Civil and Environmental Research
ISSN 2224-5790 (Paper) ISSN 2225-0514 (Online)
Vol.6, No.6, 2014

A Comparative Study of the Quality of Wastewater from Tema Oil Refinery (TOR) Against EPA Standards and its Effect on the Environment

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Abstract

The proliferation of industrialization has resulted in increased wastewater generation and its disposal has rapidly been of serious concern in recent times to environmental scientists. The discharge of these untreated or partially treated effluents into the environment, especially, surface water poses a great threat to the environment and also causes adverse human health. Industrial wastewater may contain high levels of contaminants such as suspended, colloidal and dissolved minerals, inert organic matter, heavy metals, possible pathogenic bacteria which might be either excessively acidic or alkaline in a way that may have negative impact on all forms of life in the environment. This study was therefore conducted to determine the treated effluent quality of Tema (Ghana) Oil Refinery against the Ghana Environmental Protection Agency (EPA standards and also assess its impact on the environment. Samples of the effluents discharged from the refinery were taken and analyzed for physico-chemical parameters as well as Heavy Metals; lead (Pb), manganese (Mn), chromium(Cr), vanadium (V), nickel (Ni), copper (Cu) and iron (Fe) for three consecutive months and their mean values compared with EPA standard. The results revealed that, all the heavy metals were within the standard of the EPA regulatory standard but mean conductivity was very high with a mean value of 10399.0$\mu s/cm$ as against 1500 $\mu s/cm$. Also a high TDS mean value of 5358.67mg/l was recorded as against the EPA standard of 1000mg/l. Unsatisfactory mean levels of BOD and COD which reflected the organic load in the water were recorded. The BOD value was found to be 60mg/l as against the EPA standard of 50mg/l while COD value was 423.7mg/l which was far above the EPA standard of 250mg/l. It is therefore recommended that, the wastewater treatment unit of the Tema Oil Refinery should be revamped to enhance the control of contaminant levels of the final effluent discharged into the environment.

Keywords: Tema Oil Refinery; environment; wastewater; regulatory bodies; waste management; Environmental Protection Agency

1. Introduction

Wastewater generation in recent times is on the increase due to rapid urbanization and increased industrialization and therefore its treatment before final disposal or reuse is now receiving greater attention from the World Bank and government regulatory bodies (Mishra and Jhansi, 2013). Untreated or inefficient treated wastewater poses great threat to the environment because of its known hazardous constituents. It pollutes water bodies, adversely affects flora and fauna; affects land use and human health; disruptive of economic activities such as agriculture, fishing and recreation (Achaw and Danso-Boateng, 2013).

Only a small fraction of the total water on earth are in usable forms. Unfortunately, the existing water sources are contaminated because untreated sewage and industrial wastewater are continually being discharged into surface waters resulting in impairment of water quality (Mustafa, 2013). Freshwater is used for various domestic and industrial activities. Once freshwater has been used for an economic or beneficial purpose, it is generally discarded as waste. In many countries, these wastewaters are discharged, either as untreated waste or as treated effluent, into natural waterways (Mishra and Jhansi, 2013). Naturally, flowing rivers and streams have the ability to undergo self purification. However, at certain levels of contamination, self purification becomes almost impossible or might take longer time. Treatment is therefore necessary to correct these wastewater characteristics in such a way that the use or final disposal of the treated effluent can take place in accordance with the rules set by the relevant legislative bodies without causing an adverse impact on the receiving bodies (Njau and Mlay, 2003).

In spite of these contaminants present in wastewater and their negative toll on the health and the environment, industrial and domestic wastewaters, especially, in developing countries are either not effectively treated or not treated at all before reuse or final disposal. An estimated 90 per cent of all wastewater generated in developing countries is discharged untreated directly into rivers, lakes or the oceans (Corcoran *et al*., 2010) because conventional wastewater treatment systems comprising of energy intensive and mechanized treatment components require heavy investment and entail high operating costs (Mustafa, 2013) which is not affordable in developing countries. In Ghana, efficient wastewater treatment is not an option for the municipal authorities and industries due to high cost involved (Keraita *et al*., 2002). Thus, increase in municipal wastewater generation originating from domestic, commercial and industrial facilities and institutions have resulted in considerable amounts of wastewater discharged into water bodies. As a result, despite considerable amount of intervention by national and municipal authorities, serious water quality problems still exist and sewage contamination of our lakes, rivers, and domestic water bodies has reached dangerous levels.

Even though domestic water usage results in wastewater generation, nevertheless, industrial development has always been afflicted with the issue of residue disposal, and it has become accepted by all bodies of knowledge that industrial effluents from oil and gas companies are one of the largest sources of water pollution and one with the most lethal composition of toxins (Mishra and Jhansi, 2013). While these petroleum refinery and petrochemical industries are most desirable for national development and improved quality of life, the unwholesome and environmentally unacceptable pollution effects of the waste from these industries are cause for worry (Atubi, 2011). The process of converting crude oil into petroleum products (liquefied petroleum gas, naphtha, kerosene, diesel oil and residual oil) and petrochemical products (polypropylene, polyethylene), generates different kinds of waste. Because of its known constituents (Suleimanov, 1995) of the waste generated by these companies and its known environmental and health hazards, it must immediately be conveyed away from its generation sources and treated appropriately before final disposal (Turkar *et al.,* 2001). Due to this, regulatory bodies like the Environmental Protection Agency (EPA) have acceptable wastewater standards concerning the quality of effluent disposal and highly recommend that, before these industrial effluents are discharged into river bodies, they must be effectively treated to the recommended standards. However, it is not known whether the legally accepted levels for refinery effluents are adhered to.

Nevertheless, some industries in Ghana are unable to treat effluent to harmless levels to meet the acceptable effluent quality standards set by EPA. The Tema Oil Refinery (TOR) according to EPA publication on industry specific environmental rating (2001), is unable to treat effluent discharged effectively and is therefore below the agency's Regulatory standard. The current project therefore seeks to determine the quality of the treated effluents discharged into the environment and to demonstrate their compliance with Ghana EPA effluent quality guidelines.

2. Methodology

Tema Oil Refinery (TOR) is located in the heavily industrialized area of Tema in Ghana and is situated 24km east of the capital, Accra. TOR It is linked to an Oil Jetty at the Tema Harbour by pipelines of various diameters for transportation of raw materials (crude oil) and finished products. The land of the refinery is 440000 square meters. The land area provides opportunity for on-site disposal of solid wastes. TOR is Ghana's only refinery established in 1963 to enhance the country's economic, investment and development programs. Crude Oil is used as a raw material by the refinery for production. The crude oil is usually imported from neighboring Nigeria and transported through pipelines to the refinery storage and tanks for processing into several finished products. The wastewater from the refinery is treated by the Wastewater Treatment Unit before it is being discharged into the environment. The wastewater comprises of storm water basin, stripped sour water and domestic wastewater. All these are channeled through the refinery wastewater treatment unit before it is discharged into the environment to a nearby lagoon called the Chemu Lagoon.

Figure 1: Location of the Tema Oil Refinery (courtesy: Google maps)

The study was cross-sectional and retrospective in design and used both qualitative and quantitative methods to collect the required data. Informed consent was also sought from the Human Resource Department of the Tema Oil Refinery stating clearly the objectives of the study, what would be involved and its significance before data collection. Samples of the discharged effluent were taken and analyzed for physico-chemical parameters such as Total Suspended Solids (TSS), Conductivity, Temperature, Colour, Turbidity, pH, Total Dissolved Solids (TDS), Chemical Oxygen Demand (COD) and Biological Oxygen Demand (BOD). Heavy Metals concentration analysis were done for lead (Pb), manganese (Mn), Chromium (Cr), Vanadium(V), nickel(Ni), copper(Cu) and iron(Fe). Sampling was done bimonthly and the average values for each month used for the study. The sampling months were January, February and March 2013. In all, sixty (60) samples representing three (3) effluents samples taken at each treatment plant were analyzed. The instrument used in this study includes Bulk Scientific Atomic Absorption Spectrophotometer (AAS) Computerized Model 210VGP with Epson Printer LX300 which was used to measure the heavy metals. Conductivity was measured with the suntex conductivity meter, Total Dissolved Solids (TDS) was measured with the Hatch TDS meter, Total Suspended Solids (TSS) was determined using weight loss technique. Temperature of the samples was measured in-situ with Hanna Instrument checktemp packet digital thermometer with stainless steel penetration probe. BOD was analyzed using the BOD_5 determination method. The 5 – day BOD test (BOD_5) was done by placing samples of the effluent into two standard BOD bottles. One sample was analyzed immediately to measure the initial dissolved oxygen concentration in the effluent using the Winkler titration. The second BOD bottle was sealed and stored at 20 ℃ in the dark to avoid photosynthetic oxygen generation. The amount of dissolved oxygen remaining in the sample after 5 days was measured and the BOD_5 was calculated from the results. The COD was determined using the standard COD determination procedure. The effluent samples collected were immediately stored in an ice-chest and transported to Tema Oil Refinery Chemical laboratory for analysis for other parameters. The results from the Laboratory analysis were compared to the EPA acceptable effluent quality standards.

3. Results and Discussions

The physico-chemical parameters used to assess the quality of effluent discharged into the environment from the two wastewater treatment systems are temperature, pH, conductivity, biochemical oxygen demand (BOD), Chemical Oxygen Demand (COD), total suspended solids (TSS), Total dissolved solids (TDS), as well as heavy metals (Iron, Manganese, Nickel, Copper, Lead and Vanadium. A summary of the wastewater results of the study are given in Table 1. The table shows the mean monthly effluent values for pH, temperature, conductivity, Chemical Oxygen Demand (COD), Biochemical Oxygen Demand (BOD), Total Suspended Solids (TSS) and Total Dissolved Solids (TDS) as well as the heavy metals studied. A comparison of these values with standards of the Ghana Environmental Protection Agency (EPA) is also shown in the table.

Table 1. Monthly mean of physic-chemical parameters and heavy metals compared to EPA standard

Parameter	WWT Effluent for January	WWT Effluent for February	WWT Effluent for March	Average Mean Effluent	EPA Standard
pH	8.00	8.17	8.03	8.10	6-9
Temperature (℃)	34	33	35	34.0	< 3 ℃ amb
Conductivity($\mu S/cm$)	5200	4397	21600	10399	1500
COD (mg/L)	247	746	219	423.7	250
BOD (mg/L)	59	60	61	60	50
TSS (mg/L)	32	49	61	47.3	50
TDS (mg/L)	2193	2083	11800	5358.67	1000
Iron (mg/L)	0.200	0.102	0.100	0.134	3
Manganesse (mg/L)	0.120	0.022	0.020	0.054	0.2
Chromium (mg/L)	0.210	0.112	0.110	0.144	0.2
Nickel (mg/L)	0.125	0.027	0.025	0.059	0.5
Copper (ppm)	0.600	0.502	0.050	0.384	5
Lead (ppm)	0.101	0.003	0.001	0.036	0.1
Vanadium (ppm)	0.102	0.004	0.002	0.036	1

From Fig. 2, there was a high increase in the mean monthly conductivity value of 10399.0$\mu S/cm$ as against the EPA standard of 1500 $\mu S/cm$. The high effluent conductivity values may be attributed to the high concentration of dissolved ions present in the wastewater (Agyeman *et al.*, 2013) and showed the ability of water to conduct electrical current and will therefore contribute to more organic matter and salinity in water thereby having a major effect on the environment.

The chemical oxygen demand (COD) and the biological oxygen demand (BOD) are the most important parameters commonly used to examine wastewater quality since they reflect the organic load to in wastewater. The mean monthly BOD value of 6**0**mg/l from the graph was slightly higher than the EPA standard of 50mg/l. However, the mean monthly COD from the graph was 423.7mg/l as against the EPA standard of 250mg/l. This was indeed, on the higher side. These higher COD and BOD values amply suggest that there could be depletion of natural oxygen resources in the effluent which may lead to the development of more devastating conditions and also significantly high level of biodegradability in the environment as was reported by Hodgson (2007). Nevertheless, the mean monthly TSS value of 47.3mg/l as against the EPA standard of 50mg/l recorded was very encouraging and most satisfactory. However, a high monthly mean TDS value of 5358.67mg/l was recorded as against the EPA standard of 1000gm/l. In fact, this figure was extremely high and thus, unacceptable. This high mean monthly level of TDS could be due to high concentrations of dissolved inorganic and organic molecules and ions present in the wastewater. Therefore the final exit of the effluent into the nearby lagoon will pose a threat to aquatic life in the water body (Mishra and Jhansi, 2013; Corcoran, 2010). Mean monthly effluent temperature value of 34^{o}C was within the EPA standard of < 3^{o}C amb. The slight drop in temperature of about 0.05 ℃ of the mean value could be due to loss of heat by convection to the atmosphere and conduction to the walls of the asbestos pipes conveying the effluent to the receiving drain. The comparatively low mean monthly temperature recorded could enhance the growth and activity of most micro-organisms (Pearson *et al.*, 1987).

Furthermore, the mean monthly pH value of 8.10 (slightly alkaline) was within the EPA standard pH range of 6 to 9 as shown in Table 1. The alkalinity of the effluent might be due to the salt in the raw material (crude oil) which could be suitable for the existence of most biological life or activities according to Tchobanogolous *et al.*, 2003).

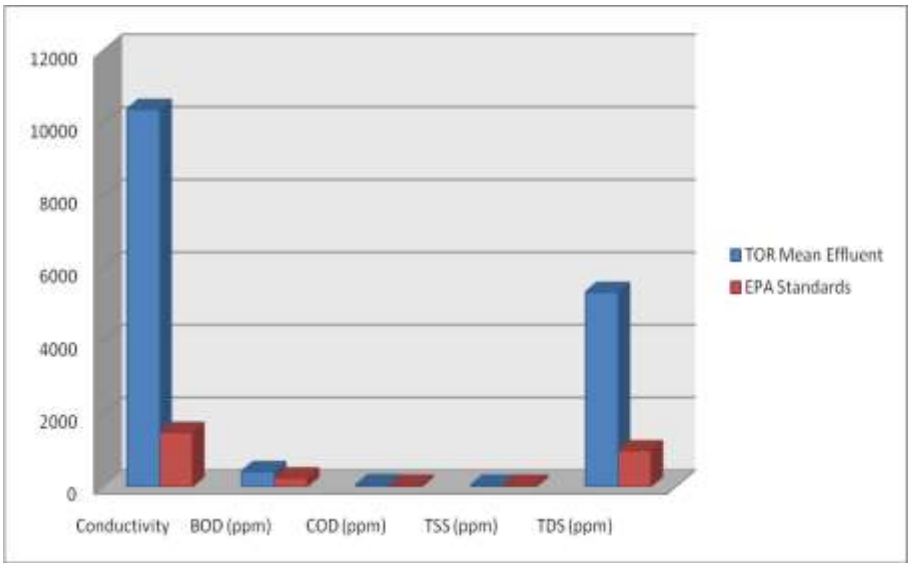

Figure 2: Mean TOR Effluent against the EPA standards

Finally, the mean monthly effluent heavy metal concentrations were found to occur within the EPA standard values as shown in Figure 3. Theses mean monthly values were 0.134. 0.054, 0.144, 0.059, 0.384, 0.036 and 0.036 for Fe, Mn, Cr, Ni, CU, PB and V respectively as against the EPA standards of 3.0, 0.2, 0.2, 0.5, 5.0, 0.1 and 1.0 respectively. In fact, these low levels of mean monthly effluent heavy metals like Lead, Nickel and Chromium might have been due to bioaccumulation by plants, which may lead to degradation as was reported by Sorme and LagerKvist (2002).

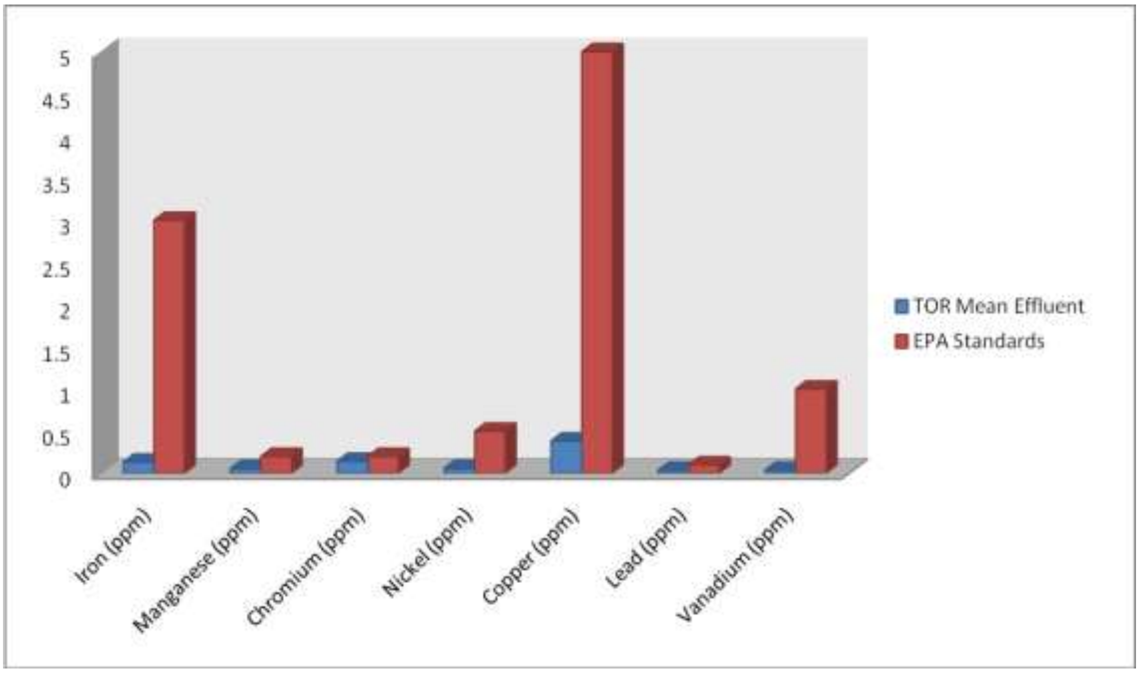

Figure 3: TOR Effluent Heavy metals against EPA standards

4. Conclusion and Recommendation

Treated effluent from the refinery showed high levels of COD, BOD, TDS as well as conductivity which were unsatisfactory, though the other parameters like Temperature, pH, TSS and the heavy metals were within the permissible limits of EPA. However, the efficiency of the wastewater treatment plant which is not functioning to its maximum capacity might have contributed to some of these unacceptable levels which were far above the EPA limits. It is therefore recommended that disinfection of the effluent wastewater may be carried out before final discharge into receiving water bodies. Also the damaged embankments of the waste treatment plant should be repaired. Regular cleaning of the inlet and outlet chambers of the waste stabilization ponds is recommended. Finally, the time for aeration of the Activated-sludge treatment plant should be increased to enhance the activated sludge formation and separation through sedimentation.

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