ISSN 2398-1385

ASSESSMENT OF AN OILY WASTEWATER TREATMENT PLANT IN NYANKROM INDUSTRIAL AREA, GHANA: PHYSICO-CHEMICAL QUALITY OF EFFLUENT WATER AND TREATMENT EFFICIENCY

Godfred Safo-Adu
Department of Integrated Science Education
Faculty of Science Education
University of Education, Winneba
GHANA
gsafoadu@gmail.com

ABSTRACT

The study assessed the physico-chemical quality of effluent water and the efficiency of an oily wastewater treatment plant in an oily waste treatment facility in Nyankrom industrial area in the Western Region of Ghana. The oily wastewater treatment plant had a flow rate of 4 m^3/hour and a treatment capacity of 50 m^3. Influent and effluent water samples were collected monthly, starting from November 2018 to October 2019. Twenty physico-chemical parameters of the influent and effluent samples were analysed. The average removal efficiency of each parameter was calculated and the quality of effluent water was assessed by comparing the levels of effluent water parameters to the Ghana EPA effluent water guideline values. Pearson correlation and independent t -tests were used to analyse the data. The study revealed that the oily wastewater received at the oily waste treatment facility for treatment had high level of dissolved salt. The oily wastewater treatment plant had high efficiency in removing turbidity (87.0 %), TSS (95.5 %), TDS (94.6 %), EC (94.8 %), BOD (91.7 %), oil/grease (96.2 %) and moderate efficiency in dealing with Cr (67.7 %), Zn (66.4 %), Cu (68.6 %) and Fe (66.7 %). Moreover, the oily wastewater treatment plant removal efficiency of Hg (30.0 %), As (50.0), and Pb (50.0 %) was low. There was no significant difference between influent and effluent mean concentrations of Hg, Pb, and As ($p>0.05$). The mean effluent physico-chemical parameters met the Ghana EPA effluent water guideline values. However, the maximum levels of TDS, EC and total phosphorus exceeded the Ghana EPA guideline values. Statistically, the effluent TDS contributed moderately to the level of EC ($r = 0.70$, $p<0.05$). Conclusively, the physico-chemical quality of oily wastewater treatment plant effluent was satisfactory but can be improved. It is recommended that chemical precipitation and coagulation unit should be integrated into the oily wastewater treatment plant to help boost the treatment plant ability to deal with TDS, EC and total phosphorus and improve efficiency in removing As, Hg and Pb.

Keywords: Effluent, Physico-chemical, Oily wastewater, Quality, Treatment efficiency.

INTRODUCTION

Oily wastewater is waste originating from industries primarily in crude oil refining, manufacturing fuels, lubricants, and petrochemical intermediates (Hui, Yan, Juan & Zhongming, 2014). According to Chikwe and Okwa (2016), about 98 % of the total volume of waste generated by oil and gas exploration and production activities is oily wastewater. Oily wastewater is made up of light and heavy hydrocarbons, lubricant oils, surfactants, heavy metals, fatty oil, sand and gravel (Penny & Yeh, 2006). Among the many contaminants in oily wastewater, petroleum hydrocarbon is the contaminant of concern (Asselin, Drogui, Brar &

Benmoussa, 2008), which is emulsified (Penny & Yeh, 2006). In addition, oily wastewater contains high level of dissolved salts, which create operational, maintenance and material problems. The principal problems include process upset, corrosion and scale formation (Guyer, 2013). The types and concentration of contaminants in oily wastewater from different sources vary greatly. According to Sekman, Top, Uslu, Varank and Bilgili (2011), the physico-chemical characteristics of oily wastewater vary in wide range of suspended solids (13.3 – 660.0) mg/L, chemical oxygen demand (240.0 – 2783.0) mg/L and oil/grease (6.5 – 736.0) mg/L. The variable physico-chemical characteristics of oily wastewater make the treatment difficult as a result; more attention has to be given to the treatment of oily wastewater (Yu, Han & He, 2013). This suggests that the treatment efficiency of an oily wastewater treatment plant cannot be undermined.

Water is polluted when the quality parameters become hampered by unguided irregularities from several anthropogenic activities. Thus, rendering water unfit for intense use (Adejumoke et al., 2018). Water pollution has become a global challenge and developing countries like Ghana are highly affected due the drive for development. Untreated wastes from industries, solid wastes from urban and commercial areas, pesticides and fertilisers are the main sources of water pollution (Chakraborty, Hug, Ahmed, Tabassum & Miah, 2013). Oily wastewater from onshore and offshore industry and from engine rooms of ships popularly called bilge water are the major pollutants of the aquatic environment (Grita, Karakulsky & Morawski, 2001). Every year at least 500 to 1000 million tons of oily wastewater is discharged accidentally into water bodies through variety of ways, which causes serious water pollution and waste of resources (Zhang, Zhu, Xiao, Zia & Meng, 2007). According to Amoo, Adeleye, Ijanu, Omokhudu and Okoli (2017), industrial effluent discharge is the main source of pollution to streams and other water bodies. Improperly treated effluent water has high level of organic pollutants and heavy metals which bioaccumulate in the environment (Morrison, Fatoki, Persson & Ekberg, 2001) and persist. Industrial effluent water has different degree of pollution loads due to its complex chemical nature (Bernard, 2010).

The release of untreated effluent water into the environment endangers aquatic resources and human health, causes atmospheric pollution, affects crop production and devastates natural landscape (Poulopoulos, Voutsas, Grigoropoulou, & Philoppopoulos, 2005). In view of this, assessing the physico-chemical quality of effluent water is vital for controlling water pollution and preserving its physico-chemical quality. A study carried out by Nkwocha, Ekele, Kamen and Oghome (2013) in Anambra state in Nigeria showed that pH, biochemical oxygen demand (BOD), total organic carbon (TOC) and oil/grease levels exceeded the Federal Environmental Protection Agency standards for assessing effluent quality. Similarly, a study carried out by Abubakari, Oppong-Kyekyeku, Donkor and Nyantakyi (2016) on the effect of industrial effluent on the quality of Onukpawahe stream in Ghana revealed that the average physico-chemical parameters, apart from pH and dissolved oxygen were all above Ghana Environmental Protection Agency (EPA) effluent guideline values and established that industries have polluted the stream.

Treatment techniques employed for treating oily wastewater include chemical precipitation coagulation, flotation, membrane separation, adsorption, chemical oxidation and ion – exchange (Hui et al., 2014). According to Sekman et al. (2011), technologies used for oily wastewater treatment consist of series of physical and chemical processes, which include chemical emulsion breaking, dissolved air flotation, clarification and filtration. The oily wastewater treatment plant in Nyankrom industrial area in the Western Region of Ghana, functions using the principle of sedimentation, pH correction, adsorption and ion exchange. The sedimentation process was achieved through gravity separation and acid or base addition to break emulsion and correct pH. The adsorption process was used to remove organic and inorganic contaminants and odour from the oily wastewater. Adsorption involves the mass transfer of ions from the liquid to the surface of the solid phase bounded by physical and or chemical interactions (Aljaberi & Mohammed, 2018). Ion-exchange technique removes pollutants from wastewater by changing the chemical form of these pollutants through the attraction of soluble ions from the liquid phase to the solid phase, held by mixed anionic and cationic groups (Gaikwad, Sapkal & Sapkal, 2010). Ion-exchange resins and other chelating ion-exchangers have low heavy metal removal ability (Aljaberi & Mohammed, 2018).

The treatment efficiency of a wastewater treatment plant in pollutant removal depends on its design, how well it is managed and process conditions. The quality of influent and effluent water at a waste treatment plant determines the pollutant removal efficiency of the treatment plant when compared to regulatory standards (Amoo et al., 2017). Furthermore, the pollutants removal efficiency of a wastewater treatment plant is the ratio of the removed concentration of pollutants to their initial concentrations (Vitez, Sevcikova. & Oppeltova, 2012). A study carried out by Aljaberi, Abdulmajeed, Hassan and Ghadban (2020) showed that an electrocoagulation reactor for treating oily wastewater had oil and turbidity removal efficiencies of 85.9 and 84.4 % respectively. Gowthaman et al. (2017) carried out a study on the efficiency of a wastewater treatment plant and reported that the overall efficiency of the treatment plant for removing BOD (57.7 %), oil/grease (3.0 %) and turbidity (95.3 %) was moderate. Furthermore, Agyemang, Awuah, Darkwa, Arthur and Osei (2013) showed that a wastewater treatment plant in Ghana had a high treatment efficiency in removing key pollutants such as biochemical oxygen demand (93 %), Ammonia (82 %) and chemical oxygen demand (82 %) concluded that the treatment plant was efficient. Again, Sekman et al. (2011) showed electrocoagulation unit for treating oily wastewater in Turkey had suspended solids, Chemical Oxygen Demand (COD) and oil/grease removal efficiencies of 98.8, 90.0 and 80.0 % respectively.

The effective treatment of oily wastewater prior to discharge is a challenge to the petroleum industry (Yu, et al., 2013). Oily wastewater generated from oil drilling activities, crude oil refining, gas processing, cleaning of ship bilges and fuel tanks in Ghana are sent to oily waste treatment facilities in Nyankrom industrial area in the Western Region of Ghana for treatment. According to Mogens, Van – Loosdrecht, Ekama and Damir (2008), for a wastewater treatment plant to be efficient in removing pollutants, it requires proper operation and maintenance and a good understanding of the processes involved. Chikwe and Okwa (2016) assert that serious attention should be given to oily wastewater treatment in both offshore and onshore locations because of the high content of oil/grease and salinity. Several problems that arise from inefficient waste treatment plants for treating oily wastewater. Some of these problems include creation of odour produced from anaerobic reactions and production of undesirable effluent quality, which might have adverse effect on receiving water body and the environment as a whole. Some of the possible effects include change in the trophic structure of the water body, loss of fish life and eutrophication.

Many oily wastewater treatment plants have several drawbacks due to the recalcitrant nature of oily wastewater. Few oily wastewater treatment facilities can reach a compromising balance between satisfying strict environmental regulations and reducing treatment cost (Hui et al., 2014). According to Sekman et al. (2011), no oily wastewater treatment plant can meet all the regulatory requirements because of the variable nature of oily wastewater. Currently, available information in the literature about the efficiency of waste treatment plant for treating oily wastewater in Ghana is limited. This study was designed to fill the gap. The study assessed the efficiency of an oily wastewater treatment plant in an oily waste treatment facility in Nyankrom industrial area in Western Region of Ghana. Specifically, the study sought to assess the physico-chemical quality of oily wastewater plant effluent in Nyankrom Industrial area in Western Region of Ghana using Ghana EPA guideline values for assessing effluent water quality. It also sought to assess the efficiency of an oily wastewater treatment plant in removing turbidity, total suspended solids (TSS), oil/grease, total dissolved solids (TDS), electrical conductivity (EC), chemical oxygen demand (COD), biochemical oxygen demand (BOD) and heavy metals from oily wastewater. The data obtained in this study provides baseline information about the physico-chemical quality of effluent water and the efficiency of the oily wastewater treatment plant in Ghana.

MATERIALS AND METHODS

Description of the study area

The study was carried in an oily waste treatment facility located in Nyankrom industrial area in the Western Region of Ghana. The study area is about 242 km to the west of Accra, the capital city of Ghana and approximately 280 km from La Côte d'Ivoire in the west. The oily waste treatment facility treats oily wastes originating from industries primarily in crude oil refining, fuel manufacturing, gas processing, cleaning of ship bilges and fuel tanks. The oily wastewater received at the facility for treatment comprised of bilge water, gas condensate, contaminated ballast water, produced water, and tank cleaning washouts. The sources of the oily wastewater varied. The flow rate of the oily wastewater treatment plant was 4000 L/hour and 8 hours oily wastewater treatment was carried out each day, starting from 8:00 am to 5:00 pm. Thus, on the average, 24 m^3 of oily wastewater was treated daily. The oily waste treatment plant has a treatment capacity of 50 m^3.

The oily wastewater treatment plant has two 45m^3 tanks for receiving oily wastewater, which was allowed to settle to effect hydrocarbon (oil/grease) and sediment separation by gravity. The water is then channeled into two mixing tanks where it is neutralised with either acid or base. The acid or base also helps to break the emulsion. The water then passes through series of well-conditioned sawdust media and activated carbon media for adsorption. The sawdust adsorbs chemical contaminants in the oily wastewater through ion - exchange and hydrogen bonding (Parihar & Malaviya, 2013). The cell wall of sawdust mainly consist of cellulose and lignin and many hydroxyl groups such as tannins or other phenolic compounds, which act as ion exchangers and based on their electron donating nature of heavy metals, the ion – exchangers and hydrogen bonding could be exploited (Shukla, Zhang, Dubey, Margrave & Shukla, 2002). Figure 1 presents the schematic flow diagram of the oily wastewater treatment plant in Nyankrom industrial area.

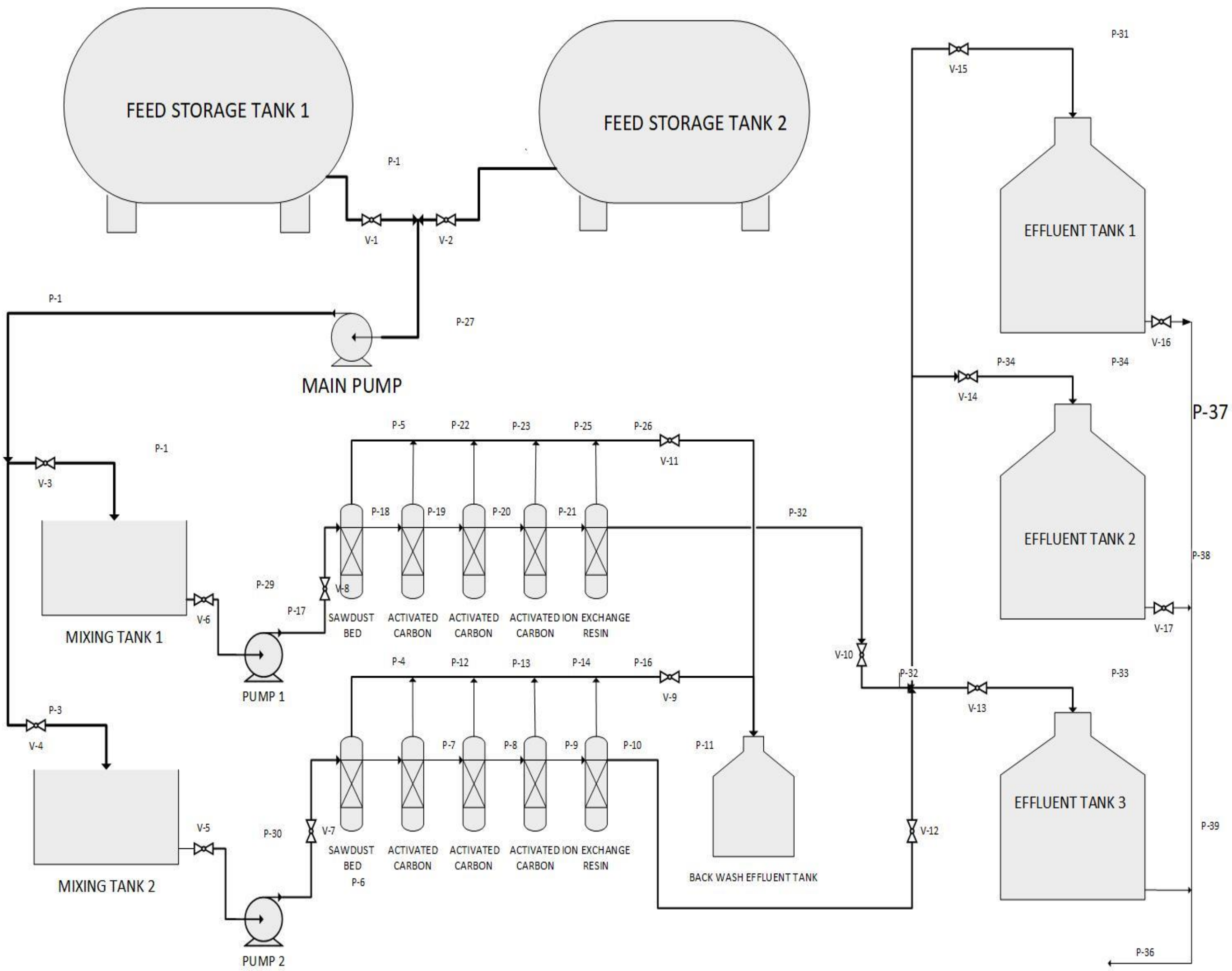

Figure 1: Schematic flow diagram of an oily wastewater treatment plant in Nyankrom industrial area.

Sample collection

Standard methods of water sampling were employed in sampling influent and effluent water samples (American Public Health Association, 1998). Influent and effluent water sampling was done monthly for a period of 12 months, starting from November 2018 to October 2019. Samples were taken on every Tuesday of the first week of the month at 8: 00 o'clock. Three samples were collected at two-hour intervals and pooled together to form a composite sample for the month. Twenty four (24) samples representing twelve (12) influent and twelve (12) effluent water were sampled. Influent and effluent water samples were collected from storage tanks and at the point of discharge of the treatment plant respectively. The samples were put into 2 L stoppered polyethylene bottles, which had been earlier pre-treated with dilute HNO_3 and distilled water. Before use, the bottles were rinsed with the sample twice. The samples were preserved in an ice- chest and transported immediately to Ghana Atomic Energy Commission for physico-chemical analysis.

Sample analysis

Samples were analysed using standard methods for examination of water and wastewater (American Public Health Association, 1998). The physico-chemical parameters analysed in both influent and effluent samples were pH, temperature, turbidity, total dissolved solids (TDS), electrical conductivity (EC), total suspended solids (TSS), oil/grease, Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), total phosphorus, sulphide and nitrate ions and heavy metals (Hg, Cr, Zn, Cu, Fe, As, Pb, Cd). These parameters were analysed considering Ghana EPA effluent standards set for the oil and gas industry. TDS, EC, pH, and temperature were measured in situ (200 ml sample) using HI 9829 multi-parameter (Hanna instrument, USA). In addition, gravimetric method and 2100P turbidimeter (HACH model) were used to determine the TSS and turbidity of the samples respectively. HI 83099 multi-parameter photometer (Hanna instrument, USA) was used to measure COD, total phosphorus, sulphide and nitrate ions of the samples whilst Winkler method was employed to determine the BOD level of the samples. The oil and grease content of the samples was measured using TD 500 D oil in water meter and Atomic Absorption Spectrophotometer (AAS, Perkin – Elmer, NY, USA) was used to analyse the heavy metal content of the samples. All analytical instruments were calibrated before use. Average percentage removal efficiencies for each parameter was calculated using the relation:

Efficiency (%) = $[(C_{inf} - C_{eff})/C_{inf}]*100$ (Hayata, Dootsi and Sayadi (2013).

Where C_{inf} is the concentration of parameter in effluent while C_{eff} is the concentration of parameter in effluent water.

RESULTS AND DISCUSSION

Physico-chemical quality of oily wastewater treatment plant effluent

To assess the quality of effluent water, the levels of physico-chemical parameters of effluent were compared to Ghana EPA effluent water guideline values. The physico-chemical characteristics of effluent water and the Ghana EPA effluent water guidelines for assessing effluent quality are shown in Table 1 whilst Table 2 presents the effluent TDS and EC correlation analysis results.

Table 1: Physico-chemical characteristics of effluent water

Parameters	Mean	SD	Max	Min	Ghana EPA effluent water guideline values (EPA, 2012)
pH (unit)	6.60	0.40	7.10	6.10	6.00 – 9.00
Temp. (°C)	29.10	0.88	29.90	27.30	<30.00
Turbidity (mg/L)	65.20	15.77	80.00	24.50	75.00
EC (us/cm)	1489.16	16.63	1520.00	1460.00	1500.00
TDS (mg/L)	985.50	26.61	1020.00	950.00	1000.00
TSS(mg/L)	45.00	8.040	49.00	20.00	50.00
BOD(mg/L)	48.10	4.180	60.00	43.00	50.00
COD(mg/L)	240.10	56.58	355.00	135.00	250.00
Oil/grease (mg/L)	1.10	0.67	2.80	0.50	10.00
Sulphide ions (mg/L)	0.13	0.11	0.40	0.10	1.50
Nitrate ions (mg/L)	6.25	1.35	9.00	5.00	50.00
Total phosphorus (mg/L)	0.80	1.08	4.00	0.20	2.00
Hg (mg/L)	<0.01	<0.01	0.01	<0.01	0.01
Cr(mg/L)	0.01	<0.01	0.02	0.01	0.10
Zn(mg/L)	1.23	0.35	1.50	0.16	10.00
Cu(mg/L)	0.85	0.30	1.14	0.10	5.00
Fe(mg/L)	1.52	0.26	1.92	1.20	10.00
As(mg/L)	0.01	0.01	0.05	<0.01	0.10
Cd(mg/L)	<0.01	<0.01	0.01	<0.01	0.10
Pb(mg/L)	0.01	0.02	0.05	<0.01	0.10

***SD = Standard deviation**

Table 2: Correlation between mean TDS and EC of effluent water

Relationship	Correlational value	p – value
TDS and EC	0.70	0.03

The maximum and the minimum levels of effluent physico-chemical parameters presented in Table 1 shows that there was variation among effluent water physico-chemical parameters. This could be due to the different sources and physico-chemical characteristics of oily wastewater received at the oily waste treatment facility for treatment. The pH value of the effluent water ranged from 6.10 to 7.10 with an average value of 6.60±040. The average pH value of effluent was within Ghana EPA guideline range of 6.00 to 9.00. This means the effluent water when disposed will not have effect on the environment in terms of its hydrogen ions concentration. The average temperature of effluent water calculated to be 29.10 ^{o}C ranging from 27.00 to 29.9 ^{o}C. The mean TSS concentration was (45.00±8.04) mg/L in the range of 20.00 to 49.00 mg/L, which was below the Ghana EPA guideline value of 50.00 mg/L. Again, the mean effluent turbidity was (65.20±15.77) mg/L in the range of 24.30 to 80.00 mg/L, which was also below the Ghana EPA guideline value of 75.00 mg/L. This means that the amount of turbidity in the effluent will never contribute to the large amount of suspended solids to receiving waters when discharged (Sulaiman, 2016). The findings of this study is in contrast with the study carried out by Agyemang et al. (2013) in a wastewater treatment facility in Ghana where the mean pH, temperature, TSS, turbidity levels were recorded to be 8.8±0.0, (28.30±0.30)^{o}C, (176.70± 114.30) mg/L, (94.80±67.80) mg/L respectively. Comparatively, the mean values of pH, TSS and turbidity of effluent recorded by Agyemang et al. (2013) were higher than the mean values of effluent pH, TSS and turbidity recorded in this study. The difference in levels of physico-chemical parameters recorded by Agyemang et al. (2011) and that of this study could be due to difference in techniques employed in treating the wastewater and more importantly difference in pollution load of the wastewater treated.

The mean TDS and EC of effluent were 985.50 mg/L (950.00 – 1020.00) mg/L and 1489.16 µS/cm (1460.00 – 1520.00) µS/cm respectively. The mean TDS and EC values were below Ghana EPA guideline values of 1000 mg/L and 1500 µS/cm respectively. However, the maximum levels of TDS (1020.00 mg/L) and EC (1520.00 µS/cm) of effluent slightly exceeded Ghana EPA guideline values of 1000 mg/L and 1500 µS/cm respectively. This implies that the effluent water produced within certain months during the period of study had high levels of dissolved salts. Effluent water with high level of salts pose threat to plant species when disposed of into the environment. From Table 2, there was a significant moderate correlation between mean TDS and EC of effluent ($r = 0.70$, $p <0.05$). Thus, the effluent TDS contributed 70 % to the level of EC. This confirms the assertion that EC is greatly dependent on TDS (Julian, Marianne & Shaun, 2018). Also, a study carried out by Khatoon, Khan, Rehman and Pathak (2013) showed that there was significant correlation between TDS and EC ($r = 0.846$, $p <0.01$). Again, Agyemang et al. (2013) recorded average effluent TDS and EC levels of (839.8±59.3) and (842±58.8) µS/cm respectively, which were lower than the mean values of effluent TDS and EC recorded in this study. The difference in mean TDS and EC levels recorded by Agyemang et al. (2013) and that of this study could be due to difference in wastewater characteristics and treatment efficiencies of the wastewater treatment plants.

From Table 1, the mean concentration of effluent BOD was (48.10±4.18) mg/L ranging from 43.00 to 60.00 mg/L whilst that of COD was (240.00±56.58) mg/L ranging from 135.00 to 355 mg/L. It was found that the mean effluent BOD and COD concentrations were slightly below the Ghana EPA guideline values of 50.00 and 250.00 mg/L respectively. This suggests that the effluent water had low concentration of organic matter and inorganic matter pollution. According to Rachna and Disha (2016), BOD greatly influences dissolved oxygen in water and that the higher the BOD, the lower the dissolved oxygen and vise – versa. This means the effluent water produced by the oily wastewater treatment plant had high concentration of dissolved oxygen to sustain aquatic life when discharged into any aquatic environment. The mean oil/grease concentration of effluent was (1.10±0.67) mg/L ranging from 0.50 to 2.80 mg/L. Again, the average effluent oil/grease concentration was below the Ghana EPA guideline value of 10 mg/L. This means that when the effluent is discharged into the environment would not interfere with plant growth and would not form film sheets on water surfaces to prevent light penetration. The mean concentrations of oil/grease and BOD of effluent recorded by Gowthaman et al. (2017) were 54 mg/L and 2.65 mg/L, which were different from the findings of this study. The difference in mean values of oil/grease and BOD concentrations could be due to difference in wastewater characteristics and difference in pollution loads. Notwithstanding, Agyemang et al. (2013) recorded BOD and COD mean concentrations of (49.8±32.9) and (569.2 ±115.3) mg/L, which is in contrast with the findings of this study. Again, this difference in mean values could be attributed to difference in treatment efficiencies of the wastewater treatment plants.

The mean concentrations of effluent nitrate ion and total phosphorus were 6.23 mg/L (5.00 – 9.00) mg/L and 0.80 mg/L (0.20 – 4.00) mg/L respectively. Furthermore, the minimum and the maximum concentrations of sulphide ions in the effluent water were 0.20 and 4.00 mg/L respectively with a mean concentration of 0.1 mg/L. The mean concentrations of nitrate ions, sulphide and total phosphorus in the effluent water were below the EPA Ghana guideline values of 50.00, 1.50 and 2.00 mg/L respectively. Notwithstanding, it was found that the maximum concentration of total phosphorus significantly exceeded the Ghana EPA guideline value for assessing effluent quality. According to Walakiraa and Okot-Okumu (2011), excessive presence of phosphorus cause algal bloom formation, cyanobacteria growth and subsequently death of aquatic species. The maximum concentration of effluent exceeding the Ghana EPA guideline value means that the effluent water when discharged into water environment could promote toxic cyanobacteria growth, which in turn depletes dissolved oxygen, causing death of aquatic species.

The increasing order of mean concentrations of heavy metals was Cd<Hg<Pb<Cr<As<Cu<Zn<Fe. All the mean concentrations of heavy metals in effluent water were below the EPA Ghana guideline values (Table 1). This means that the effluent water when discharged will not have toxic effect on the environment as Edokpayi at al. (2017) assert that Hg, Cd, Pb and Cu are toxic at high concentrations.

The study revealed that all the mean levels of physico-chemical parameters of effluent water met the EPA Ghana guideline values, which suggests that the effluent water quality was encouraging. The findings of this study is in contrast to the findings of the study carried out by Abubakari et al. (2016), where apart from the pH all the mean levels of physico-chemical parameters of effluent water were above the Ghana EPA guideline values. Again, the findings of this study is different from the findings of the study carried out by Nkwocha et al. (2013) where BOD and oil/grease levels exceeded the Federal EPA standard. A research study on industrial effluent quality carried out by Copaciu et al. (2015) in Romania showed that most of the parameters (pH, BOD, COD, TSS, total phosphorus) exceeded the set national effluent guideline values. According to Copaciu et al. (2015), differences in treatment methods account for the difference in effluent water quality produced from two different treatment plants. This implies that the differences in mean levels of effluent water parameters recorded by Abubakari et al. (2016), Copaciu et al. (2015) and Nkwocha et al. (2013) as compared to that of the present study could be attributed to the differences in pollution loads of the influent water from which the effluent water was produced, and differences in the treatment plants abilities. On the contrary, the maximum levels of TDS, EC and total phosphorus exceeded the Ghana EPA guideline values for assessing effluent quality. This clearly indicates that not all the effluent water produced during the period of study had encouraging physico-chemical quality parameters. As a result, could pose public health threat when disposed, as Copaciu et al. (2015) posit that improperly treated effluent pose serious public health when disposed into the environment.

Treatment efficiency of oily wastewater treatment plant

The treatment efficiency of the oily wastewater treatment plant in the study area in removing turbidity, TSS, TDS, EC, BOD, COD, oil/grease and heavy metals from the oily wastewater is shown in Table 3. The independent t–test analysis result testing whether statistical significant difference exist between the mean concentrations of influent and effluent water parameters is also presented in Table 3.

Table 3: Oily wastewater treatment efficiency and t – test analysis results

Parameters	Mean levels		Treatment efficiency (%)	t – value	p-value
	Influent	Effluent			
pH (unit)	7.02	6.60	-	-	-
Turbidity	500.80	65.20	87.00	6.38	<0.05
EC (us/cm)	25854.60	1489.16	94.80	7.81	<0.05
TDS (mg/L)	17191.50	985.50	94.60	7.89	<0.05
TSS (mg/L)	995.80	45.00	95.50	1.97	<0.05
BOD (mg/L)	577.80	48.10	91.70	7.55	<0.05
COD (mg/L)	1494.40	240.10	83.80	10.07	<0.05
Oil/grease (mg/L)	29.40	1.10	96.20	10.44	<0.05
Sulphide ions (mg/L)	1.04	0.13	86.88	2.06	<0.05
Nitrate ion (mg/L)	20.80	6.30	69.99	9.90	<0.05
Total phosphorus (mg/L)	6.40	0.80	87.50	4.79	<0.05
Hg (mg/L)	0.01	<0.01	30.00	0.50	>0.05
Cr (mg/L)	0.03	0.01	67.74	3.40	<0.05
Zn(mg/L)	3.69	1.23	66.47	19.54	<0.05
Cu(mg/L)	2.74	0.85	68.64	18.05	<0.05
Fe(mg/L)	4.59	1.52	66.77	26.66	<0.05
As(mg/L)	0.02	0.01	50.00	0.92	>0.05
Cd(mg/L)	0.06	<0.01	87.50	8.79	<0.05
Pb(mg/L)	0.02	0.01	50.00	0.01	>0.05

The maximum and the minimum levels of influent water physico-chemical parameters presented in Table 2 indicate that there was variation among influent water physico-chemical parameters. This could be attributed to the fact that the influent water treated was from different sources with different physico-chemical characteristics. The results showed that the pH value of influent water reduced from 7.02 to 6.60. The decrease in pH value could be due to the dosing of acid at the pre-treatment stage to break emulsions. The turbidity concentration significantly reduced from 500.80 to 65.20 mg/L whilst TSS concentration reduced from 995.80 to 45.00 mg/L. The turbidity and TSS removal efficiencies of the treatment plant were 87.0 and 95.5 % respectively. The findings of this study is in contrast with the study conducted by Agyemang et al. (2013) where turbidity and TSS concentrations increased after treatment from 46.80 to 94.80 mg/L and 87.70 to 176.70 mg/L respectively. Notwithstanding, Amoo et al. (2017) recorded TSS treatment efficiency of a wastewater treatment plant in federal capital territory in Abuja in Nigeria to be 96.0 %. The difference in the wastewater treatment plant efficiency could be due to difference in the treatment techniques employed for treating the wastewater and the difference in treatment plants operational principles. From Table 3, the TDS and EC levels reduced significantly from 17191.50 to 985.50 mg/L and 25854.60 to 1489.16 µS/cm respectively. The TDS and EC removal efficiencies of the oily wastewater treatment plant were 94.6 and 94.8 % respectively. This implies that the treatment plant had high efficiency in removing dissolved solids from the wastewater. An independent t-test analysis results showed that there was a significant difference between influent and effluent mean turbidity concentration ($t = 6.38$, $p<0.05$), TSS ($t = 1.97$, $p<0.05$), TDS ($t = 7.86$, $p<0.05$) and EC ($t = 7.86$, $p<0.05$). Even though, the oily wastewater treatment plant efficiency in removing TDS and EC was high and there was significant difference between mean influent and effluent TDS and EC, the maximum levels of TDS and EC in effluent water measured during the period of study slightly exceeded the Ghana EPA guideline values for assessing effluent quality. This gives an indication that the oily wastewater received at the oily waste treatment facility for treatment had high level of dissolved salt.

The oily wastewater treatment plant efficiency in removing BOD (91.7 %) and COD (83.8 %) was high. This means the oily wastewater treatment plant was efficient in removing organic and inorganic pollutants from wastewater as Aniyikaiye, Oluseyi, Odiyo and Edokpayi (2019) posit that BOD and COD removal from wastewater is important as they give strong indication of organic matter pollution in water. Furthermore, the oil/grease concentration in the influent (29.40 mg/L) was significantly decreased from 29.40 to 1.10 mg/L. This suggests that the treatment plant was efficient in removing oil/grease from the wastewater with a high treatment efficiency of 96.2 %. The finding of this study is in contrast with a study carried out by Aljaberi et al. (2020) where an electrocoagulation reactor had an oil removal efficiency of 85.9 %. Amoo et al. (2017) reported that a wastewater treatment plant had COD and BOD removal efficiencies of 89.0 and 96.5 % respectively whilst Agyemang et al. (2011) showed that a wastewater treatment had COD and BOD removal abilities of 93.0 and 82.0 % respectively. Again, Gowthaman et al. (2017) reported that the BOD and oil/grease removal efficiencies of an oily water treatment plant were 57.7 and 3.0 % respectively whilst Sekman et al. (2011) revealed wastewater treatment plant for treating oily wastewater had suspended solids, COD and oil/grease removal efficiencies of 98.8, 90.0 and 80.0 % respectively. The difference in treatment plant efficiency reported by Aljaberi et al. (2020), Amoo et al. (2017), Gowthaman et al. (2017) and Sekman et al. (2011) as compared to the finding of this study is due to difference in the treatment techniques employed for treating the wastewater and the difference in treatment plants operational principles. Statistically, there was significant difference between mean influent and effluent BOD ($t = 7.55$, $p<0.05$), COD and oil/grease ($t = 10.44$, $p<0.05$).

The oily wastewater treatment plant efficiencies in removing sulphide ions, nitrate ions and phosphorus were 86.8, 69.9 and 87.5 % respectively (Table 3). Sulphide ions, nitrate ions and phosphorus concentrations decreased from 1.04 to 0.13 mg/L, 20.80 to 6.30 mg/L and 6.40 to 0.80 mg/L respectively. This implies that the oily wastewater treatment plant had a high efficiency in removing sulphide ions and phosphorus but moderate efficiency in removing nitrate ions. Influent As, Hg and Pb concentrations reduced from 0.02 to 0.01 mg/L, 0.01 to 0.007 mg/L and 0.02 to 0.01 mg/L respectively. The oily wastewater plant efficiency in removing Hg, As and Pb were 30.0, 50.0 and 50.0 % respectively. This suggests that the oily wastewater treatment plant ability in removing Hg, As and Pb was low. In addition, the mean concentration difference between influent and effluent As, Hg and Pb was not significant ($p>0.05$). This confirms the treatment plant low ability in removing As, Hg and Pb from the oily wastewater. The fact that the oily wastewater treatment plant had low efficiency in removing As, Hg and Pb but their concentrations in the effluent met the Ghana EPA guideline values, suggests that the oily wastewater was less polluted with As, Hg and Pb. However, significant difference existed between influent and effluent water in terms of Cr, Zn, Cu and Fe concentrations. This confirms that the oily wastewater treatment plant was moderately efficient in removing Cr, Zn, Cu and Fe with treatment efficiencies of 67.7, 66.5, 68.6 and 66.7 % respectively.

CONCLUSIONS

The study revealed that there was variation in influent and effluent water physico-chemical parameters and the oily wastewater received at the oily waste treatment facility for treatment had high level of dissolved salt. The oily wastewater treatment plant had a high efficiency in removing turbidity (87.0 %), TSS (95.5 %), TDS (94.6 %), EC (94.8 %), BOD (91.7 %), oil/grease (96.2 %) and moderate efficiency in removing Cr (67.7 %), Zn (66.4 %), Cu (68.6 %) and Fe (66.7 %). Moreover, the oily wastewater treatment plant had low efficiency in dealing with Hg (30.0 %), As (50.0), and Pb (50.0 %). The mean values of effluent physico-chemical parameters met Ghana EPA guideline values for assessing effluent quality. However, the maximum levels of TDS, EC and total phosphorus exceeded the Ghana EPA guideline values. Statistically, the effluent TDS contributed moderately to the level of EC ($r = 0.70$, $p<0.05$). It is concluded that the physico-chemical quality of effluent water produced by the oily wastewater treatment plant was satisfactory and can be improved.

It is therefore recommended that:

1. Chemical precipitation and coagulation unit should be integrated into the oily wastewater treatment plant to help boost the treatment plant ability to deal with TDS, EC and total phosphorus and it low efficiency in removing As, Hg and Pb.
2. An equalization tank should be integrated into the oily wastewater plant to make all influent water have the same quality and flow. Thus, avoiding differences between influent water characteristics and subsequently monthly effluent water quality.
3. Periodic maintenance should be carried out on the oily wastewater treatment plant to help maintain it efficiency and the quality of effluent should be monitored constantly to ensure that the effluent quality meets Ghana EPA standard specifications before discharged.

ACKNOWLEDGEMENTS

I would like to thank the Research Scientists at Nuclear Application Center of Ghana Atomic Energy Commission for their assistance during the laboratory work.

REFERENCES

Abubakari, A., Oppong - Kyekyeku, A.F., Donkor, E. & Nyantakyi, J.A. (2016). The effect of industrial effluents on the quality of Onukpawahe stream in Tema, Ghana. *Journal of Environmental Science and Engineering*, 5 (1), 457 – 475

Adejumoke, I.A., Babatubde, A.O., Abimbola, O.P., Tabitha, A.A., Adewumi, D.O. & Toyin, O.A. (2018). *Water pollution: effects, prevention and climate change and water challenges of urbanizing world.* Matjaz Glavan, IntechOpen Publisher.

Agyemang, E.O., Awuah, E., Darkwah, L., Arthur, R. & Osei, R. (2013). Water quality assessment of wastewater treatment plant in a Ghanaian beverage industry, *International Journal of Water Resources and Environmental Engineering*, 5 (5), 222 – 229.

Aljaberi, F., Abdulmajeed, B.A., Hassan, A.A. & Ghadban, M.L. (2020). Assessment of an electrocoagulation reactor for the removal of oil content and turbidity from oily wastewater using response surface method. *Recent innovations in Chemical Engineering*, 13 (1), 55 – 71

Aljaberi, F.Y. & Mohammed, W.T. (2018). The most practical treatment methods for wastewater treatment: A systematic review. *Mesopotemia Environmental Journal, Special issue E, 1 – 28*

American Public Health Association (1998). *Standard Methods for the Examination of Water and Wastewater.* (20th Ed). Washington, D.C.

Amoo, A.O., Adeleye, A.O., Ijanu, E.M., Omokhudu, G.I. & Okoli, C.S. (2017). Assessment of the efficiency of WUPA wastewater treatment plant in Federal capital territory, Abuja, Nigeria. *International Journal of Applied Research and Technology*, 6 (9), 3 – 9

Aniyikaiye, T., Oluseyi, T., Odiyo, J. & Edokpayi, J.N. (2019). Physico-chemical analysis of wastewater discharge from selected paint industries in Lagos, Nigeria. *International Journal of Environmental Research and Public Health*, 16 (1), 2 – 17

Asselin, M., Drogui, P., Brar, S.K., Benmoussa, H. & Blais, J.F. (2008). Organics removal in oily bilge water by electrocoagulation process. *Journal of Hazardous Materials*, 157 (1), 446 – 455.

Bernard, A. (2010). *Assessing the performance of Dompoase wastewater treatment plant and its effect on water quality of Oda river in Kumasi*. PhD Thesis. KNUST publishers

Chikwe, T.N. & Okwa, F.A. (2016). Evaluation of physico-chemical properties of produced water from oil producing well in Niger Delta area, Nigeria. *Journal of Applied Science, Environment and Management*, 20 (4), 1113 – 1117.

Copaciu, F., Roba, C., Opria, O., Bunea, A. & Miresan, V. (2015). Assessment of industrial effluent quality and their possible impact on surface water. *Bulletin UASVM Animal Science and Biotechnology*, 72 (2), 132 – 141

Charkraborty, C., Hug, M.M., Ahmed, S., Tabassum, T. & Miah, M.R. (2013). Analysis of the causes and impacts of water pollution of Buriganga river: A critical study. *International Journal of Scientific and Technology Research*, 2 (9), 245 – 251

Environmental Protection Agency (2012). "Sector specific effluent quality guidelines for discharges into natural water bodies". Retrieved from www.epa.gov.gh.

Edokpayi, J.N., Odiyo, J.O., Msagati, T.A.M., Popoola, E.O. (2015). Removal efficiency of faecal. Indication organisms, nutrients and heavy metals from peri-urban wastewater treatment plant in Thohoyandou, Limpo Province, South Africa. *International Journal of Environmental Research*, 12 (1), 2700 – 7320.

Gaikwad, R. W., Sapkal, V.S. & Sapkal, R.S. (2010). Ion – exchange design for removal of heavy metals from acid – mine drainage wastewater, *Acta Montanistica Slovaca*, 15 (4), 289 – 304

Gowthaman, S., Mafizur, R. & Sivakumar, S.S. (2017). Performance evaluation of wastewater treatment plant: An analysis of fat, oil and grease removal efficiency. *International Journal of Scientific and Engineering Research*, 8 (1), 2084 – 2089.

Grita, M., Karakulsky, K. & Morawski, W. (2001). Purification of oily wastewater by hybrid UF/MD. *Water Research Journal*, 35 (15), 3665 – 3669.

Guyer, P. (2013). *An introduction to oily wastewater collection and treatment.* Continuing Education and Development Inc. 9 Greyridge Farm Court.

Hayata, H., Dootsi, M. & Sayadi, (2013). Performance evaluation of waste stabilization pond in Birjand, Iran for treatment of municipal sewage. *Proceedings of the International Academy of Ecology and Environmental Sciences*, 3(1), 52 – 58

Hui, L., Yan, W., Juan, W. & Zhongming, L. (2014). A review. Recent advances in oily wastewater treatment. *Recent Innovations in Chemical Engineering*, 7 (1), 17 – 24

Julian, K.T., Marianne, S. & Shaun, R. (2018). Contaminated groundwater sampling and quality control of water analysis. *Environmental Geochemistry*, 2 (1), 25 – 45

Khatoon, N., Khan, A.H., Rehman, M. & Pathak, V. (2013). Correlation study for the assessment of quality of Ganga river, Kanpur, Uttar Pradesh, India. *IOSR Journal of Applied Chemistry*, 5 (3), 80 – 90

Mogens, H., Van - Loosdrecht, M.C.M., Ekama, G.A. & Damir, B. (2008). *Biological wastewater treatment principles, modelling and design.* IWA Publishing.

Morrison, G., Fatoki, O.S., Persson, L. & Ekberg, A. (2001). Assessment of the impact of point source pollution from treatment plant on the Keishmma river. *Water SA*, 27 (4), 475 – 480

Nkwocha, A. C., Ekele, I.C., Kamen, F.L. & Oghome P. I. (2013). Quality assessment of effluent discharged from vegetable oil plant. *Ethopian Journal of Environmental Studies and Management*, 6 (1), 717 – 723

Ogwo, PA. & Ogu, O.G. (2014). Assessment of wastewater treatment plant efficiency at AMA Breweries PLC, Enugu State, Nigeria. *Journal of Environmental Science and Policy Evaluation*, 4 (2), 1 – 23

Parihar, A. & Malaviya, P. (2013). Textile wastewater treatment using sawdust as adsorbent. *International Journal of Environmental Sciences*, 2 (3), 110 – 113

Penny, R.L. & Yeh, S. (2006). Biological bilge water treatment system. *Naval Engineers Journal*, 3 (1), 45 – 50.

Poulopoulos, S.G., Voutsas, E.C., Grigoropoulou, H.P., Philoppopoulos, C.J. (2005). *Journal of Hazard Materials*, 117 (1), 135 – 139

Rachna, B. & Dishna, J. (2016). Water quality assessment of lake water: A review. *Sustainable Water Resources Management*, 2(1), 161 – 173

Sekman, E., Top, S., Uslu, E.,Varank, G. & Bilgili, M.S. (2011). Treatment of oily wastewater from port waste reception facilities by electrocoagulation. *International Journal of Environmental Research*, 5 (4), 1079 – 1086.

Shukla, A., Zhang, Y.H., Dubey, P., Margrave, J.L. & Shukla, S.S. (2002). The role of sawdust in the removal of unwanted materials from water. *Journal of Hazardous Materials*, 95(1), 137 – 152.

Sulaiman, A.A., Attala, E. & Sherif, M.A.S. (2016). Water pollution: Sources and treatment. *Journal of Environmental Engineering*, 6 (1), 88 – 98

Vitez, T., Sevcikova., Oppeltova, P. (2012). Evaluation of the efficiency of wastewater treatment plant. *Acta University of Agriculture*, 40 (1), 173 – 180

effluent on water quality
receiving stream in Nakawa – Ntinda, Uganda. *Journal Applied Science and Environmental Management*, 15 (1), 289 – 296

Yu, L., Han, M. & He, F. (2013). A review of treating oily wastewater. *Arabian Journal of Chemistry*, 18 (1), 1913 – 19922

Zhang, M.S., Zhu, Y.H., Xiao, Y., Zia, W.L. & Meng, F.W. (2007). Research advance in treatment of oily wastewater. *Chinese Researches Comprehensive Utilisation*, 25 (8), 22 – 24