International Journal of
Science and Engineering Investigations vol. 2, issue 16, May 2013
ISSN: 2251-8843

Performance Evaluation of Petroleum Refinery Wastewater Treatment Plant

A. C. Nkwocha[1], I. C. Ekeke[2], F. L. Kamen[3], P. I. Oghome[4]
[1,2,3,4] Department of Chemical Engineering, Federal University of Technology, P.M.B. 1526, Owerri, Imo State, Nigeria
([1]chinkwocha1@yahoo.com, [2]ifyekeke@yahoo.com, [3]felylebye@yahoo.com, [4]ify_pros@yahoo.com)

Abstract- Performance of the wastewater treatment plant (WWTP) of a petroleum refinery located in the Niger Delta region of Nigeria was evaluated. In the study, samples of the refinery's WWTP influent and effluent were collected and analyzed weekly, using standard methods, for a period of seven weeks. The following results were obtained for the influent and effluent respectively; BOD_5 138.0mg/l, 138.0mg/l; COD 350.0 mg/l, 166.7mg/l; phosphate 16.25 mg/l, 10.84 mg/l; TDS 2100.0mg/l, 2000.0mg/l; TSS 60.0mg/l, 46.6mg/l; others are phenol 7.35 mg/l, 4.70 mg/l; oil and grease 14.75mg/l, 10.0mg/l; pH 8.00, 9.38 and temperature 39.7^0C, 38.0^0C. The results obtained for the influent and effluent for each parameter were compared in order to determine the extent of reduction, and hence the treatment effectiveness of the treatment plant. Furthermore, the effluent results were compared with the Federal Environmental Protection Agency (FEPA) recommended effluent standard, to determine the required minimum treatment effectiveness. This was used as a standard for the assessment. The study revealed that the treatment system exhibited low pollutant removal efficiency or treatment effectiveness. In this regard suggestions were made on modifications to enhance performance.

Keywords- environment, pollution, effluent

I. INTRODUCTION

There is no gainsaying the fact that industrialization is vital to a nation's socio-economic development. However, global industrialization has resulted in increased waste generation. Industries have been implicated as one of the major contributors to environmental degradation and pollution of various magnitudes [1]. The discharge of 'raw' or poorly treated waste into the environment causes pollution and degradation of the receiving environment, such as air, land or water [2,3]. Effluent discharges is becoming a serious environmental issue in Nigeria, and in other developing countries in Africa [4,5]. The ultimate recipient of all forms of pollution is the natural water body. Water which has been described by many as the most essential commodity required for man's survival has received enormous environmental abuse. Pollution of water brings about undesirable changes in the environment [6], which affect man directly or indirectly [7]. This underscores the need for environmental protection.

In Nigeria, the Federal Environmental Protection Agency (FEPA) which is charged with this responsibility has set minimum standards for industrial effluents. Consequently, industries are placed under obligation to monitor their effluent in-house, to ensure compliance with these standards. This involves analysis of the effluent to determine its composition and a possible treatment before discharge into inland water.

In the studied refinery, the liquid wastes produced in various sections of the process plant (that is, process wastewater) are combined (as influent) and sent to the treatment plant for treatment. After treatment, the treated wastewater (effluent) is discharged into the nearby river. In addition to the impurities normally found in water supply, the sources of contamination and pollution for wastewater are many and varied [8,9]. Wastewaters released by crude oil processing and petrochemical industries are characterized by the presence of large quantities of crude oil products, polycyclic and aromatic hydrocarbons, phenols, metal derivatives, surface active substances, sulphides, naphthalenic acids and other chemicals [10]. .Various studies have shown positive correlation between pollution from refinery effluents and the health of aquatic organisms [11]. Due to the ineffectiveness of purification systems, wastewater may become seriously dangerous, leading to the accumulation of toxic products in the receiving water bodies, with potentially serious consequences to the ecosystem [12,13]. Therefore, the objective of this study was to evaluate the performance of the refinery's wastewater treatment plant (WWTP) in reducing the level of pollutants to meet FEPA stipulated effluent standard.

II. MATERIALS AND METHODS

A. *Wastewater Sampling*

The process wastewater samples used for this study consist of the raw process wastewater that goes to the WWTP for treatment (that is, WWTP influent), and the treated process wastewater (that is, WWTP effluent). Sample collection was done at the inlet and discharge points respectively. Sample collection was done with 3 liter plastic bottles, previously washed thoroughly with treated potable water and dried. Before use, they were rinsed with the sample. The bottles were filled to the brim with the sample and allowed to overflow in

order to remove entrapped air. The samples were labeled, stored in ice chests and transported to the laboratory for analysis. Three samples were collected at each point weekly, at one hour intervals. Then pooled together to form the composite influent and effluent samples for the week. The samples were analyzed using standard methods [.14].

B. Statistical Analysis of Data

Because of the variation in the values of the parameters, it becomes necessary to subject the data to statistical analysis. The data were reported in terms of frequency of occurrence of a particular characteristic. This is the value of the characteristics that may be expected to be equaled or not exceeded 10, 50, or 90 percent of the time. The frequency of occurrences was determined using the procedure for data with less than 20 datum points [15].

C. Performance Evaluation of Wastewater Treatment System

To assess the operational effectiveness or efficiency of the studied wastewater treatment system in reducing pollutant levels, the 90 percent occurrence values of the WWTP influent and effluent parameters were compared.

III. RESULTS

The results of the laboratory analysis of the major parameters in the refinery wastewater are shown in Table 1. The results are means of triplicate determinations, for the seven (7) weeks experimental period. The effluent showed a reduction in the level of virtually all the parameters observed in the influent. Lead was generally not detected (<0.00l mg/l) in both influent and effluent. The 90 percent occurrence values of the parameters (obtained by statistical correlation) were compared with FEPA standard and presented in Table 2.

Despite the reductions, significant levels of BOD5 (40.30.mg/L), COD (166.70mg/L), phosphate (10.84mg/L), TDS (2000.00 mg/L), TSS (46.60.mg/L), and phenol (4.70mg/L) persisted in the effluent, and could not meet FEPA set limits. The WWTP exhibited low treatment level for these pollutants as shown in the results of the wastewater treatment effectiveness presented in Table 3. Figure 1 shows a comparison of the plant treatment effectiveness with the minimum treatment effectiveness required to attain FEPA effluent standard for each of the parameters.

IV. DISCUSSION

BOD5 has influent and effluent concentrations of 138.00mg/L and 40.30mg/L respectively, giving a percentage reduction of 70.80%. This clearly shows that the WWTP has a BOD removal capacity or treatment effectiveness of 70.80%. Ironically, this capacity though high, was not enough to reduce the effluent BOD level to the FEPA recommended limit of 10.00mg/L. The minimum required treatment effectiveness the treatment plant must possess for the effluent to meet FEPA standard with respect to BOD removal is 92-80%. On the other

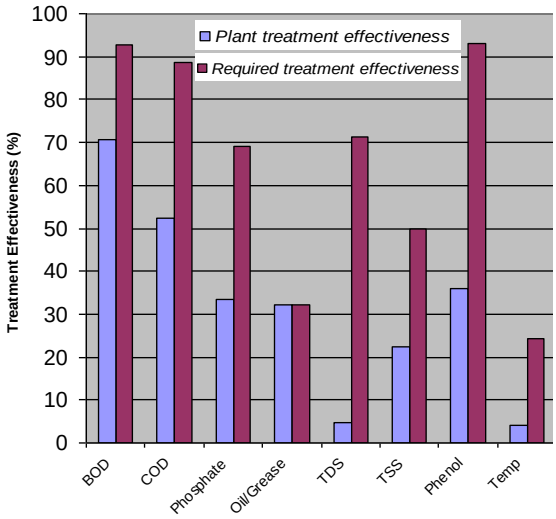

Figure 1. A comparison of treatment effectiveness

hand, COD with concentrations of 350.00mg/L and 166.70mg/L for influent and effluent respectively, has a low treatment effectiveness of 52.40%. However, to meet the regulated limit of 40.00m/L, a minimum treatment effectiveness of 88.60% required.

The high effluent concentrations of these pollutants were probably associated with their very high concentrations in the influent that goes for treatment, which probably exceeded the capacity of the WWTP. The discharge of effluent containing high levels of oxygen demanding contaminants into natural water bodies has been linked to organic pollution. This is associated with oxygen depletion in the receiving water environment and its attendant health hazards on aquatic biota [16].

As can be observed, phosphate treatment effectiveness of 33.30% is far below the minimum required treatment effectiveness of 69.20% necessary to attain the maximum permissible effluent limit of 10.84mg/L. Phosphate is a plant nutrient. Effluents containing high concentrations of plant nutrients are known to cause eutrophication in receiving water bodies [17]. Oil and grease treatment effectiveness (32.20%), though low, was just enough to reduce the level of the pollutant to the required limit of 10.00mg/L. This is because of the low level of oil and grease (14.75m/L) in the raw wastewater.

A compassion of the influent and effluent levels for TDS, TSS and phenol shows: 2100.00mg/L, 2000,00mglL; 60.00mg/L, 46.60mg/L; and 7.35mg/L, 4.70mg/L respectively. These values represent plant treatment effectiveness of 4.80%, 22.30% and 36.10%, as against the required treatment effectiveness of 71.40%, 50.00%, and 93.20% respectively. Thus, revealing the fact that the treatment has little effect on these pollutants.

Phenol is one of the major pollutants found in refinery effluents. Phenol and its derivatives occupy a prominent position on the U.S environmental protection agency priority pollutants list [18]. The major sources of phenol in the petroleum refinery process wastewater are the thermal and catalytic cracking processes. Phenol has been observed to be

very toxic to fish and other aquatic organisms and has a nearly unique property of tainting the taste of fish, if present in marine environment in concentration ranges of 0.1 to 1.0mg/L [19].

An overview of Fig 1 show that the plant average treatment effectiveness is 30-70% as against the minimum treatment effectiveness of 50-90% required to meet recommended effluent standard. This impresses the fact that the WWTP is not operating at a level that meets stipulated statutory requirement.

V. CONCLUSION

The performance of the wastewater treatment plant of a refinery was investigated. Most of the pollution parameters examined were above effluent recommended limits. The treatment plant exhibited low capacity to reduce pollutants to recommended effluent limits, and operated at a level that does not meet statutory requirements. Continued discharge of improperly treated effluent into the environment may further cause degradation of the already fragile Niger Delta ecology. It is therefore recommended that the treatment plant, and plant operations be overhauled to enhance efficiency. Alternatively, or in addition, the plant should be retrofitted to improve treatment capacity.

VI. REFERENCES

[1] FEPA - Federal Environmental Protection Agency, Guidelines and Standards for Environmental Pollution in Nigeria, 1991.

[2] A .C.Nkwocha and J. I. Okoye. "Quality evaluation of Industrial liquid effluent", Continental Journal of Applied Sciences, 2:51-55, .2007.

[3] A. C. Nkwocha, J. I, Okoye, and Ezigbo, C. I., "Physico- chemical evaluation of bore-hole ground water supply in Elele Community, Rivers State, Nigeria," Tropical Journal of Biomedical and Allied Sciences Research, 1 (2): 61 – 65, 2008.

[4] B. A. Uzoukwu, C. Ngoka, and N. Nnaji, "Mo(2004): nthly variation of the physiochemical properties of effluents from RIMCO Industries, Nnewi, Nigeria," Global Journal of Pure and Applied Sciences, 10(1):203 – 210, 2004.

[5] G.H. Briton Bi,, B. Yao, and G. Ado. "Evaluation of the Abidjan Lagoon pollution." Journal of Applied Science and Environmental Management 10:175 -181, 2006.

[6] K. I. T. Eniola, and A. B. Olayemi, "Impacts of effluents from a detergent producing plant on some water bodies in Ilorin, Nigeria," International Journal of Environmental Health Research, 9:335-340. 1999.

[7] O. A. Eletta, F, A. Adekola, and M. A. Aderanti, "Effects of wastewater discharge from soft drink plant into Asa River."ournal of Applied Science and]Environmental Management, 9(1) :187-190, 2005.

[8] A. C. Nkwocha, J. I. Okoye, and A. O, Agbo, "Municipal solid waste management – A Case study of Port Harcourt City, in Rivers State, Nigeria," Journal of Environmental Research and Policies, 3(4): 108-111, 2008.

[9] S. O. Obiekezie, "Quality characteristics of groundwater utilized in Awka, Anambra State, Nigeria," International Journal of Biotechnology and Allied Sciences Research, !(1):1-4, 2006.

[10] R. A. Suleimanov, "Conditions of waste fluid accumulation at petrochemical and procesing enterprises and prevention of their harm to water bodies," Meditsina Truda i Promyshlennaia Ekdogiia 12:31-36, 1995.

[11] T. V. Otokunebor, and Obiukwu, C., "Impact of refinery effluent on the physicochemical properties of a water body in the Niger Delta," Applied Ecology and Environmental Research, 3 (1): 61-72, 2005.

[12] M. U. Beg, S. Al-Muzaini, T. Saeed, P. G, Jacob, K. R. Beg, M. Al-Bahloul, K. Al- Matrouk, T. Al- Obaid, and A. Kurian, "Chemical contamination and toxicity of sediment from a coastal area receiving industrial effluents in Kuwait," Archives of Environmental Contamination and Toxicology 41:289-297, 2001.

[13] M. U. Beg, T. Saeed, S. Al-Muzaini, K. R. Beg, and M. Al-Bahloul. "Distribution of petroleum hydrocarbon in sediment from coastal area receiving industrial effluents in Kuwait." Ecotoxicol. Environ Saf. 54:47-55, 2003.

[14] APHA Standard Methods for the Examination of Water and Wastewater, 19th edition. American Public Health Association, Washington D.C . 1995.

[15] G. Tchobanoglous, and E .D. Schroeder, Water Quality Management, Addis Wesley Publishing Co. Inc., New York, 1995, pp 405.

[16] G. Kiely, Environmental Engineering. McGraw Hill. Inc., New York. 1993, pp. 493-790.

[17] J. Cloern, T. Krantz,. and J. E. Duffy, "Eutrophication," in .Encyclopedia of Earth,-Environmental Information Coalition, National Council for Science and Environment, Cleveland, C.J. Ed., 2007, Retrieved January 16, 2008 from <http:www.eoearth.org/article/Eutrophication>

[18] A. K. Khan. M. T. Saidan, and W. H. Cross, "Anaerobic activated carbon filter for the treatment of phenol-bearing wastewater." Journal of Water Pollution Control Federation 53(10): 1519-1532, 1981.

[19] C. A. Staples, P. B. Dom, G. M. Klecka, S. T., O'Block, and L. B. Harris, "A revof the environmental fate, effects and exposures of bisphenol A," ,Chemosphere 36:2149 - 2173, 1998.

TABLE I. RESULT [1] OF LABORATORY ANALYSIS OF REFINERY WASTEWATER

Parameter	Sampling Period (Week)													
	1		2		3		4		5		6		7	
	Influent	Effluent	Influent	Effluent	Influent	Effluent	Influent	Effluent	Influent	Effluent	Influent	Effluent	Influent	Effluent
BOD_5, mg/l	120.00	40.00	100.00	30.00	130.00	24.00	140.00	20.00	75.00	10.00	130.00	40.60	110.00	30.70
COD, mg/L	324.00	161.00	200.00	100.00	350.00	170.00	255.00	123.00	160.00	100.00	350.00	125.00	195.00	38.50
Phosphate, mg/L	17.40	4.95	14.50	6.70	6.90	4.25	12.50	4.38	9.80	12.40	7.90	4.65	12.8	4.30
Oil and grease, mg/L	12.00	9.70	14.00	10.00	10.60	8.70	14.20	9.80	13.50	8.20	11.40	9.30	14.70	8.80
TDS, mg/L	660.00	680.00	1400.00	1,800.00	6800.00	6600.00	2000.00	140.00	1200.00	1300.00	1300.00	1600.00	890.00	668.00
TSS, mg/L	40.00	44.00	50.00	38.40	48.10	5040	44.50	35.30	47.10	20.7	43.00	34.00	66.80	31.00
Lead, mg/L	<0.002	<0.001	<0.001	<0.001	<0.001	<0.001	-	<0.001	<0.001	<0.002	-	-	<0.001	<0.001
Phenol, mg/L	6.90	4.39	1.50	1.20	3.88	1.40	7.40	3.39	4.80	1.50	6.90	4.80	4.80	2.50
pH	2.90	8.60	7.20	9.30	6.80	7.40	7.30	9.40	6.40	8.20	7.70	9.20	6.40	8.00
Temp ^{0}c	36.4	38.20	35.30	37.30	36.60	33.40	34.70	37.50	40.00	36.20	35.00	34.40	35.60	34.30

1 = Results are means of triplicate determination

TABLE II. A COMPARISON OF 90 PERCENT VALUES OF PARAMETERS WITH FEPA SET LIMIT

Parameter	90 Percent Values		FEPA Effluent Limit FEPA (1991)
	Influent	Effluent	
$BOD_{5,}$ mg/l	138.00	40.00	10.00
COD, mg/l	350.00	166.70	40.00
Phosphate, mg/l	16.25	10.84	5.00
Oil and grease, mg/l	14.75	10.00	10.00
TDS, mg/l	2100.00	2,000.00	600.00
TSS, mg/l	60.00	46.60	600.00
Lead, mg/l	<0.001	<0.001	0.05
Phenol, mg/l	7.35	4.70	0.50
pH	8.00	9.38	6.50-8.50
Temp ^{0}c	39.70	38.00	40.00

Values with the 'less than' (<) sign were below detection level.

TABLE III. WASTEWATER TREATMENT EFFECTIVENESS

Parameter	90 Percent Values		Treatment effectiveness 100 (a-b)/a %	Required treatment effectiveness 100 (a-F)/a %
	Influent, mg/L (a)	Effluent, mg/L (b)		
BOD_5	138.00	40.30	70.80	92.80
COD	350.00	166.70	52.40	88.60
Phosphate	16.25	10.84	33.30	69.20
Oil and grease	14.75	10.00	32.20	32.20
TDS	2100.00	2000.00	4.80	71.40
TSS	60.00	46.60	22.30	50.00
Phenol	7.35	4.70	36.10	93.20

F= FEPA set effluent limit