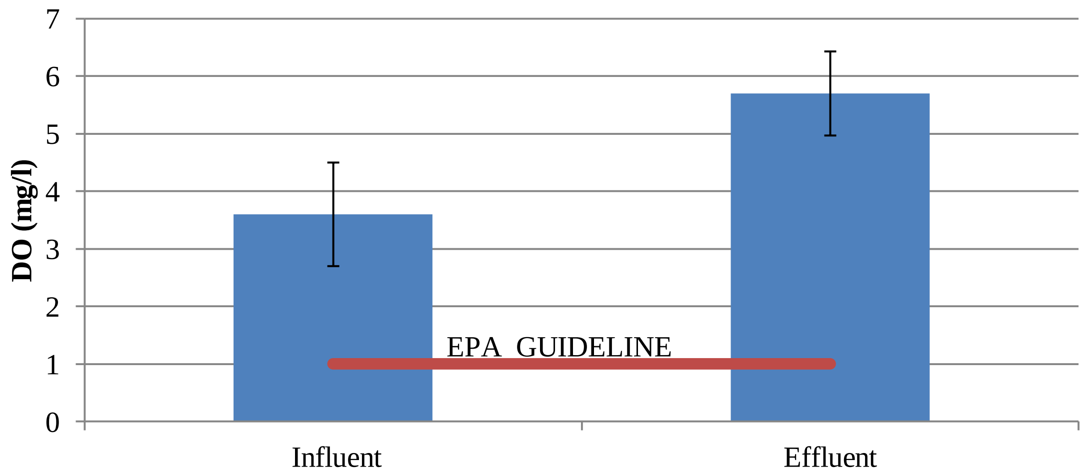

Figure 3. Influent and effluent DO and EPA guidelines.

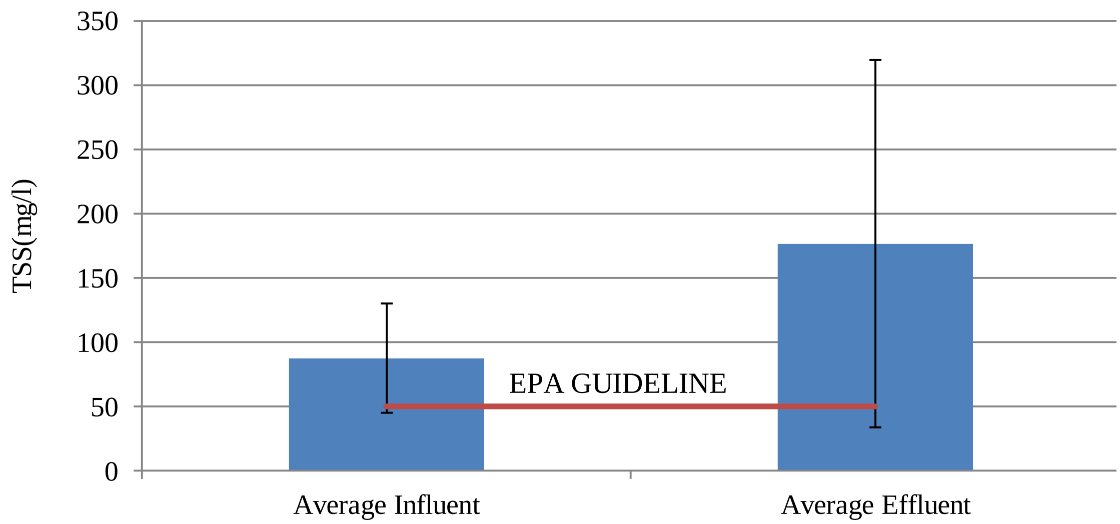

Figure 4. Influent and effluent TSS and EPA guideline.

guideline of <0.02 mg/l.

Copper

The mean influent copper concentration was 0.0 mg/l and the mean effluent was 0.0 mg/l. Both influent and effluent copper concentration were within the EPA Ghana guideline of <1 mg/l and was satisfactory.

Lead

The mean influent lead concentration was 0.0 mg/l and the mean effluent was 0.0 mg/l. Both influent and effluent lead concentrations results obtained were below the EPA Ghana guideline of 1 mg/l.

Coliforms

The mean influent coliforms count ranged from 0.26E+04 to 1.02E+04 C/100 ml and registered an average of 0.55E+04 C/100 ml. The effluent coliforms count ranged from 0.55E+04 to 2.54E+04C/100 ml with an average of 1.66E+04 C/100 ml. The low influent coliform concentration could be due to the fact that at a high pH and temperature, most coliform group die or remain inactive. Although it was expected that the total number of effluent coliforms be reduced after treatment the reverse

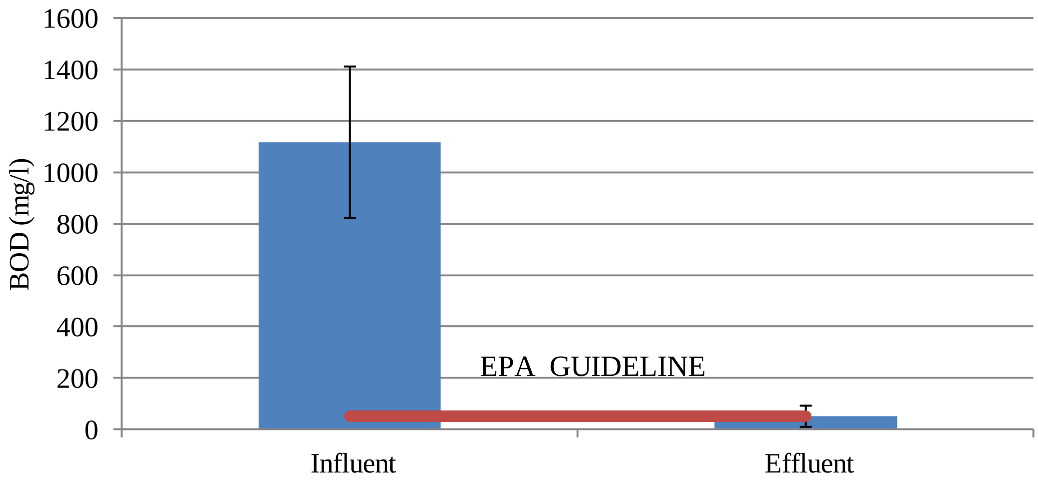

Figure 5. Influent and effluent BOD and EPA guideline.

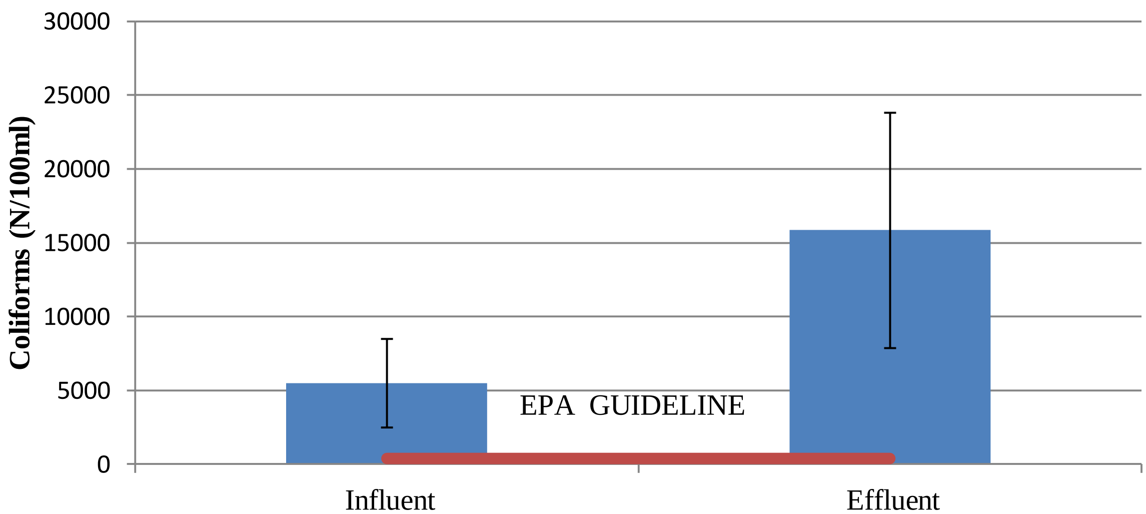

Figure 6. Influent and effluent coliforms and EPA guideline.

was observed. The increase in the effluent coliform concentration could be attributed to the high organic matter content (>20 mg/l BOD) in the treatment tank which serves as food for the bacteria to grow, proliferating rapidly in numbers, the small number of predators in the treatment tanks to devour the bacteria or on the grounds that the treatment tanks have not been desludged since its working life. Figure 6 is a plot of the average influent and effluent coliform results and the EPA Ghana guideline.

CONCLUSION AND RECOMMENDATION

The wastewater treatment plant has a high potential of removing key pollutants and could be used for better treatment of wastewater if managed properly. The removal efficiencies of key parameters such as conductivity, BOD, COD and ammonia were between 50 and 100%. The wastewater treatment plant is efficient; however parameters such as total coliforms, TSS and turbidity were unsatisfactory. By recommendation, a slow sand filter may be introduced after the sequential batch reactor II to improve the effluent wastewater quality. Tanks within the treatment units should be desludged in order to improve on the effluent wastewater quality. Consequently disinfection of the effluent wastewater may be carried out before final discharge into the Atonsu stream.

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